# REQUEST FOR LETTER OF AUTHORIZATION FOR THE INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM TRAINING AND RESEARCH, DEVELOPMENT, TESTING AND EVALUATION ACTIVITIES CONDUCTED WITHIN THE MARIANA ISLANDS RANGE COMPLEX

**Submitted to:**

**Office of Protected Resources**
**National Marine Fisheries Service**
**1315 East-West Highway**
**Silver Spring, Maryland 20910-3226**

**August 2008**

This Page Intentionally Left Blank

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAFB | Andersen Air Force Base |
| AAMEX | Air-to-Air Missile Exercise |
| AAR | After Action Report |
| ACM | Air Combat Maneuvers |
| ACTH | adrenocorticotropic hormone |
| ADC | Acoustic Device Countermeasures |
| ADEX | Air Defense Exercise |
| AEER | Acoustic Extended Echo Ranging |
| AFAST | Atlantic Fleet Active Sonar Training |
| AIMT | Air Interdiction of Maritime Target |
| ARP | Autonomous Recording Package |
| A-S GUNEX | Air-to-Surface Gunnery Exercise |
| A-S MISSILEX | Air-to-Surface Missile Exercise |
| AS | ankylosing spondylitis |
| ASW | Anti-Submarine Warfare |
| ATCAA | Air Traffic Control Assigned Airspace |
| ATOC | Acoustic Thermometry of Ocean Climate |
| AW | Air Warfare |
| BOMBEX | Bombing Exercise |
| BSS | Beaufort Sea State |
| C2 | Command and Control |
| CASS/GRAB | Comprehensive Acoustic System Simulation Gaussian Ray Bundle |
| CATM | Captive Air Training Missile |
| CFR | Code of Federal Regulations |
| CG | Guided Missile Cruiser |
| CHESS | Chase Encirclement Stress Studies |
| CIWS | Close-in Weapons System |
| CNA | Center for Naval Analysis |
| CNMI | Commonwealth of the Northern Mariana Islands |
| COMNAVSURFPAC | Commander, Naval Surface Forces Pacific |
| COMPTUEX | Composite Training Unit Exercise |
| CSG | Carrier Strike Group |
| CV | Coefficient of Variation |
| dB | decibel |
| DCA | Defensive Counter Air |
| DDG | Guided Missile Destroyer |
| DDT | dichlorodiphyenyl trichloroethane |
| DEMO | demolition |
| DICASS | Directional Command Activated Sonobuoy System |
| DOC | Department of Commerce |
| DoD | Department of Defense |
| DoD REP | Defense Representative |
| DoN | Department of the Navy |
| EA/OEA | Environmental Assessment/Overseas Environmental Assessment |
| EER | Extended Echo Ranging |
| EEZ | Exclusive Economic Zone |
| EIS | Environmental Impact Statement |
| EIS/OEIS | Environmental Impact Statement/Overseas Environmental Impact Statement |
| EL | Energy Flux Density Level (dB re 1µPa$^2$-s) |
| EMATT | Expendable Mobile Acoustic Training Target or Expendable Mobile Anti-Submarine Warfare Target |
| ENP | Eastern North Pacific |
| EPA | Environmental Protection Agency |
| ESA | Endangered Species Act |

| | |
|---|---|
| ETP | Eastern Tropical Pacific |
| EXTORP | Exercise Torpedo |
| FAST | Floating-at-Sea Target |
| FFG | Fast Frigate |
| FEIS | Final Environmental Impact Statement |
| FM | Frequency Modulation |
| FR | Federal Regulation |
| FSM | Federated States of Micronesia |
| ft | foot |
| FY | fiscal year |
| GRAB | Gaussian Ray Bundle |
| GUNEX | Gunnery Exercise |
| HARM | High-speed Anti-Radiation Missile |
| HARMEX | HARM Exercise |
| HFA | High-Frequency Active |
| HPA | hypothalamic pituitary adrenal |
| $HSO_3$ | bisulfite |
| Hz | hertz |
| ICES | International Council for the Exploration of the Sea |
| IEER | Improved Extended Echo Ranging |
| IHA | Incidental Harassment Authorization |
| ISR/Strike | Intelligence, Surveillance, Reconnaissance, Strike |
| ISTT | Improved Surface Towed Target |
| IUCN | International Union for the Conservation of Nature |
| IWC | International Whaling Commission |
| JTFEX | Joint Task Force Exercises |
| kHz | kilohertz |
| km | kilometer |
| L | liters |
| lb | pound |
| $L_{dn}$ | Day/Night Sound Level |
| LFA | Low-Frequency Active |
| LFS SRP | Low Frequency Sound Scientific Research Program |
| LOA | Letter of Authorization |
| m | meter |
| MCM | Mine Countermeasures |
| MFA | Mid-Frequency Active |
| MI | Maritime Interdiction |
| min | minute |
| MINEX | Mine Laying Exercise |
| MIRC | Mariana Islands Range Complex |
| MISSILEX | Missile Exercise |
| MISTCS | Mariana Islands Sea Turtle and Cetacean Survey |
| MIW | Mine Warfare |
| MMHSRP | Marine Mammal Health and Stranding Response Program |
| MMPA | Marine Mammal Protection Act |
| MOUT | Military Operations on Urban Terrain |
| μPa | micropascal |
| MPRSA | Marine Protection, Research and Sanctuaries Act |
| MRA | Marine Resources Assessment |
| MSAT | Marine Species Awareness Training |
| MSC | Military Sealift Command |
| MSE | Multiple Successive Explosions |
| msec | millisecond |
| NAS | Naval Air Station or National Academies of Science |
| NASA | National Aeronautics and Space Administration |

| | |
|---|---|
| NATO | North Atlantic Treaty Organization |
| NAVEDTRA | Naval Education and Training |
| NDE | National Defense Exemption |
| NEPA | National Environmental Policy Act |
| NEW | Net Explosive Weight |
| nm | nautical miles |
| NMFS | National Marine Fisheries Service |
| NMMSN | National Marine Mammal Stranding Network |
| NMMTB | National Marine Mammal Tissue Bank |
| NOAA | National Oceanic and Atmospheric Administration |
| NPIW | North Pacific Intermediate Water |
| NRC | Nuclear Regulatory Commission or National Research Council |
| NSFS | Naval Surface Fire Support |
| NSG | Naval Strike Group |
| OCE | Officer-in-Charge of the Exercise |
| OF | Otto Fuel |
| ONR | Office of Naval Research |
| OPAREA | Operating Area |
| OPFOR | Opposition Forces |
| PCB | polychlorinated biphenyl |
| PIFSC | Pacific Fisheries Science Center |
| PMRF | Pacific Missile Range Facility |
| PIRO | Pacific Islands Regional Office |
| ppt | parts per trillion |
| psi | pounds per square inch |
| PTS | Permanent Threshold Shift |
| PUTR | Portable Undersea Training (or Tracking) Range |
| RDT&E | Research, Development, Test, and Evaluation |
| REXTORP | Recoverable Exercise Torpedo |
| RIMPAC | Rim of the Pacific |
| RL | Received Level |
| rms | root-mean-square |
| SAG | Surface Action Group |
| SD | Standard Deviation |
| SEL | sound exposure level |
| SEPTAR | Seaborne Powered Target |
| SI | International System |
| SINKEX | Sinking Exercise |
| SL | Source Level |
| SLAM-ER | Standoff Land Attack Missile – Expanded Response |
| SNS | Sympathetic Nervous System |
| SOE | Schedule of Events |
| SPAWAR | Navy’s Space and Naval Warfare System Center |
| SPECWAROPS | Special Warfare Operations |
| SPL | Sound Pressure Level |
| S-S GUNEX | Surface-to-Surface Gunnery Exercise |
| S-S MISSILEX | Surface-to-Surface Missile Exercise |
| SSC | SPAWAR Systems Center |
| SSGN | Submersible Ship Guided Nuclear |
| SSN | Submersible Ship Nuclear |
| SST | Sea Surface Temperature |
| STW | Strike Warfare |
| SURTASS LFA | Surveillance Towed Array Sensor System Low Frequency Active |
| SUW | Surface Warfare |
| SWFSC | Southwest Fisheries Science Center |
| TM | Tympanic Membrane |

| | |
|---|---|
| TORPEX | Torpedo Exercise |
| TRACKEX | Tracking Exercise |
| TS | Threshold Shift |
| TTS | Temporary Threshold Shift |
| $TTS_2$ | TTS measured two minutes after exposure |
| UME | Unusual Mortality Event |
| UNDET | Underwater Detonation |
| U.S. | United States |
| USAF | United States Air Force |
| U.S.C. | United States Code |
| USCG | United States Coast Guard |
| USFWS | United States Fish and Wildlife Service |
| USMC | United States Marine Corps |
| USN | United States Navy |
| USWEX | Undersea Warfare Exercise |
| USWTR | Undersea Warfare Training Range |
| UUV | Unmanned Undersea Vehicles |
| UXO | Unexploded Ordnance |
| VS | Valiant Shield |
| WESTPAC | Western Pacific |

# EXECUTIVE SUMMARY

With this submittal, the United States (U.S.) Navy (Navy) requests a five-year Letter of Authorization (LOA) for the incidental harassment of marine mammals during training events and research, development, test, and evaluation within the Mariana Islands Range Complex (MIRC) for the period January 2010 through December 2014, as permitted by the Marine Mammal Protection Act (MMPA) of 1972, as amended in 1994 (16 United States Code [U.S.C.] Section [§] 1371[a][5]). 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 2004 (Public Law 108-136). The training events may expose certain marine mammals that may be present within the MIRC to sound from low-, mid- and high-frequency active (LFA/MFA/HFA) tactical sonar or to pressures from underwater detonations during training, testing and evaluation, research, and development.

In order to estimate acoustic exposures from the MIRC anti-submarine warfare (ASW) training events, acoustic sources to be used were examined with regard to their operational characteristics. An analysis was conducted for MIRC training events, modeling the potential interaction of active sonar and underwater explosives, with marine mammals in the MIRC.

The potential sonar exposures represent the estimated annual maximum number of exposures to marine mammals that may result in incidental harassment of marine mammals during Navy training and testing in the MIRC. Based on the regulatory framework established under the MMPA, the Navy has worked with the National Marine Fisheries Service (NMFS) to develop criteria and methodology for evaluating when sound exposure might constitute incidental harassment. The MMPA defines two types of harassment, and Level A (potential injury) and Level B (disturbance), evaluated here as follows for MFA and HFA sound sources:

- Level A: Consistent with prior actions, permanent physiological effects are considered injury, and energy flux density level (EL) is appropriate for evaluating when a sound exposure may cause a permanent physiological effect to marine mammals. EL exposures at or above the lowest threshold at which the onset of a permanent physiological effect, permanent threshold shift (PTS) may occur are used to define potential Level A harassment for cetaceans (215 decibels [dB] reference one micropascal squared-seconds [dB re 1 $\mu Pa^2$-s]).
- Level B: Consistent with prior actions, temporary, recoverable physiological effects are considered to potentially result in disturbance of marine mammals. Exposures below 215 dB re 1 $\mu Pa^2$-s EL and at or above the lowest exposures at which temporary physiological effects may occur (195 dB re 1 $\mu Pa^2$-s) are used to define potential Level B harassment from temporary threshold shift (TTS) for cetaceans.

  In addition to considering temporary physiological effects that may cause disturbance, this action also considers the potential for behavioral and physiological responses (e.g., stress) from exposure of marine mammals to stimuli that NMFS would classify as harassment under MMPA for military readiness activities. Based on comments received on prior Navy actions, a risk-function or, dependent on the circumstances, a non-temporary threshold shift (TTS) is used to determine when these responses might be considered Level B harassment.

The Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) system is anticipated to be used during three operations in the Guam mission site # 4, which overlaps with the MIRC Study Area (Department of the Navy [DoN] 2007a). With the use of mitigation measures, no animals will be exposed to LFA sonar above 180 dB sound pressure level (SPL) and only a small percentage (< 3.81%) of animals will be exposed to sound levels below 180 dB SPL (DoN 2007a). SURTASS LFA activities are presented in this LOA request solely for discussion and analysis of potential cumulative effects. This LOA does not include a request for a specifc use of LFA but does recognize an association with the use of SURTASS LFA sonar and High Frequency and Mid-Frequency sonar for training. . Analysis of the SURTASS LFA system was previously presented in a series of documents (DON 1999, 2002b, 2007a) and addressed by NOAA/NMFS (2002a, 2007) in consideration of applicable regulations including the potential for synergistic and cumulative effects. When and if use of the SURTASS LFA system was to occur concurrent with other Navy MFA/HFA sonars and/or commercial sonar systems, synergistic effects are not probable because of differences between these systems (DoN 2007a). For the sound fields to converge, the multiple sources would have to transmit exactly in phase (at the same time), requiring similar signal characteristics, such as time of transmissions, depth, frequency, bandwidth, vertical steering angle, waveform, wavetrain, pulse length, pulse repetition rate, and duty cycle. The potential for synergistic effects occurring is negligible. The potential for cumulative masking of marine mammal vocalizations in the event of the simultaneous use of LFA and MFA/HFA is also negligible given the fact that the frequencies are relatively narrowband (compared to ambient noise in the ocean) and the systems frequencies do not overlap the frequency band of best hearing for mysticetes and odontocetes (Richardson, et al., 1995a; Edds-Walton, 1997; Ketten, 2000; Wursig and Richardson 2002). In addition to Level A and Level B harassment, the potential for mortality from mid-frequency and high-frequency sonar must also be considered in impacts to marine mammals for LOA authorizations.

The analysis used to estimate the number of marine mammals that could be exposed annually by Navy training activities via use of the risk function will overestimate the number of potential exposures. This is due to the conservative assumptions used in the modeling. Post modeling analysis is undertaken to increase the accuracy of the estimate and includes reducing acoustic footprints where they encounter land masses, accounting for acoustic footprints for sonar sources that overlap to accurately sum the total area when multiple ships are operating together, and to better account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of one day or a discreet continuous sonar event. In addition, the Navy routinely employs a number of mitigation measures, outlined in Chapter 11, which will substantially decrease the number of animals potentially exposed and affected by high levels of sonar sound, however, a reduction in the potential number of marine mammals exposed as a result of these mitigation measures is not factored into the quantification of exposures as presented below.

The total potential annual Level B harassment exposures from MFA and HFA sonar using the risk function and TTS is 37,447. Behavioral effects modeling using the risk function methodology estimates 36,852 annual acoustic exposures that exceed the SPL risk function curve and would result in behavioral harassment (Level B harassment from non-TTS) for mid-frequency sonar. The modeling also estimates 595 annual sonar exposures that exceed the threshold for TTS and would also result in Level B harassment. The modeling estimates there will be no exposures to sound levels from sonar that may exceed the threshold for PTS (Level A harassment).

The potential explosive exposures outlined in Chapter 6 represent the maximum expected number of marine mammals that could be affected from underwater explosives for mine countermeasures (MCMs), demolition of underwater obstacles, missile exercises (MISSILEX), bombing exercises (BOMBEX), gunnery exercises (GUNEX), and ship sinking exercise (SINKEX). For underwater detonations, the dual criteria threshold for potential Level B harassment is at 182 dB re 1 $\mu Pa^2$-s or at 23 pounds per square inch (psi). For dual criteria, the criteria resulting in the greatest number of exposures is used. Level A thresholds are 50 percent tympanic membrane rupture, onset of slight lung injury at 205 dB or 13 psi-ms. In addition to Level A and B harassment is the onset of extensive lung injury and mortality at a threshold of 31 psi-ms. For multiple successive explosions potentially occurring during MINEX, MISSILEX, BOMBEX, SINKEX, GUNEX, and NSFS (when using other than inert weapons), the acoustic criterion for a sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels that may cause TTS. The sub-TTS threshold is 177 dB re 1 μPa2-s for multiple successive explosions.

Modeling estimates that 42 marine mammals may be exposed to sound or pressure from underwater detonations that could cause sub TTS behavioral response (Level B harassment), 14 marine mammals to TTS (Level B harassment), and no marine mammals would be exposed to pressures that would cause injury (Level A harassment); or severe injury or mortality.

As with the acoustic impacts from sonar training activities, the analysis used to estimate the maximum number of marine mammals that could be affected by Navy training activities will overestimate the potential exposures because of the use of marine mammal densities over the entire modeling area. In addition, the Navy routinely employs a number of mitigation measures, outlined in Chapter 11, which substantially decreases the number of animals potentially affected by activities involving underwater detonations.

Level B harassment, in the context of military readiness activities under the National Defense Authorization Act (NDAA) for Fiscal Year 2004 (Public Law 108-136), is defined as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered. This estimate of total predicted marine mammal sound exposures potentially constituting Level B harassment is presented without consideration of standard protective operating procedures. In addition, the assessment of whether temporary physiological effects or behavioral responses may cause behavioral patterns to be abandoned or significantly altered is considered in the context of an analytical framework for active sonar. This framework acknowledges that only a subset of exposures are likely to result in Level B harassment, and that multiple exposures of the same individual have a higher likelihood of disturbance than single exposures. All predicted acoustic exposures are presented in this analytical framework to support NMFS assessment of those exposures that may result in Level B harassment.

Based on the long history of conducting these ongoing training activities using the same basic equipment and in the same areas for decades without any indications of effects to marine mammals (e.g. Hawaii and Southern California Range Complexes), the incidental harassment of marine mammals associated with the proposed Navy action will have no more than negligible impacts on marine mammal species or stocks. For species listed and protected under the ESA, modeling estimates that five species may be exposed to sound levels that may cause a behavioral response or reach the threshold for TTS and that may affect these species. The ESA Section 7 consultation will examine the anticipated responses and any associated fitness consequences for these ESA-listed species. However, given implementation of mitigation measures, it is unlikely that training activities would adversely affect these species. Based on the widely dispersed geography of the activities and evaluation of the potential for physiological and behavioral disturbance coupled with the reduction of potential effects attributed to the mitigation measures to be executed, the interpretation of the modeling estimates that only Level B harassment is anticipated for all marine mammal species in the MIRC. In all cases, the conclusions are that Level B harassment to a small number of marine mammals would have a negligible impact on marine mammal species or stocks.

Evidence from five beaked whale strandings, all of which have taken place outside the MIRC and have occurred over approximately a decade, suggests that the exposure of beaked whales to mid-frequency sonar in the presence of certain conditions (e.g., multiple units using tactical sonar, steep bathymetry, constricted channels, strong surface ducts, etc.) may result in strandings, potentially leading to mortality. Although these physical factors believed to contribute to the likelihood of beaked whale strandings are not present, in their aggregate, in the MIRC, scientific uncertainty exists regarding what other factors, or combination of factors, may contribute to beaked whale strandings. Accordingly, to allow for scientific uncertainty regarding contributing causes of beaked whale strandings and the exact mechanisms of the physical effects, the Navy will also request authorization for take, by mortality, of the beaked whale species present in the MIRC.

Neither NMFS nor the Navy anticipates that marine mammal strandings or mortality will result from the use of LFA, MFA or HFA sonar during Navy exercises within the MIRC. In a letter from NMFS to Navy dated October 2006, NMFS indicated that Section 101(a)(5)(A) authorization is appropriate for MFA/HFA sonar activities because it allows NMFS to consider the potential for incidental mortality. NMFS' letter indicated, "Because mid-frequency sonar has been implicated in several marine mammal stranding events including some involving serious injury and mortality, and because there is no scientific consensus regarding the causal link between sonar and stranding events, NMFS cannot conclude with certainty the degree to which mitigation measures would eliminate or reduce the potential for serious injury or mortality." Given the potential for naturally occurring marine mammal strandings in MIRC (e.g., natural mortality), it is conceivable that a stranding could co-occur with a Navy exercise even though the stranding is actually unrelated to and not caused by Navy activities. Accordingly, the Navy's LOA application will include requests for take, by mortality, of the most commonly stranded non ESA-listed species.

# 1 DESCRIPTION OF ACTIVITIES

## 1.1 Introduction

This Chapter describes the mission activities conducted within the Mariana Islands Range Complex (MIRC) that could result in Level B harassment and possibly Level A harassment, under the Marine Mammal Protection Act (MMPA) of 1972, as amended in 1994 (16 United States Code [USC] Section [§] 1371[a][5]). The MMPA of 1972, authorizes the issuance of regulations and Letters of Authorization (LOAs) for the incidental taking of marine mammals by a specified activity for a period of not more than 5 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 (NDAA) for Fiscal Year 2004 (Public Law 108-136). The actions are Navy exercises and training events involving mid-frequency active (MFA) tactical sonar from 1 to 10 kilohertz (kHz), high-frequency active (HFA) sonar systems greater than 10 kHz, and underwater detonations (UNDETs) with the potential to affect marine mammals that may be present within the MIRC. The bases of this LOA are (1) the analysis of spatial and temporal distributions of protected marine mammals in the MIRC area of responsibility (MIRC Study Area) (Figure 1-1.), (2) a review of training activities that have the potential to affect marine mammals, and (3) a technical risk assessment to determine the likelihood of effects from low-frequency active (LFA), MFA and HFA sonar and underwater detonations during MIRC training activities.

## 1.2 Purpose and Need

To fulfill their statutory missions, each of the Services needs combat-capable forces ready to deploy worldwide. U.S. military forces must have access to the ranges, operating areas, and airspace needed to develop and maintain skills for the conduct of military activities. Ranges, operating areas, and airspace must be sustained to support the training needed to ensure a high state of military readiness. Activities involving Research, Development, Test, and Evaluation (RDT&E) for military systems are an integral part of this readiness mandate.

The Navy’s mission is to maintain, train, and equip combat-ready naval forces capable of winning wars, deterring aggression, and maintaining freedom of the seas. Title 10, USC 5062 directs the Chief of Naval Operations to train all naval forces for combat. The Chief of Naval Operations meets that direction, in part, by conducting at-sea training exercises and ensuring naval forces have access to ranges, operating areas and airspace where they can develop and maintain skills for wartime missions and conduct RDT&E of naval weapons systems. For purposes of this LOA, the Proposed Action would support and maintain U.S. Pacific Fleet training and assessments of current capabilities, and RDT&E activities, and associated range capabilities (including hardware and infrastructure improvements in the MIRC). Training and RDT&E do not include combat operations, operations in direct support of combat, or other activities conducted primarily for purposes other than training).

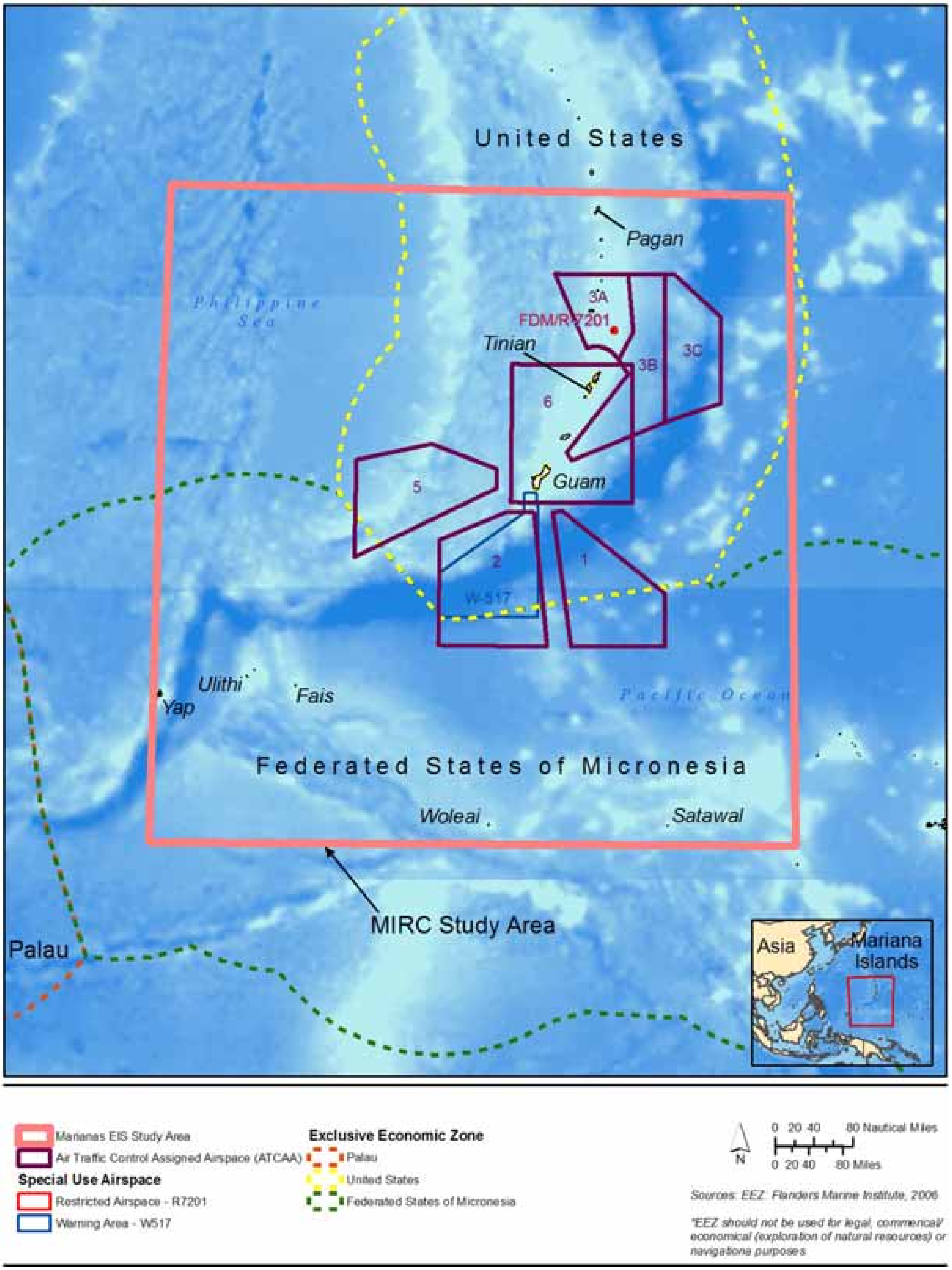


**Figure 1-1. Map of the MIRC**

The Proposed Action is to support and conduct current and emerging training and RDT&E activities in the MIRC. The Military Services need to implement actions within the MIRC to support current, emerging, and future training and RDT&E activities. These actions include:

- Maintain baseline training and RDT&E activities at mandated levels;
- Provide the potential to increase training activities and exercises from current levels;
- Accommodate increased readiness activities associated with the force structure changes (human resources, new platforms, additional weapons systems, including underwater tracking capabilities and training activities to support Intelligence, Surveillance, Reconnaissance, Strike [ISR/Strike]); and
- Implement range complex investment strategies that sustain, upgrade, modernize, and transform the MIRC to accommodate increased use and more realistic training scenarios.

The MIRC consists of airspace, surface and undersea space, and land range facilities and training areas. The activities analyzed in this LOA include current and future proposed Navy training and RDT&E activities analyzed within the MIRC Environmental Impact Statement (EIS) study area.

The MIRC is one of the Pacific range complexes the Navy uses for training and testing. Four ranges, including Hawaii, Southern California, Pacific Northwest and the Mariana Islands Range Complexes, support the Pacific Fleet, headquartered at Pearl Harbor. These range complexes contain some common capabilities, but each range contains distinctive individual capabilities as well. The enhancement of each range complex will be analyzed separately for potential environmental impacts. All ranges, including the MIRC, will require adequate capabilities and the flexibility to enhance and sustain Navy training and testing. This document analyzes activities that may affect marine mammals that are present in the MIRC.

The open ocean of the MIRC presents a realistic environment for strike warfare training, including amphibious, nearshore, and Anti-Submarine Warfare (ASW). Training may be conducted within a few miles of land masses so that battle situations may be realistically simulated. There is room and space to operate within proximity of land but at safe distances from other simultaneous training activities.

The Navy has conducted a thorough review of all continuing/ongoing training conducted in the MIRC, in addition to those proposed training activities and RDT&E events, to determine whether there is a potential for harassment of marine mammals. Section 1.3 and Section 1.4 provide an overview of those training activities and events that would result in the generation of sound in the water, either through the use of sonar or from the use of live ordnance, including the detonation of explosives in the water.

## 1.3 Proposed ASW Activities

The types of ASW training conducted within the MIRC involve the use of ships, submarines, aircraft, exercise weapons, and other training-related devices. ASW training involves the use of MFA and HFA and passive devices. A description of ASW and the sonar devices is provided below.

### 1.3.1 ASW Training Activities

ASW involves helicopter and sea control aircraft, ships, and submarines, operating alone or in combination, to locate, track, and neutralize submarines. Controlling the undersea battlespace is a unique naval capability and a vital aspect of sea control. Undersea battlespace dominance requires proficiency in ASW. Every deploying strike group and individual surface combatant must possess this capability.

Various types of active and passive sonars are used by the Navy to determine water depth, locate mines, and identify, track, and target submarines. Passive sonar "listens" for sound waves by using underwater microphones, called hydrophones, which receive, amplify and process underwater sounds. No sound is introduced into the water when using passive sonar. Passive sonar can indicate the presence, character and movement of submarines. However, passive sonar provides only a bearing (direction) to a sound-emitting source; it does not provide an accurate range (distance) to the source. Active sonar is needed to locate objects because active sonar provides both bearing and range to the detected contact (such as an enemy submarine).

Active sonar transmits pulses of sound that travel through the water, reflect off objects and return to a receiver. By knowing the speed of sound in water and the time taken for the sound wave to travel to the object and back, active sonar systems can quickly calculate direction and distance from the sonar platform to the underwater object. There are three types of active sonar: low-frequency, mid-frequency, and high-frequency.

Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar operates below 1 kHz and is designed to detect extremely quiet diesel-electric submarines at ranges far beyond the capabilities of MFA sonars. There are currently only two ships in use by the Navy that are equipped with LFA sonar; both are ocean surveillance vessels operated by Military Sealift Command (MSC).

MFA sonar, as defined in this LOA application, operates at frequencies between 1 and 10 kHz. MFA systems are deployed during testing and training and are designed to detect submarines in tactical operational scenarios.

HFA sonar, as defined in this LOA application, operates at frequencies greater than 10 kHz. At higher acoustic frequencies, sound rapidly dissipates in the ocean environment, resulting in short detection ranges, typically less than five nm. High-frequency sonar is used primarily for determining water depth, hunting mines, and guiding torpedoes.

#### 1.3.1.1 Tracking Exercise (TRACKEX)

A TRACKEX tests the Naval Strike Group's (NSG) ability to locate and track an unknown or hostile submarine over a predetermined time. This exercise tests the NSG's ability to coordinate the positioning of assets (including surface, air, and undersea) and the effective communication and turnover of responsibility for maintaining coverage of the unknown submarine. Sensors that are part of this exercise include (see Table 1-1):

- AN/AQS-22 and/or AN/AQS-13 (Dipping Sonar)
- AN/SSQ-62 (Directional Command Activated Sonobuoy System [DICASS] MFA Sonobuoy)
- AN/SSQ-125 (Acoustic Extended Echo Ranging [AEER] MFA Sonobuoy)
- AN/SQS-53 (MFA Sonar; Guided Missile Destroyer [DDG] and Guided Missile Cruiser [CG])
- AN/SQS-56 (MFA Sonar; Fast Frigate [FFG])
- AN/BQQ-10 (MFA Sonar; Submarine)
- Submarine Auxiliary Sonar Systems AN/BQS-14/15 and AN/WQC-2A

#### 1.3.1.2 Torpedo Exercise (TORPEX)

Anti-submarine Warfare (ASW) TORPEX activities train crews in tracking and attack of submerged targets, firing one or two exercise torpedoes (EXTORPs) or recoverable exercise torpedoes (REXTORPs). TORPEX targets and systems used in the Offshore Areas may include live submarines, MK-46, MK-54, and MK-48 torpedoes, MK-30 ASW training targets, and MK-39 Expendable Mobile ASW Training Targets (EMATTs). The target may be non-evading while operating on a specified track, or it may be fully evasive, depending on the training requirements of the training exercise.

Submarines periodically conduct torpedo firing training exercises within the MIRC. Typical duration of a submarine TORPEX exercise is 10 hours, while air and surface ASW platform TORPEX exercises using the MK-46 and MK-54 torpedoes are considerably shorter.

**Table 1-1. ASW Sonar Systems and Platforms**

| System | Frequency | Associated Platform |
|---|---|---|
| AN/SQS-53 | MF | DDG and CG hull-mounted sonar |
| AN/AQS-13 or AN/AQS-22 | MF | Helicopter dipping sonar |
| AN/SQS-56 | MF | FFG hull-mounted sonar |
| MK-46, MK-54, or MK-48 Torpedo | HF | Ship, aircraft, or submarine fired exercise torpedo |
| AN/BQQ-10 | MF | Submarine hull-mounted sonar |
| Tonal sonobuoy (DICASS;AN/SSQ-62 and AEER;AN/SSQ-125) | MF | Helicopter and MPA deployed |
| CG – Guided Missile Cruiser; DDG – Guided Missile Destroyer; DICASS – Directional Command-Activated Sonobuoy System; AEER – Acoustic Extended Echo Ranging (sonobuoy); FFG – Fast Frigate; HF – High-Frequency; MF – Mid-Frequency. | | |

### 1.3.2 Active Acoustic Devices

Modern sonar technology has developed a multitude of sonar sensor and processing systems. In concept, the simplest active sonars emit omni-directional pulses (“pings”) and time the arrival of the reflected echoes from the target object to determine range. More sophisticated active sonar emits an omni-directional ping and then rapidly scans a steered receiving beam to provide directional, as well as range, information. More advanced sonars transmit multiple preformed beams, listening to echoes from several directions simultaneously and providing efficient detection of both direction and range.

The tactical military sonars to be deployed during testing and training in the MIRC are designed to detect submarines and mines. This task requires the use of the sonar mid-frequency range of 1 to 10 kHz predominantly. HFA in the range above 10 kHz are used during training and testing in the MIRC and include fathometers, tracking pingers, and telemetry from various Unmanned Undersea Vehicles (UUVs). These systems are not expected to represent significant sources of sound exposure given the generally lower source levels and characteristic rapid attenuation of high frequency sound waves underwater; however, further analysis of these sources is continuing. If further analysis determines there may be effects from these sources, supplemental information will be provided. Accordingly, the only HFA source modeled for potential exposures to marine mammals in the MIRC area is associated with the MK-48 torpedo.

Although the SURTASS LFA system may also be used during some of the Navy’s training and testing scenarios within the MIRC Study Area, that system’s use was analyzed in other environmental documentation (DON 1999, 2002b, 2007a; NOAA 2002a, 2007).

The types of acoustic sources that would be used in training events are discussed in the following paragraphs.

- **Surface Ship Sonars.** A variety of surface ships participate in testing and training events. Some ships (e.g., aircraft carriers, amphibious assault ships) do not have any onboard active sonar systems, other than fathometers (HFA sonars for determining bottom depth-common in commercial and recreational vessels). Others, like guided missile cruisers, are equipped with active as well as passive tactical sonars for mine avoidance and submarine detection and tracking. For purposes of the analysis, all SQS-53 sonars were modeled as having the nominal source level of 235 decibels (dB) re 1 µPa (micropascals) @ 1 m (meter). Sonar ping transmission durations were modeled as lasting 1 second per ping and omni-directional, which is a conservative assumption that will overestimate potential effects. Actual ping durations will be less than 1 second. The SQS-53 hull-mounted sonar transmits at center frequencies of 2.6 kHz and 3.3 kHz.

Effects analysis modeling used frequencies that are required in tactical deployments such as those during Joint Multi-strike Group Exercise. Details concerning the tactical use of specific frequencies and the repetition rate for the sonar pings is classified but was modeled based on the required tactical training setting.

The SQS-56 is a hull-mounted, surface ship sonar (not as powerful as the SQS-53) that operates for many hours at a time, so it is most useful to calculate and report SQS-56 exposures per hour of training. The SQS-56 is not as powerful as the SQS-53 and therefore was modeled separately.

- **Submarine Sonars.** Submarine sonars (e.g., AN/BQQ-10) are used to detect and target enemy submarines and surface ships. Because submarine active sonar use is very rare and in those rare instances, very brief, it is extremely unlikely that use of active sonar by submarines would have any measurable effect on marine mammals. This type of sonar was modeled separately from the SQS-53 and SQS-56 sonars. In addition, submarines have a high frequency AN/BQS-15 sonar used for navigation safety and mine avoidance that is not unlike a fathometer in source level or output. There is, at present, no mine training range in the MIRC area. Therefore, given its limited use and rapid attenuation as a high frequency source, the AN/BQS-15 should have no impact on marine mammals.

- **SURTASS LFA.** SURTASS LFA is a long-range, all-weather, sonar system that operates in the low frequency band (100-330 Hz). The system has both passive and active components. The active system component, LFA, is an augmentation to the passive detection system, and is planned for use when passive system performance proves inadequate. LFA is a set of acoustic transmitting source elements suspended by cable from underneath a ship. These elements, called projectors, are devices that produce the active sound pulse, or ping. The projectors transform electrical energy to mechanical energy that set up vibrations or pressure disturbances within the water to produce a ping. The passive, or listening, part of the system is SURTASS, which detects returning echoes from submerged objects, such as submarines, through the use of hydrophones. The SURTASS hydrophones are mounted on a receive array that is towed behind the vessel. The return signals or echoes, which are usually below background or ambient sound level, are then processed and evaluated to identify and classify potential underwater targets. SURTASS LFA was not modeled as part of the MIRC DEIS/OEIS or this LOA application but has been modeled for the MIRC area in the 2007 SURTASS LFA Supplemental EIS (Department of the Navy [DoN] 2007a).

- **Aircraft Sonar Systems.** Aircraft sonar systems that would operate in the MIRC include sonobuoys and dipping sonar. Sonobuoys may be deployed by maritime patrol aircraft or helicopters; dipping sonars are used by carrier-based helicopters. A sonobuoy is an expendable device used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Most sonobuoys are passive, but some can generate active acoustic signals, as well as listen passively. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets. During ASW training, these systems' active modes are only used briefly for localization of contacts and are not used in primary search capacity. Because active mode dipping sonar use is very brief, it is extremely unlikely its use would have any effect on marine mammals. However, the AN/AQS-22 dipping sonar was modeled based on estimated use during major training exercises within the MIRC.

- **Torpedoes.** Torpedoes are the primary ASW weapon used by surface ships, aircraft, and submarines. The guidance systems of these weapons can be autonomous or electronically controlled from the launching platform through an attached wire. The autonomous guidance systems are acoustically based. They operate either passively, exploiting the emitted sound energy by the target, or actively, ensonifying the target with high frequency sonar and using the received echoes for guidance. The MK-48 torpedo was modeled for active sonar transmissions as a high frequency source during specified training activities within the MIRC. The use of MK-46 and MK-54 torpedoes will also occur in MIRC, however, their use was accounted for by modeling all torpedo use in MIRC as if they were MK-48 torpedoes.

- **Acoustic Device Countermeasures (ADCs).** ADCs (e.g., AN/SLQ-25 ("NIXIE"), MK-2 and MK-3 are, in effect, decoys to avert localization and/or torpedo attacks. These do not represent a significant source of sound given their intermittent use and operational characteristics (source output level and/or frequency). Given the sporadic use of these devices, the potential to affect marine mammals is unlikely, therefore these sources were not modeled or considered further in this analysis.

- **Training Targets.** ASW training targets such as are used to simulate opposition submarines. They are equipped with one or a combination of the following devices: (1) acoustic projectors emanating sounds to simulate submarine acoustic signatures, (2) echo repeaters to simulate the characteristics of the echo of a particular sonar signal reflected from a specific type of submarine, and (3) magnetic sources to trigger magnetic detectors. Based on the operational characteristics (source output level and/or frequency) of these acoustic sources, the potential to affect marine mammals is unlikely, and therefore they were not modeled for this analysis.

- **AEER AN/SSQ 125.** The AEER system will use the same ADAR sonobuoy as the acoustic receiver and will be used for a large area ASW search capability in both shallow and deep water. However, instead of using an explosive AN/SQS-110A as an impulsive source for the active acoustic wave, the AEER system will use a battery powered (electronic) source for the AN/SSQ 125 sonobuoy. The output and operational parameters for the AN/SSQ-125 sonobuoy (source levels, frequency, wave forms, etc.) are classified, however, this sonobuoy is intended to replace the EER/IEER's use of explosives and is scheduled to enter the fleet in 2011. Upon further development of the system, modeling analysis will be evaluated based on the actual system parameters. In the interim, the potential impact from each AN/SSQ-125 will be assumed to be the same as that for a DICASS sonobuoy for purposes of quantifying exposures to marine mammals. Potential for effect from future use of AEER also assumes AEER in a one-for-one replacement of the EER/IEER sonobuoy using the exposures that would result from use of the DICASS sonobuoy's acoustic output.

- **Other Sources (Non tactical).** Tracking pingers are active HFA acoustic devices that allow each of the in-water platforms engaged in training activities (e.g., ships, submarines, target simulators, and exercise torpedoes) to be tracked by a hydrophones deployed as part of the Portable Undersea Tracking Range (PUTR). In addition, various devices such as those used for underwater communication with submarines or telemetry from Unmanned Underwater Vehicles will be used in the MIRC area. Operational characteristics of these sources such as intermittent usage, short duration, a generally low source output level and/or high frequency indicate a very unlikely potential for these types of non-tactical sources to affect marine mammals. Therefore, these types of sources were not modeled or considered further in this analysis.

## 1.4 Proposed Non-ASW Sonar Activities

### 1.4.1 Mine Countermeasures (MCM)

MCM training with active sonar engages ships' crews in the use of sonar for mine detection and avoidance, and minefield navigation and reporting. No active sonar MCM training is currently conducted in the MIRC study area. A new mine warfare (MIW) range that would support shallow water active sonar

MCM exercises has been proposed but not sited. Upon further development of the MIW, the appropriate environmental documentation and permitting will be completed.

## 1.4.2 Training-Underwater Detonations

Underwater detonation activities can occur at various depths depending on the activity (Sinking Exercise [SINKEX] and mine neutralization), but may also include activities which may have detonations at or just below the surface (SINKEX, Gunnery Exercise [GUNEX], or Missile Exercise [MISSILEX]).

### 1.4.2.1 Sinking Exercise (SINKEX)

In a SINKEX, a specially prepared, deactivated vessel is deliberately sunk using multiple weapons systems. The exercise provides training to ship and aircraft crews in delivering both live and inert ordnance on a real target. These target vessels are empty, cleaned, and environmentally-remediated ship hulk. A SINKEX target is towed to sea and set adrift at the SINKEX location. The duration of a SINKEX is unpredictable since it ends when the target sinks, sometimes immediately after the first weapon impact and sometimes only after multiple impacts by a variety of weapons. Typically, the exercise lasts for 4 to 8 hours over 1 to 2 days. SINKEXs occur only occasionally during MIRC exercises. Potential harassment would be from underwater detonation.

SINKEX events have been conducted in the open ocean of the western Pacific and within the MIRC, in compliance with 40 CFR Part 229.2.

The Environmental Protection Agency (EPA) grants the Navy a general permit through the Marine Protection, Research, and Sanctuaries Act to transport vessels “for the purpose of sinking such vessels in ocean waters…” (40 CFR Part 229.2). Subparagraph (a)(3) of this regulation states “All such vessel sinkings shall be conducted in water at least 1,000 fathoms (6,000 feet) deep and at least 50 nautical miles from land.”

### SINKEX Participants

Navy participants in SINKEX events are typically planned to include at least one surface combatant (frigate, destroyer, or cruiser); one submarine; and numerous fixed-wing and rotary-wing aircraft. One surface ship will serve as a surveillance platform to ensure the hulk does not pose a hazard to navigation prior to and during the SINKEX.

### SINKEX Weapons

The weapons actually expended during a SINKEX can vary greatly. A table for SINKEX expenditure of weapons is listed in Table 1-2. This table reflects the planning for weapons, which may be expended during one SINKEX in the MIRC Study Area. This level of ordnance is expected for each of the SINKEX events in the Joint Multi-strike Group exercise. With the exception of the torpedo, which is designed to explode below the target hulk in the water column, the weapons deployed during a SINKEX are intended to strike the target hulk, and thus not explode within the water column.

**Table 1-2. MIRC SINKEX Typical Weapons**

| Weapon | Net Explosive Weight | Expenditure |
|---|---|---|
| AGM-88 High Speed Antiradiation Missile (HARM) | 47 lbs/21.3 kg | 2 |
| Standoff Land Attack Missile – Expanded Response (SLAM-ER) | 164 lbs/74.4 kg | 1 |
| AGM-84 HARPOON Missile | 215 lbs/97.5 kg | 5 |
| 5” Naval Surface Gunfire | 8.8 lbs/4.0 kg | 400 |
| AGM-114 HELLFIRE Missile | 13.7 lbs/6.21 kg | 2 |

| | | |
|---|---|---|
| MAVERICK Missile | 78.5 lbs/35.6 kg | 8 |
| MK-82/GBU-12 Bombs (precision guided) | 192 lbs/87.1 kg | 10 |
| MK-84/GBU-10 Bombs (precision guided) | 945 lbs/428.6 kg | 4 |
| MK-48 Torpedo | 650 lbs/294.8 kg | 1 |
| Underwater Demolition | 100 lbs/45.6 kg | 2 |

#### 1.4.2.2 Air-to-Surface Gunnery Exercise (A-S GUNEX)

A-S GUNEX training activities are conducted by rotary-wing aircraft against stationary targets (Floating at-sea Target [FAST] and smoke buoy). Rotary-wing aircraft involved in this activity would include a single helicopter using either 7.62-mm or .50-caliber door-mounted machine guns. A typical GUNEX will last approximately one hour and involve the expenditure of approximately 400 rounds of 0.50-caliber or 7.62-mm ammunition. Due to their being inert and the small size of the rounds, they are not considered to have an underwater detonation impact.

#### 1.4.2.3 Surface-to-Surface Gunnery Exercise (S-S GUNEX)

S-S GUNEX take place in the open ocean to provide gunnery practice for Navy and Coast Guard ship crews. GUNEX training activities conducted in the offshore study area involve stationary targets such as a MK-42 FAST or a MK-58 marker (smoke) buoy. The gun systems employed against surface targets include the 5-inch, 76 millimeter (mm), 25-mm chain gun, 20-mm Close-in Weapon System (CIWS), and .50 caliber machine gun. Typical ordnance expenditure for a single GUNEX is a minimum of 21 rounds of 5-inch or 76-mm ammunition, and approximately 150 rounds of 25-mm or .50-caliber ammunition. Both live and inert training rounds are used. After impacting the water, the rounds and fragments sink to the bottom of the ocean. A GUNEX lasts approximately 1 to 2 hours, depending on target services and weather conditions. The live 5-inch and 76-mm rounds are considered in the underwater detonation modeling. Potential harassment would be from underwater detonation.

#### 1.4.2.4 Air-to-Surface Missile Exercise (A-S MISSILEX)

The A-S MISSILEX consists of the attacking platform releasing a forward-fired, guided weapon at the designated towed target. The exercise involves locating the target, then designating the target, usually with a laser.

A-S MISSILEX training that does not involve the release of a live weapon can take place if the attacking platform is carrying a captive air training missile (CATM) simulating the weapon involved in the training. The CATM MISSILEX is identical to a live-fire exercise in every aspect except that a weapon is not released. The training requires a laser-safe range as the target is designated just as in a live-fire exercise.

From 1 to 16 aircraft, carrying live, inert, or CATMs, or flying without ordnance (dry runs) are used during the exercise. At sea, seaborne powered targets (SEPTARs), Improved Surface Towed Targets (ISTTs), and decommissioned hulks are used as targets. A-S MISSILEX assets include helicopters and/or 1 to 16 fixed wing aircraft with air-to-surface missiles and anti-radiation missiles (electromagnetic radiation source seeking missiles). When a high-speed anti-radiation missile (HARM) is used, the exercise is called a HARMEX. Targets include SEPTARs, ISTTs, and excess ship hulks. Potential harassment would be from underwater detonation.

#### 1.4.2.5 Surface-to-Surface Missile Exercise (S-S MISSILEX)

S-S MISSILEX involves the attack of surface targets at sea by use of cruise missiles or other missile systems, usually by a single ship conducting training in the detection, classification, tracking and engagement of a surface target. Engagement is usually with HARPOON missiles or Standard missiles in the surface-to-surface mode. Targets could include virtual targets or the SEPTAR or ship deployed surface target. S-S MISSILEX training is routinely conducted on individual ships with embedded training devices.

A S-S MISSILEX could include 4 to 20 surface-to-surface missiles, SEPTARs, a weapons recovery boat, and a helicopter for environmental and photo evaluation. All missiles are equipped with instrumentation packages or a warhead. Surface-to-air missiles can also be used in a surface-to-surface mode. Each exercise typically lasts five hours. Future S-S MISSILEX could range from 4 to 35 hours. Potential harassment would be from underwater detonation.

#### 1.4.2.6 Bombing Exercise (BOMBEX)

Fixed-wing aircraft conduct BOMBEX training activities against stationary targets (MK-42 FAST or MK-58 smoke buoy) at sea. An aircraft clears the area, deploys a smoke buoy or other floating target, and then sets up a racetrack pattern, dropping on the target with each pass. A BOMBEX may involve either live or inert ordnance. Potential harassment would be from underwater detonation.

#### 1.4.2.7 Mine Neutralization

Mine Neutralization involves the detection, identification, evaluation, rendering safe, and disposal of mines and unexploded ordnance (UXO) that constitutes a threat to ships or personnel. Mine neutralization training can be conducted by a variety of air, surface and undersea assets. Potential harassment would be from underwater detonation.

Tactics for neutralization of ground or bottom mines involve the diver placing a specific amount of explosives, which when detonated underwater at a specific distance from a mine results in neutralization of the mine. Floating, or moored, mines involve the diver placing a specific amount of explosives directly on the mine. Floating mines encountered by Fleet ships in open-ocean areas are detonated at the surface. In support of an expeditionary assault, divers and Navy marine mammal assets deploy in very shallow water depths (10 to 40 feet) to locate mines and obstructions. Divers are transported to the mines by boat or helicopter. Inert dummy mines are used in the exercises. The total net explosive weight used against each mine ranges from less than 1 pound to 20 pounds.

Various types of surveying equipment may be used during mine detection. Examples include the Canadian Route Survey System that hydrographically maps the ocean floor using multi-beam side scan sonar and the Bottom Object Inspection Vehicle used for object identification. These units can help in supporting mine detection prior to Special Warfare Operations (SPECWAROPS) and amphibious exercises.

All demolition activities are conducted in accordance with Commander, Naval Surface Forces Pacific (COMNAVSURFPAC) Instruction 3120.8F, Procedures for Disposal of Explosives at Sea/Firing of Depth Charges and Other Underwater Ordnance (DoN 2003).

Before any explosive is detonated, divers are transported a safe distance away from the explosive. Standard practices for tethered mines require ground mine explosive charges to be suspended 10 feet below the surface of the water.

#### 1.4.2.8 EER-IEER AN/SSQ-110A

The Extended Echo Ranging and Improved Extended Echo Ranging (EER/IEER) Systems are airborne ASW systems used in conducting “large area” searches for submarines. These systems are made up of airborne avionics ASW acoustic processing and sonobuoy types that are deployed in pairs. The IEER

System's active sonobuoy component, the AN/SSQ-110A Sonobuoy, generates a sound similar to a “sonar ping" using a small explosive and the passive AN/SSQ-101A ADAR Sonobuoy "listens" for the return echo of the “sonar ping” that has been bounced off the surface of a submarine. These sonobuoys are designed to provide underwater acoustic data necessary for naval aircrews to quickly and accurately detect submerged submarines. The sonobuoy pairs are dropped from a fixed-wing aircraft into the ocean in a predetermined pattern with a few buoys covering a very large area. The AN/SSQ-110A Sonobuoy Series is an expendable and commandable sonobuoy. Upon command from the aircraft, the bottom payload is released to sink to a designated operating depth. A second command is required from the aircraft to cause the second payload to release and detonate the explosive to generate a “ping”. There is only one detonation in the pattern of buoys at a time. Potential harassment would be from underwater detonations.

Mitigation measures for EER-IEERs are detailed in Section 11 of this LOA application. The AEER system (described in Section 1.3.2; being deployed in 2011) will eventually replace use of the EER/IEER system and was analyzed for this LOA application.

## 1.5 Multi Strike Group Overview and Training Components

The Navy proposes to conduct an annual multi strike group exercise each summer. The exercise involves various warfare areas in order to maintain a level of skill developed during previous Carrier Strike Group (CSG) training exercises. These training exercises involve Navy assets engaging in a schedule of events (SOE) battle scenario, with U.S. forces pitted against a notional opposition force (OPFOR). Participants use and build upon previously gained training skill sets to maintain and improve the proficiency needed for a mission-capable, deployment-ready unit.

Three CSGs are proposed to participate in the exercise. A single CSG consists of an aircraft carrier with approximately 60 air wing aircraft embarked, and typically three to six surface combatant ships. The air wing includes fixed-wing strike aircraft, surveillance and support aircraft, and helicopters. The surface combatant ships are a combination of Frigates, Destroyers, and Cruisers. In addition to the CSGs, 10 to 12 other ships will participate.

The Exercise is an SOE exercise in which events are scheduled and take place according to a set timeline. Some scheduled events include an opportunity for “free-play” in which the scenario evolves according to actions and reactions by the exercise participants. Objectives of the exercise are to conduct:

- Command and Control (C2) Training Activities
- Air Warfare (AW) (MISSILEX and Defensive Counter Air [DCA])
- Surface Warfare (SUW) (Maritime Interdiction [MI], Air Interdiction of Maritime Targets [AIMT], SINKEX)
- ASW
- Strike Warfare (STW)

## 1.6 Missile Exercise

MISSILEX events provides crews with experience in using missile firing systems, and to develop new firing tactics. During VS 07, jet target drones were launched and used as high-speed, realistic targets for AW training. Additionally, un-powered glider target drones may be used. The targets are tracked by the firing ship or aircraft and then missiles are launched at the drones. At the completion of the exercise, the powered target drones are recovered for later reuse. The un-powered targets are not recovered. The MISSILEX consists of several ships, 1 to 6 target drones, 2 to 20 aircraft, 2 to 20 missiles, and a weapons recovery boat for target recovery. A typical exercise lasts 2 to 6 hours. Potential harassment would be from underwater detonations.

## 1.7 Maritime Interdiction and Air Interdiction of Maritime Target

MI is the offensive targeting of OPFOR ships by friendly Navy ships. AIMT is similar in that the target remains the same. In AIMT however, aircraft are conducting the attack against the OPFOR navy. AIMT training activities will include an OPFOR surface action group (SAG) consisting of United States Navy (USN) surface combatants, MSC ships, and a United States Coast Guard (USCG) Cutter. Friendly forces involved in MI/AIMT training activities will consist of USN frigates, cruisers and destroyers, carrier air wing aircraft from the three USN aircraft carriers and United States Air Force (USAF) F-15/F-22 aircraft.

USAF and United States Marine Corp (USMC) expeditionary forces aircraft will operate from Andersen Air Force Base (AAFB) in Guam, while carrier air wing aircraft operate from their respective aircraft carriers. The aircraft will coordinate efforts with friendly force surface ships to locate, target, and simulate strikes against the OPFOR SAG. These training activities will take place during both day and night, as dictated by the schedule. Potential harassment associated with this activity is unlikely.

## 1.8 Air Combat Manuevers

Strike fighter aircraft perform intricate flight maneuvers to achieve a gun or missile firing position from which an attack can be made on a threat aircraft with the goal of destroying the adversary aircraft. Air Combat Manuever (ACM) is the general term used to describe an air-to-air (A-A) event involving two or more aircraft. These aircraft may be similar or dissimilar. Aircraft are considered similar if they are of the same aircraft type and model. For example, an F/A-18C is similar to an F/A-18E, whereas an F/A-18 and an F-15 are dissimilar. Unit Level ACM training consists of three levels: Basic Fighter Maneuvering (BFM), intermediate level Offensive Counter Air (OCA), and Defensive Counter Air (DCA) training. No live-weapons are fired during ACM operations. During BFM, two aircraft (one vs. one) will engage in offensive and defensive maneuvering against each other.

During OCA or DCA training, three or more aircraft (one vs. two, two vs. two, or three vs. one) will engage in offensive and defensive maneuvering. Participating aircraft will be separated at the start by distances up to 50 nm. During OCA training, a force of two or more aircraft will attempt to establish and maintain air superiority over a defined battle space by defeating a force of defending aircraft. During DCA training, a force of two or more aircraft will attempt to retain air superiority over a defined battle space by defeating a force of aggressor aircraft. Unit level OCA and DCA training, which is a precursor to joint and combined integrated range operations, involves high airspeeds (from high subsonic to supersonic) and rapidly changing aircraft altitudes and attitudes.. These ACM training activities will take place during both day and night, as dictated by the schedule. Potential harassment associated with this activity is unlikely.

## 1.9 Antisubmarine Warfare Training

During ASW training, air, surface and submarine units will be used during the day and at night to locate and localize OPFOR submarines. In addition to the CSG forces conducting ASW, up to two SURTASS LFA sonar ships will conduct search procedures in support of the friendly forces.

### 1.9.1.1 ASW Training Activities from Surface Ships

Surface ships with ASW capability include frigates, destroyers, and cruisers. Each CSG will include a mix of surface ships, typically including two destroyers, one frigate, and one cruiser. Ship ASW sensors include radar, passive hull-mounted and towed array sonar which generate no acoustic energy in the water, and active hull-mounted mid-frequency sonar. A ship may use all of its sensors at various times during the course of an exercise depending on whether it is in a search, localization, or tracking mode.

Surface ship active sonar operates in the mid-frequency range, between 1.0 and 10.0 kHz at varying power levels, pulse types, and transmission intervals. Surface ships may also launch exercise torpedoes, some of which may actively ensonifying targets with high frequency sonar.

#### 1.9.1.2 ASW Training Activities from SURTASS LFA Ships

SURTASS LFA sonar systems are long-range sonars that operate day or night in most weather conditions in the low frequency range of 100 to 500 hertz (Hz). The SURTASS LFA system consists of an active component and a passive component. The active component of the system, LFA, is a set of low frequency acoustic transmitting source elements (called projectors) suspended by cable from underneath the ship. These projectors produce the active sonar signal or "ping." The passive or listening component of the system is SURTASS, which detects returning echoes from submerged objects, such as OPFOR submarines. The returning signals are received through hydrophones that are towed behind the ship on a receiving array. The long-range capability of the sensitive receiving array and onboard acoustic processing provides a large geographic area of protection and submarine detection (DoN 2001). Potential harassment from SURTASS LFA sonar has been evaluated for the MIRC area in the 2007 SURTASS LFA Supplemental EIS (Department of the Navy [DoN] 2007a) and for synergistic affects of use of the systems for training in this LOA request

The potential cumulative impact issue associated with SURTASS LFA sonar operations is the addition of underwater sound to oceanic ambient noise levels and its use during the operation of MFA/HFA sonar in the MIRC area. While the operation of LFA and MFA/HFA sonar together in the MIRC area have the potential to expose marine mammals to these sources, there should not be any cumulative or synergistic effects given the differences in the systems frequencies as detailed below.

Anthropogenic sources of ambient noise that are most likely to contribute to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other use of sonar (International Council for the Exploration of the Sea, 2005). Increases in ambient noise levels have the potential to cause masking, and decrease in distances that underwater sound can be detected by marine animals. These effects have the potential to cause a long-term decrease in a marine mammal's efficiency at foraging, navigating, or communicating (International Council for the Exploration of the Sea, 2005). National Research Council (2003) discussed acoustically-induced stress in marine mammals. National Research Council stated that sounds resulting from one-time exposure are less likely to have population-level effects than sounds that animals are exposed to repeatedly over extended periods of time.

Broadband, continuous low-frequency shipping noise is more likely to affect marine mammals than narrowband, low duty cycle SURTASS LFA sonar or the brief and intermittent signals from MFA/HFA sources. SURTASS LFA sonar bandwidth is limited (approximately 30 Hz), the average maximum pulse length is 60 seconds, signals do not remain at a single frequency for more than 10 seconds, and during an operation the system is off nominally 90 to 92.5 percent of the time. Most mysticete vocalizations are in the low frequency band below 1 kHz. No direct auditory measurements have been made for any mysticete, but it is generally believed that their frequency band of best hearing is below 1,000 Hz, where their calls have the greatest energy (Clark, 1990; Edds-Walton, 2000; Ketten, 2000). However, with the nominal duty cycle of 7.5 to 10 percent, masking would be temporary. For these reasons, any masking effects from SURTASS LFA sonar are expected to be negligible and extremely unlikely.

Odontocetes have a broad acoustic range and hearing thresholds measure between 400 Hz and 100 kHz (Richardson, et al., 1995a; Finneran et al., 2002). It is believed that odontocetes communicate above 1,000 Hz and echolocate above 20 kHz (Würsig and Richardson, 2002). While the upward spread of masking is known to exist, the phenomenon has a limited range in frequency. Yost (2000) showed that magnitude of the masking effect decreases as the difference between signal and masking frequency increase; i.e., the masking effect is lower at 3 times the frequency of the masker than at 2 times the frequency. Gorga et al. (2002) demonstrated that for a 1.2-kHz masking signal, the upward spread of masking was extinguished at frequencies of 6 kHz and higher. Therefore, while the phenomenon of upward spread of masking does exist, it is unlikely that LFA would have any significant effect on the hearing of higher frequency animals. Gorga et al. (2002) also demonstrated that the upward spread of masking is a function of the received level of the masking signal. Therefore, a large increase in the masked bandwidth due to upward masking would only occur at high received levels of the LFA signal. In a recent analysis for the Policy on Sound and Marine Mammals: An International Workshop sponsored by the Marine Mammal Commission (United States) and the Joint Nature Conservation Committee (United Kingdom) in 2004, Dr. John Hildebrand provided a comparison of anthropogenic underwater sound sources by their annual energy output. On an annual basis, four SURTASS LFA systems are estimated to have a total energy output of 6.8 x $10^{11}$ Joules/yr. Seismic air gun arrays were two orders of magnitude greater with an estimated annual output of 3.9 x $10^{13}$ Joules/year. MFA and super tankers were both greater at 8.5 x $10^{12}$ and 3.7 x $10^{12}$ Joules/year, respectively (Hildebrand, 2004). Hildebrand concluded that increases in anthropogenic sources most likely to contribute to increased noise in order of importance are commercial shipping, offshore oil and gas exploration and drilling, and naval and other uses of sonar. The use of SURTASS LFA sonar is not scheduled to increase past the originally analyzed four systems during the next 5-year regulation under the Marine Mammal Protection Act (MMPA). The percentage of the total anthropogenic acoustic energy budget added by each LFA source is actually closer to 0.5 percent per system (or less), when other man-made sources are considered (Hildebrand, 2004). When combined with the naturally occurring and other manmade sources of noise in the oceans, the intermittent LFA signals barely contribute a measurable portion of the total acoustic energy.

In a recently released report entitled “Ad-Hoc Group on the Impact of Sonar on Cetaceans,” the International Council for the Exploration of the Sea (International Council for the Exploration of the Sea, 2005) concluded that shipping accounts for more than 75 percent of all human sound in the sea, and sonar amounts to no more than 10 percent or so. It further stated that sonar (noise budget) would probably never exceed 10 percent, but that sonar deployment seems likely to increase in the future. Therefore, the SURTASS LFA Final Supplemental Environmental Impact Statement (SEIS) dated April 2007 concluded that because LFA transmissions would not significantly increase anthropogenic oceanic noise, cumulative impacts and synergistic effects from the proposed four SURTASS LFA sonar systems for masking would not be a reasonably foreseeable significant adverse impact on marine animals.

### Synergistic Effects

The potential for synergistic effects of the operation of SURTASS LFA sonar with overlapping sound fields from other anthropogenic sound sources was initially analyzed based on two LFA sources (U.S. Department of the Navy, 2007). In order for the sound fields to converge, the multiple sources would have to transmit exactly in phase (at the same time), requiring similar signal characteristics, such as time of transmissions, depth, vertical steering angle, waveform, wavetrain, pulse length, pulse repetition rate, and duty cycle. In the very unlikely event that this ever occurred, the analysis demonstrated that the “synergistic” sound field generated would be 75 percent or less of the value obtained by adding the results. Therefore, adding the results conservatively bounds the potential effects of employing multiple LFA sources. In the areas where marine mammals would potentially be affected by significant behavioral changes, they would be far enough away that they would discern each LFA sonar as an individual source. Standard operational employment of two SURTASS LFA sonars calls for the vessels to be nominally at least 185 km (100 nm) apart (U.S. Department of the Navy, 2007). Moreover, LFA sources would not normally operate in proximity to each other and would be unlikely to transmit in phase as noted above. Based on this and the coastal standoff restriction, it is unlikely that LFA sources, under any circumstances, could produce a sound field so complex that marine animals would not know how to escape it if they desired to do so.

Because of the potential for seismic surveys to interfere with the reception of passive signals and return echoes, SURTASS LFA sonar operations are not expected to be close enough to these activities to have any synergistic effects. Because of the differences between the LFA coherent signal and seismic air gun impulsive “shots,” there is little chance of producing a “synergistic” sound field. Marine animals would perceive these two sources of underwater sound differently and any addition of received signals would be insignificant. This situation would present itself only rarely, as LFA testing and training operations have not been, and are not expected to be conducted in proximity to any seismic survey activity.

If SURTASS LFA sonar operations were to occur concurrent with other military (including MFA/HFA sonars) and commercial sonar systems, synergistic effects are not probable because of differences between these systems (U.S. Department of the Navy, 2007). For the sound fields to converge, the multiple sources would have to transmit exactly in phase (at the same time), requiring similar signal characteristics, such as time of transmissions, depth, frequency, bandwidth, vertical steering angle, waveform, wavetrain, pulse length, pulse repetition rate, and duty cycle. The potential for this occurring is negligible.

Another area for potential cumulative effects would be those associated with marine mammal populations. To evaluate the effects of MIRC area sonar operations, it is necessary to place it in perspective with other anthropogenic impacts on marine resources.

**Bycatch**

Increases in ambient noise levels have the potential to mask an animal's ability to detect objects, such as fishing gear, thus increasing their susceptibility to becoming bycatch. Because LFA/MFA/HFA transmissions are intermittent and would not significantly increase anthropogenic oceanic noise, cumulative impacts and synergistic effects from masking by MIRC activities signals are not a reasonably foreseeable significant adverse impact on marine animals.

**Ship Strikes**

Increases in ambient noise levels have the potential to mask an animal's ability to detect approaching vessels, thus increasing their susceptibility to ship strikes. Because LFA/MFA/HFA transmissions are intermittent and will not significantly increase anthropogenic oceanic noise, cumulative impacts and synergistic effects from ship strikes due to masking are not a reasonably foreseeable significant adverse impact on marine animals from MIRC activities.

#### 1.9.1.3 ASW Training Activities from Submarines

Submarine ASW sensors are passive hull-mounted and towed array sonar, and hull-mounted active sonar. During submarine versus submarine exercises, passive sonar is used almost exclusively. Active sonar use is very rare, because it reveals the tracking submarine's presence to the target submarine. Submarines may also launch MK-48 torpedoes, which can operate in a passive mode or actively by ensonifying the target with high frequency sonar. The MK-48 torpedo was modeled for active sonar transmissions as a high frequency within the MIRC. As many as four USN submarines may take part in an ASW exercise. Potential harassment would be from MFA and HFA sonar.

#### 1.9.1.4 ASW Training Activities from Aircraft

Aircraft involved in ASW are fixed-wing P-3C aircraft and rotary-wing SH-60 helicopters. The P-3C ASW sensors are radar, magnetic anomaly detection, and sonobuoys (the use of MK-46 and MK-54 torpedoes is considered separately under TORPEX). Of these, only sonobuoys operate in the water. The sonobuoys can be either active or passive. Active sonobuoys emit a sound pulse (ping), or an explosion from an SSQ-110A sonobuoy, to generate an echo from the target. Passive sonobuoys listen for acoustic energy (sound), but are not a sound source. Active sonobuoys include DICASS AN/SSQ-62, AEER AN/SSQ-125, and EER/IEER SSQ-110A sonobuoys. DICASS and AEER sonobuoys transmit mid-frequency sonar that reflects off the target. Potential harassment would be from MFA sonar and underwater detonations.

The EER/IEER system uses a mix of multiple active and passive sonobuoys, deployed in different patterns depending on the tactical situation. The active component of the EER/IEER system is the SSQ-110A sonobuoy that projects sound energy in the water using small explosive charges. Any sound energy returning to the passive sonobuoys in the pattern is processed as potential submarine targets. The sonobuoys sink when manually scuttled, after their battery is exhausted, or after the erosion of salt-water plugs designed to allow the buoy to sink. A P-3C can monitor 32 passive or four active buoys at once, and carries a maximum of 84 sonobuoys. The P-3C usually drops 15-20 buoys in a given exercise, although this can vary greatly depending on the tactical situation. For VS 07, P-3C crews used SSQ-110A sonobuoys during four separate events. Each event consisting of an average 15-buoy pattern. The analysis that follows in this document will estimate that each of the 15 sonobuoy charges will be detonated, making a total of 30 detonations for an entire exercise. In the future (the timeframe at present is unknown), the AN/SQS-125 (AEER system) will be replacing EER/IEER. Potential harassment would be from underwater detonations.

The Navy uses the H-60 airframe under three ASW model designations SH-60B (Bravo), SH-60F (Foxtrot), and MH-60R (Romeo). The SH-60B, operating from cruisers, destroyers, and frigates, can monitor eight passive or two active sonobuoys at once, and can carry a maximum of 25 sonobuoys. The SH-60B usually drops 8-14 buoys in a given exercise. The SH-60F, operating from the aircraft carrier, can employ active and passive dipping sonar to perform the same function. The MH-60R, introduced to the Navy in 2002, is a multi-mission model that can perform the capabilities of both the SH-60B and SH-60F.

### Table 1-3. Summary of Training Events Within the MIRC

| **Exercise Type** | **SINKEX** | **EER/IEER** | **DEMO** | **BOMBEX** | **GUNEX** | **MISSILEX** | **Other ASW TRACKEX/TORPEX** | **Multi Strike Group [1]** |
|---|---|---|---|---|---|---|---|---|
| Anticipated Takes | Yes | No | Yes* | Yes* | Yes* | Yes* | Yes | Yes |
| Sources/Weapons/Rounds per year | See Table 1.2 | SSQ-110A (6.72 pound [lb] NEW) | 10 and 20 lb NEW | MK-82/GBU-12 MK-84/GBU-10 Bombs | 5 in gun | AGM-88 Missile<br>AGM-84 Missile<br>SLAM Missile<br>AGM-114 Missile<br>Maverick Missile | AN/SQS-53 MFA Sonar<br>AN/SSQ-62 DICASS MFA Sonobuoy<br>AN/SSQ-125 AEER MFA Sonobuoy<br>AN/ASQ-21/13 Track Mode (Diping Sonar)<br>MK-48 Torpedo HFA Sonar | AN/SQS-53 MFA Sonar<br>AN/SSQ-62 DICASS Sonobuoy<br>AN/SSQ-125 AEER Sonobuoy<br>AN/ASQ-21/13 Track Mode (Diping Sonar)<br>MK-48 Torpedo HFA Sonar |
| Explosion in or on water | Yes | Yes | Yes | No | Yes | Yes | No | No |
| Length of Exercise | Variable | 6 hours | Variable | Variable | Variable | Variable | 12 hours reset for modeling | 14 days (12 hours reset for modeling) |
| Detonations/hours/rounds/sonobuoy or torpedo deployments, or helicopter sonar dips per exercise or year | See Table 1.2 | 140 deploy/yr (60 deploy for Multi Strike Group and 80 deploy/yr) | 46/yr (10 lb)<br>6/yr (20 lb) | MK-82/ GBU-12 20 bombs<br>MK-84/ GBU-10 8 bombs | 800 Rounds | 4 AGM-88 Missiles<br>10 AGM-84 Missiles<br>2 SLAM Missiles<br>4 AGM-114 Missiles<br>16 Maverick Missiles | SQS-53 (Search Mode) =134 hrs/yr<br>SQS-53 (Kingfisher) = 30 hrs/yr<br>SSQ-62 DICASS = 46 Sonobuoys/yr<br>ASQ-21/13 Track Mode =128 Dips/yr<br>MK 48 Torpedo = 9 torpedoes/yr | SQS-53 (Search Mode) = 866 hrs/yr<br>SQS-53 Kingfisher 0 hrs<br>SSQ-62 DICASS[1] 254 Sonobuoys/yr<br>ASQ-21/13 Track Mode =288 Dips/yr<br>MK 48 Torpedo[1] 1/yr |
| Number Exercises per Year (Note 2) | 2 | N/A | N/A | 2 | 2 | 2 | N/A | 1 |
| Area Used | South and East | South and East | Agat Bay and Outer Apra Harbor | South and East | South and East | South and East | General MIRC | General MIRC |
| Months of Year conducted | Year Round | Year Round | Year Round | Year Round | Year Round | Year Round | Summer | Summer |

[1] SURTASS LFA activities will occur as part of the Joint Multi-strike Group exercises

* Modeled under SINKEX

† Part of Joint Multi-strike Group Exercise

For ASW TRACKEX and ASW TORPEX: 53-C and 56-C number equates to annual hours of use; buoys number equates to annual number of sonobuoys used; AQS22 number equates to annual number of dips; MK48 number equates to annual number of MK48 torpedoes used.

NEW = Net explosive weight, SINKEX = Sinking exercise, DEMO = Demolition, GUNEX = Gunnery exercise, MISSILEX = Missile exercise

[1] Hours of sonar training activities included in ASW TRACKEX/TORPEX

## 1.10 Proposed Action and Alternatives

The Department of Defense (DoD) Representative Guam, Commonwealth of the Northern Mariana Islands (CNMI), Federated States of Micronesia (FSM) and Republic of Palau (DoD REP) is preparing an EIS/Overseas Environmental Impact Statement (OEIS) to assess the potential environmental effects associated with continuing and proposed military activities within the MIRC. The DoD REP proposes to improve training activities in the MIRC by selectively improving critical facilities, capabilities, and training capacities. The Proposed Action would result in focused critical enhancements and increases in training that are necessary to maintain a state of military readiness commensurate with the national defense mission. The Proposed Action includes minor repairs and upgrades to facilities and capabilities but does not include any military construction requirements. Three alternatives, including the No Action Alternative, were included for analysis in the MIRC EIS/OEIS. Under all three Alternatives, the Navy would conduct active sonar training and activities at current tempo and intensity.

The No-Action Alternative is the continuation of current training activities, RDT&E activities, and continuing base activities. This includes all multi-Service training activities on DoD training areas. The No-Action Alternative, or the current level of training and RDT&E activities, has been evaluated in the Military Training in the Marianas EIS, June 1999.

ASW Training—ASW training engages helicopter and sea control aircraft, ships, and submarines, operating alone or in combination, in training to detect, localize, and attack submarines. ASW training involves sophisticated training and simulation devices, including underwater targets and sonobuoys, which emit sound through the water. When the object of the exercise is to track the target but not attack it, the exercise is called a TRACKEX. A TORPEX takes the training one step further, culminating in the release of an actual torpedo, which can be either running (EXTORP) or non-running (REXTORP). All torpedoes used in such training have inert warheads.

MIW Training—MIW training includes MCM Exercises and Mine Laying Exercises (MINEX). MINEX events involve aircraft dropping inert training shapes, and less frequently submarine mine laying.

AW Training—AW training includes Surface-to-Air GUNEX, Air Defense Exercise (ADEX), simulated S-A MISSILEX, simulated Air-to-Air Missile Exercise (AAMEX), Air Combat Maneuvers (ACM): and MISSILEX.

SUW Training—SUW training includes S-S GUNEX and SINKEX:

Alternative 1 is a proposal designed to meet the Services' current and foreseeable training requirements. If Alternative 1 were to be selected, in addition to accommodating the No-Action Alternative, it would include increased training as a result of upgrades and modernization of existing capabilities. This alternative also includes training associated with ISR/Strike and other AAFB initiatives. Training will also increase as a result of the acquisition and development of new PUTR capabilities. PUTR trains personnel in undersea warfare including conducting TRACKEX and TORPEX activities. Helicopter, ship, and submarine sonar systems will use this capability. Small arms range capability improvements and military operations on urban terrain (MOUT) training facility improvements would also increase training activities. These increased capabilities will result in increased multi-national and/or joint exercises.

Major Exercises—Training would increase to include major exercises involving multiple strike groups and task forces. Major exercises provide multi-Service and multi-national participation in realistic maritime and expeditionary training that is designed to replicate the types of training and challenges that could be faced during real-world contingency. Major exercises provide training to submarine, ship, aircraft, and special warfare forces in mission tactics, techniques, and procedures.

ISR/Strike—The USAF has established the ISR/Strike program at AAFB, Guam. ISR/Strike will be implemented in phases over a planning horizon of fiscal year (FY) 2007–FY 2016. ISR/Strike force structure consists of up to 48 fighter, 12 aerial refueling, six bomber, and four unmanned aircraft with associated support personnel and infrastructure. Aircraft training activities out of AAFB ultimately will increase by 45 percent over the current level (FY 2006). There will be increased activity on all the current training areas supporting USAF training: W-517, Air Traffic Control Assigned Airspaces (ATCAAs), and FDM/R-7201.

ASW—ASW describes the entire spectrum of platforms, tactics, and weapon systems used to neutralize and defeat hostile submarine threats to combatant and non-combatant maritime forces. A critical component of ASW training is the PUTR. The PUTR is an instrumented range that allows near real-time tracking and feedback to all participants. Guam-homeported submarine crews, as well as crews of transient submarines require ASW training events to maintain qualifications. A MIRC instrumented ASW portable undersea range, target support services, and assigned torpedo retriever craft would meet support requirements for TORPEX and TRACKEX activities in the MIRC in support of Submersible Ship Nuclear (SSN) and Submersible Ship Guided Nuclear (SSGN) and other deployed forces.

MOUT—MOUT training is conducted within a facility that replicates to the extent practicable an urban area.

Alternative 2 would include all of the activities described in Alternative 1. Implementation of Alternative 2 would include all the actions proposed for MIRC in Alternative 1 and increased training activity associated with major exercises. Additional major exercises would provide additional ships and personnel maritime training including additional use of sonar that may improve the level of joint operating skill and teamwork between the Navy, Joint Forces, and Partner Nations. Submarine, ship, and aircraft crews train in tactics, techniques, and procedures for ASW, SUW, AW, and operational level C2 of maritime forces. The major exercise would take place within the MIRC and would focus on defense of the Mariana Islands.

Alternative 1 has been selected as the Navy’s Preferred Alternative. This LOA request is for the conduct of activities in accordance with Alternative 1 of the MIRC EIS/OEIS.

# 2 DURATION AND LOCATION OF ACTIVITIES

Training events would be conducted on the MIRC throughout the year from January 2010 through December 2014 along the appropriate Fleet Response timeline.

## 2.1 Location and Description of the MIRC

Guam is located roughly three quarters the distance from Hawaii to the Philippines, about 1,600 miles east of Manila and 1,550 miles southeast of Tokyo. The southern extent of the Commonwealth of the Northern Mariana Islands (CNMI) is located 40 miles north of Guam (Rota Island) and extends 330 miles to the northwest. Saipan, the CNMI capital, is 3,300 miles west of Honolulu and 1,470 miles south-southeast of Tokyo. The MIRC is of particular significance for the training of U.S. military forces in the Western Pacific because of its location. As the westernmost complex in U.S. territory, it provides the only opportunity for forward-deployed U.S. forces to train on U.S.-owned lands without having to return to Hawaii or the continental United States.

### 2.1.1 Physiography and Bathymetry

The seafloor of the MIRC is characterized by the Mariana Trench, the Mariana Basin, the Mariana Ridge, ridges, numerous seamounts, hydrothermal vents, and volcanic activity. These areas are comprised of very deep water with a very rapid transition from the shelf to deep water. The Mariana Trench is located east to south-east of Guam and the Mariana Islands and is characterized by deep depths of 16,404 to 32,808 feet [ft] (5,000 to 10,000 m) (Fryer et al. 2003). The Mariana Basin is located west of Guam and the Mariana Islands, and is characterized by an average depth of 11,483 ft (Taylor and Martinez 2003; Yamazaki et al. 1993). The Mariana Ridge consists of Guam and the Mariana Islands and the waters out to the Mariana Trench, and is characterized by shallow water transitioning deep water of 11,483 ft (3,500 m) (Taylor and Martinez 2003; Yamazaki et al. 1993). The bottom substrate covering the seafloor in the MIRC is primarily volcanic or marine in nature (Eldredge 1983).

### 2.1.2 Physical Oceanography

The water column can be divided into three separate water masses: a surface layer, an intermediate layer of rapidly changing temperature referred to as the thermocline, and a deepwater layer (Pickard and Emery 1982). Wind and water density differences drive the circulation of water masses in the ocean. Surface currents are primarily driven by the wind (wind-driven circulation), affecting the upper 328 ft (100 m) of the water column. Variations in temperature and salinity will cause changes in water density, which in turn drives the thermohaline circulation capable of moving water masses at all levels of the water column (Pickard and Emery 1982). The general oceanic circulation surrounding the study area and the Mariana Islands is little known as few studies have investigated the major current pattern around the islands (Eldredge 1983).

### 2.1.3 Hydrography

Hydrography refers to the scientific study of the measurement and description of the physical features of the oceans. The following sections briefly describe the temperature of water at the ocean surface, the vertical structure of temperature within the water column, and the horizontal and vertical distribution of the salinity in the MIRC.

#### 2.1.3.1 Sea Surface Temperature

The waters of the MIRC Study Area undergo an annual cycle of temperature change, however this temperature flux is only a few degrees each year, as would be expected from a tropical climate. The temperature throughout the year ranges from about 25° to 31°C with an annual mean temperature of 27° to 28°C for the years ranging from 1984 to 2003 (National Oceanic and Atmospheric Administration

[NOAA] 2004). Temperatures increase during the summer and autumn months with peak temperatures occurring in September/October.

Along the reef flats near the shoreline, sea surface temperature (SST) has been reported to average 2°C higher than those reported in nearshore waters and may reach temperatures as high as 34°C during periods of extensive low tide (Eldredge 1983).

Increases in SST caused by El Nino events can influence the distribution pattern of fishes (Lehodey et al. 1997). Further, prolonged high SST will cause the bleaching of corals, coral mortality and induce the outbreak of coral diseases within the study area (Harvell et al. 1999; Richmond et al. 2002).

#### 2.1.3.2 Thermocline

The water column in the MIRC Study Area contains a well-mixed surface layer ranging from 295 ft to 410 ft (90 to 125 m). Immediately below the mixed layer is a rapid decline in temperature to the cold deeper waters. Unlike more temperate climates, the thermocline is relatively stable, rarely turning over and mixing the more nutrient waters of the deeper ocean in to the surface layer. This constitutes what has been defined as a “significant” surface duct (a mixed layer of constant water temperature extending from the sea surface to 100 feet or more), which influences the transmission of sound in the water. This factor has been included in the modeling analysis of marine mammal impacts.

#### 2.1.3.3 Salinity

The MIRC lies in a region near the equator of low surface salinity bound to the north and south by regions of higher salinity (Pickard and Emery 1982). Surface salinity is lower towards the southern end of the Mariana archipelago and increases towards the north. At a depth of 100 to 200 m, there is a spike in salinity that corresponds with the input of high saline tropical waters (Eldredge 1983). Below this region, the salinity drops to a minimum (approximately 34.5 parts per trillion [ppt]) and corresponds to the influx of North Pacific Intermediate Water (NPIW). NPIW is formed as cold, fresh, dense water sinks below the more saline water in the north subarctic Pacific Ocean and can be recognized by its overall lower salinity and location within the water column (1,640 ft to 2,297 ft [500 to 700 m] depth) (Eldredge 1983).

### 2.1.4 Biological Oceanography

Most of the marine flora in the MIRC Study Area is composed of phytoplankton. The western Pacific, including the MIRC, can be considered an oligotrophic region. The water column in the MIRC is composed of a nutrient depleted surface layer overlying a deeper nutrient rich layer (Rodier and LeBorgne 1997). As such, standing stocks of phytoplankton biomass (Radenac and Rodier 1996) and concentrations of chlorophyll a are low throughout the study area (less than 0.1 milligrams per cubic meter [$m^3$]) (National Aeronautics and Space Administration [NASA] 1998). In regions in which overall nutrient concentrations are low, the phytoplankton communities are dominated by small nanoplankton and picoplankton (Le Bouteiller et al. 1992; Higgins and Mackey 2000). This is true for the MIRC, as phytoplankton communities in the western Pacific are dominated by cyanobacteria (*Synechococcus* sp.), prochlorophytes, haptophytes, and chlorophytes (Higgins and Mackey 2000). Cells less than one micron (µm) in size comprise 60% of the total chlorophyll a measured (Le Bouteiller et al. 1992).

# 3 MARINE MAMMALS

Thirty-one marine mammal species, stocks or populations have confirmed or possible occurrence in the marine waters off the Mariana Islands, including 28 cetaceans (whales, dolphins, and porpoises), two pinnipeds (Hawaiian monk seal and northern elephant seal), and one sirenian, the dugong (DoN 2005; 2007b). Of these 31, there are approximately 22 that are regularly found in the area, four that are rare and four that are extralimital (DoN 2005; 2007).

Table 3-1 lists species and probable seasonal occurrence within the marine waters of Mariana Islands.

## 3.1 Species and Occurrence

### 3.1.1 Information Sources

Eldredge (1991) compiled the first list of published and unpublished records for the greater Micronesia area, reporting 19 marine mammal species. Some of these species accounts were based on unsubstantiated reports and may not reflect true species distribution in the region. Eldredge (2003) refined this list specifically for 13 cetacean species thought to occur around Guam (Eldredge 2003). The first comprehensive marine mammal survey of waters off the Mariana Islands was conducted from mid-January to mid April of 2007 (DoN 2007b). Given the survey’s seasonal coverage and relatively low number of sightings, density estimates derived from the survey data are augmented by density and abundance estimates from the western North Pacific and the NOAA Fisheries Southwest Fisheries Science Center surveys of the eastern tropical Pacific and Hawaiian Islands (Ferguson and Barlow 2001, 2003; Barlow 2003, 2006). Guam references currently available are Kami and Lujan (1976), Donaldson (1983), and Eldredge (1991, 2003).

The Mariana Islands Marine Resource Assessment (MRA) (DoN 2005c) includes a summary of scientific literature on marine species occurrence within the MIRC. For this LOA, MRA information was supplemented with additional citations derived from new survey efforts, and scientific publications. Literature searches were conducted using the search engines: Biosis, Cambridge Abstract's Aquatic Sciences, University of California Melvyl, Biosis, and Zoological Record Plus. Searches were also conducted on peer reviewed journals that regularly publish marine mammal related articles (e.g., Marine Mammal Science, Canadian Journal of Zoology, Journal of Acoustical Society of America, Journal of Zoology, and Aquatic Mammals). Additional references were also obtained from previous Navy environmental documents, and other regionally based reports.

Recent advances in marine mammal tagging and tracking have contributed to the growth of biological information including at-sea movements and diving behavior. Given the development of this new technology and difficulties in placing tags on marine mammals in the wild, the body of literature and sample size, while growing, is still relatively small. For difficult to study marine mammals such as a beaked whale, an audiogram from a Gervais beaked whale stranded from natural causes (Cook et al. 2006) with only a sample size of one contributes new information that had not been available previously. Additional information was also solicited from acknowledged experts within academic institutions and government agencies such as Southwest Fisheries Science Center, NMFS with expertise in marine mammal biology, distribution, and acoustics.

## Table 3-1. Summary of Marine Mammal Species, Status, and Abundance in the MIRC

| Common Name | Species Name | IUCN/ ESA/ MMPA Status | Occurrence | |
|---|---|---|---|---|
| | | | Summer July-Nov | Winter Dec-June |
| **ESA Species** | | | | |
| **Mysticetes** | | | | |
| Blue whale | *Balaenoptera musculus* | E, D, S | Rare | Rare |
| Fin whale | *Balaenoptera physalus* | E, D, S | Rare | Regular |
| Sei whale | *Balaenoptera borealis* | E, D, S | Rare | Regular |
| **Odontocetes** | | | | |
| Humpback whale | *Megaptera novaeangliae* | E, D, S | Rare | Regular |
| North Pacific right whale | *Eubalaena japonica* | E, D, S | Rare | Rare |
| Sperm whale | *Physeter macrocephalus* | E, D, S | Regular | Regular |
| **Pinniped** | | | | |
| Hawaiian Monk Seal | *Monachus schauinslandi* | T, D, S | Extra-limital | Extra-limital |
| **Sirenia** | | | | |
| Dugong | *Dugong dugon* | E, V | Extra-limital | Extra-limital |
| **Non ESA Species** | | | | |
| **Mysticetes** | | | | |
| Bryde's whale | *Balaenoptera edeni* | | Regular | Regular |
| Minke whale | *Balaenoptera acutorostrata* | | Rare | Regular |
| **Odontocetes** | | | | |
| Blainville's beaked whale | *Mesoplodon densirostris* | | Regular | Regular |
| Bottlenose dolphin | *Tursiops truncatus* | | Regular | Regular |
| Cuvier's beaked whale | *Ziphius cavirostris* | | Regular | Regular |
| Dwarf sperm whale | *Kogia sima* | | Regular | Regular |
| False killer whale | *Pseudorca crassidens* | | Regular | Regular |
| Fraser's dolphin | *Lagenodelphis hosei* | | Regular | Regular |
| Ginkgo-tooth beaked whale | *Mesoplodon ginkgodens* | | Rare | Rare |
| Hubbs beaked whale | *Mesoplodon carlhubbsi* | | Extra-limital | Extra-limital |
| Indo-Pacific bottlenose dolphin | *Tursiops aduncus* | | Extra-limital | Extra-limital |
| Killer whale offshore | *Orcinus orca* | | Regular | Regular |
| Longman's beaked whale | *Indopacetus pacificus* | | Regular | Rare |
| Melon-headed whale | *Peponocephala electra* | | Regular | Regular |
| Pantropical spotted dolphin | *Stenella attenuata* | | Regular | Regular |
| Pygmy killer whale | *Feresa attenuata* | | Regular | Regular |
| Pygmy sperm whale | *Kogia breviceps* | | Regular | Regular |
| Risso's dolphin | *Grampus griseus* | | Regular | Regular |
| Rough-toothed dolphin | *Steno bredanensis* | | Regular | Regular |
| Short-beaked common dolphin | *Delphinus delphis* | | Rare | Rare |
| Short-finned pilot whale | *Globicephala macrorhynchus* | | Regular | Regular |
| Spinner dolphin | *Stenella longirostris* | | Regular | Regular |
| Striped dolphin | *Stenella coeruleoalba* | | Regular | Regular |
| **Pinniped** | | | | |
| Northern elephant seal | *Mirounga angustirostris* | | Extra-limital | Extra-limital |

E = Endangered under the Endangered Species Act (ESA); T = Threatened under the ESA; D = Depleted under the MMPA; S = Strategic Stock under the MMPA; V = Vulnerable under the International Union for the Conservation of Nature (ICUN) Red List (Reeves et al. 2003)

Extralimital: Species that has occurred rarely in the past, may be only one or several documented sightings or may occur based on general distribution patterns.

### 3.1.2 Endangered Species Act (ESA) Listed Marine Mammal Species Excluded From Further Analysis

**North Pacific Right Whale**

The likelihood of a North Pacific right whale (*Eubalaena japonica*) occurring in the action area is extremely low. The north Pacific right whale population is the most endangered of the large whale species (Perry et al. 1999) and, currently, there is no reliable population estimate for this species, although the population in the western North Pacific Ocean is considered to be very small, perhaps in the tens to low hundreds of animals. Commercial whaling reduced the right whale population to 29-100 animals (Wada 1973). Despite many years of systematic aerial and ship-based surveys for marine mammals off the western coast of the U.S., only seven documented sightings of right whales were made from 1990 through 2005 near Alaska (Waite et al. 2003; Wade et al. 2006). Based on this information, it is highly unlikely for a right whale to be present in the action area. Consequently, this species will not be considered in the remainder of this analysis.

**Hawaiian Monk Seal**

The likelihood of a Hawaiian monk seal (*Monachus schauinslandi*) being present in the action area is extremely low. The Hawaiian monk seal is listed as endangered under the ESA and depleted under the MMPA (Ragen and Lavigne 1999; Carretta et al. 2007). Hawaiian monk seals are managed as a single stock within the Hawaiian Islands and breed there exclusively (Ragen and Lavigne 1999; Carretta et al. 2004).

The best estimate of the total population size is 1,247 individuals (Carretta et al. 2007). In 2001, there were an estimated 77 seals in the main Hawaiian Islands (Baker and Johanos 2004; Carretta et al. 2004); the vast majority of the population occurs in the Northwestern Hawaiian Islands. The overall trend in abundance for the population over the past 20 years has mostly been negative except for the Main Hawaiian Islands (Baker and Johanos 2004; Carretta et al. 2004).

There are no confirmed records of Hawaiian monk seals in the Micronesia region; however, Reeves et al. (1999) and Eldredge (1991, 2003) have noted occurrence records for seals (unidentified species) in the Marshall and Gilbert islands. It is possible that Hawaiian monk seals wander from the Hawaiian Islands to appear at the Marshall or Gilbert Islands in the Micronesia region (Eldredge 1991). However, given the extremely low likelihood of this species occurrence in the action area, the Hawaiian monk seal will not be considered in the remainder of this analysis.

**Dugong**

The likelihood of a dugong being present in the action area is extremely low. The dugong (*Dugong dugon*) is listed as endangered under the ESA throughout its entire range (United States Fish and Wildlife Service [USFWS] 2003) and is designated as vulnerable by the International Union for the Conservation of Nature (IUCN) Red List (Marsh et al. 2003). A total of 27 individuals were counted during the course of the 2003 aerial survey at Palau, the only location in the Micronesia region with a dugong population (Davis 2004). The likelihood of a dugong occurring in the action area is extremely low. Consequently, this species will not be considered in the remainder of this analysis.

### 3.1.3 Non ESA Listed Marine Mammal Species Excluded From Further Analysis

**Hubbs Beaked Whale**

The likelihood of an Hubbs beaked whale (*Mesoplodon carlhubbsi*) occurring in the action area is extremely low. There are no occurrence records for the Mariana Islands and the nearest records are from strandings in Japan (DoN 2005). Recent data suggests that the distribution is likely north of 30$^{o}$ N (MacCleod et al. 2006). Given the extremely low likelihood of this species occurrence in the action area, the Hubbs beaked whale will not be considered in the remainder of this analysis.

**Indo-Pacific Bottlenose Dolphin**

The likelihood of an Indo-Pacific bottlenose dolphin (*Tursiops aduncas*) occurring in the action area is extremely low. The Indo-Pacific bottlenose dolphin is generally associated with continental margins and does not appear to occur around offshore islands that are great distances from a continent, such as the Marianas (Jefferson as cited in DoN 2005). Given the extremely low likelihood of this species occurrence in the action area, the Indo-Pacific bottlenose dolphin will not be considered in the remainder of this analysis.

**Northern Elephant Seal**

Northern elephant seals (*Mirounga angustirostris*) are common in on islands and mainland haul-out sites in Baja California, Mexico north through central California. Elephant seals spend several months at sea feeding and travel as far as the Gulf of Alaska. Occasionally juveniles wander great distances with several individuals being observed in Hawaii and Japan. Although elephant seals may wander great distances it is very unlikely that they would travel to Japan or Hawaii and then continue traveling to the MIRC. Given the extremely low likelihood of this species occurrence in the action area, the northern elephant seal will not be considered in the remainder of this analysis.

### 3.1.4 ESA Listed Marine Mammal Species Included in Further Analysis

Stocks of all species listed as endangered under the ESA are automatically considered ‘depleted’ and ‘strategic’ under the MMPA. The specific definition of a strategic stock is complex, but in general it is a stock for which human activities may be having a deleterious effect on the population and may not be sustainable.

Detailed information for all species is included in Section 4.

#### Cetaceans

Five cetacean species occur within the Mariana Islands and are listed as Endangered under the ESA (DoN 2005, 2007). These include the blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), sei whale (*Balaenoptera borealis*), and sperm whale (*Physeter macrocephalus*). Humpback, sei and sperm whales were detected visually and acoustically during the Navy’s 2007 survey (DoN 2007b, Fulling et al. 2007, Rivers et al. 2007, Thorson et al. 2007). Fin and blue whales were not detected visually or acoustically during this survey.

### 3.1.5 Non-Threatened and Non-Endangered Cetaceans Included in Further Analysis

**Baleen Whales**

Bryde’s whales (*Balaenoptera edeni*) and minke whales (*Balaenoptera acutorostrata*) were encountered frequently during the Navy’s 2007 survey (DoN 2007b). Bryde’s were detected visually and minke whales were detected acoustically (DoN 2007b). Both species occur regularly in the project area during the winter season.

**Toothed Whales**

The most common toothed whales within the MIRC include the bottlenose dolphin (*Tursiops truncatus*), melon-headed whale (*Peponocephala electra*), Risso's dolphin (*Grampus griseus*), short-beaked common dolphin (*Delphinus delphis*), spinner dolphin (*Stenella longirostris*), and striped dolphin (*Stenella coeruleoalba*). Dolphin species typically are the most numerous cetaceans occurring within the MIRC (DoN 2005, 2007).

## 3.2 Estimated Marine Mammal Densities for Exposure Modeling

Marine mammal species occurring off the Mariana Islands include primarily baleen whales (mysticetes) and toothed whales (odontocetes). Pinnipeds (seals and sea lions) and Sirenians (manatees and dugongs) may have occurred in the area sporadically in the past, but are unlikely to occur there now. Baleen and toothed whales, collectively known as cetaceans, spend their entire lives in the water and spend most of the time (>90% 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. In addition, because their ears are nearly always below the water's surface, they are exposed to underwater sound (both natural and anthropogenic) essentially 100% of the time.

For the purposes of this analysis, a conservative approach to underwater sound and marine mammals was adopted:

Cetaceans – assume 100% of time is spent underwater and therefore exposed to sound

Pinnipeds – considered extralimital (Hawaiian monk seal and northern elephant seal), unlikely to occur in the MIRC Study Area and therefore they were not analyzed for exposure effects

Sirenians – considered extralimital (*Dugong dugong*), unlikely to occur in the MIRC Study Area, and therefore they were not analyzed for exposure effects

**Density**

Prior to 2007 there was little information available on the abundance and density of marine mammals in the MIRC Study Area. Most information on the occurrence of marine mammals came from short surveys (several days) and opportunistic sightings (NMFS Platform of Opportunity, oceanographic cruises or strandings). The first comprehensive survey of the area, Mariana Islands Sea Turtle and Cetacean Survey (MISTCS), was funded by the Navy to gather data in support of this analysis and was conducted in early 2007 covering mid January to mid April (DoN 2007b). Densities were calculated for 13 species observed during this survey and are the only published densities derived for this area that are based upon actual sightings. In order to conduct the analysis needed for the purposes of the MIRC EIS, the Navy compiled published densities from other geographical areas with existing survey data and similar oceanography (e.g. sea surface temperature) such as the Hawaiian Islands (Barlow 2003, 2006), warm water areas of the eastern tropical Pacific (Ferguson and Barlow 2001, 2003) and Miyashita (1993). To ensure that the MISTCS estimates represented the best available science for use in acoustic effects modeling, they were compared with those from other similar geographical areas. As shown in Table 3-2, for every species that MISTCS provided an estimate for, all are either mid-range or higher in comparison. This, combined with the fact that the MISTCS survey was conducted in the MIRC Study Area, supports the Navy's decision to use MISTCS data as the primary source for modeling. Considering the similar habitat and species diversity with the MIRC Study Area, offshore survey data from the Hawaiian Islands (Barlow 2003, 2006) was used as a secondary source. Densities from the Eastern Tropical Pacific survey (Ferguson and Barlow 2001, 2003) were used for four remaining species. Miyashita 1993, was reviewed, however, no densities from that report were ultimately utilized.

The draft MISTCS density report was reviewed by local biologists at NMFS-Pacific Fisheries Science Center (PIFSC) and Pacific Islands Regional Office (PIRO), whose recommendations were incorporated into the final document. The methods used in the final MISTCS report was approved by NMFS PIFSC and PIRO for use in preparation of environmental planning documents for the Mariana Islands.

### Navy 2007 MISTCS

The MISTCS cruise was conducted from 13 January 2007 to 13 April 2007 in the Mariana Islands area, which included most of the MIRC Study Area. The survey was conducted using the systematic line transect survey protocol developed by the NMFS Southwest Fisheries Science Center (SWFSC) (Kinsey et al. 1998; Barlow 2003, 2006; Ferguson and Barlow 2001, 2003). Both visual and acoustic detection methods were used during the survey (DoN 2007b). This first systematic marine mammal survey of the Mariana Islands and Guam area was conceived and funded by the Navy to provide data to support an analysis of potential effects from ongoing military readiness activities in the Marianas Islands.

Observers visually surveyed 11,033 kilometer (km) (6,063 nm) of trackline during the MISTCS cruise. On-effort distances ranged from 220 km to 3,300 km per leg (four 21 day legs to the survey). Visual survey effort was stopped at Beaufort sea state (BSS) >7. The original intent was to stop visual effort at BSS>5; however, poor sea conditions would have prevented any survey effort on several days during the first half of the survey. Therefore, all survey effort and sightings in BSS≤6 were included in the density estimation analyses.

There were 148 total sightings of 12 marine mammal species. The sperm whale was the most frequently seen species (21 sightings) followed by Bryde’s and sei whales (18 and 16 sightings, respectively). The pantropical spotted dolphin was the most frequently encountered delphinid species (16 sightings) followed by the false killer whale and the striped dolphin (both 10 sightings). There were also three sightings of beaked whales (two *Mesoplodon* spp. and one ziphiid whale). Group size varied by species and ranged from 1 to 115 individuals. The range of bottom depth for sightings was highly variable (472-32,395 ft) and was species-dependent.

Species with similar sighting characteristics (e.g., body size, group size, surface behavior, blow visibility) were pooled to estimate $f_i(0)$ for three categories: *Balaenoptera* spp., blackfish (medium size odontocetes such as pilot and melon headed whales), and delphinids. This was done because there were insufficient numbers of sightings (<20) to model the detection function for individual species.

The full MISTCS report is provided in Appendix B.

### Densities Derived From Other Areas

Given the absence of sightings of certain expected species during MISTCS (e.g. blue whale, fin whale), density estimates derived from survey data collected in other regions were used to augment the MISTCS survey data. Information on density estimates were taken from several sources depending on the species. Density estimates from the Hawaiian Islands, the eastern tropical Pacific (ETP), and southern Japan/east Taiwan, were examined. Information on the occurrence or anticipated distribution of species was also analyzed as available. Although some species have not been observed within the Guam and Mariana Islands area, their overall distribution, habitat preference or proximity to known areas of occurrence suggest that they could use or transit this area. In addition, oceanographic changes such as shifts in sea surface temperature or current/gyre patterns, or changes in population, may cause animals to alter their normal migration patterns or ranges.

### Hawaii Offshore (Barlow 2003, 2006)

Marine mammal density estimates for the Hawaiian offshore area are reported in Barlow (2003). During the last 30 years, SWFSC has refined the techniques for conducting visual observations from ships using line transect methods (Smith 1979; Holt and Powers 1982; Hiby and Hammond 1989; Buckland et al. 2001; 1993). The methods used in the Hawaiian Islands offshore surveys are similar to those described for the Mariana Islands survey.

The outer exclusive economic zone (EEZ) of the Hawaiian Islands, 25 nautical miles (nm) beyond the coast of the islands, was surveyed during the summer and fall of 2002 (Barlow 2003; 2006). The low number of cetaceans sighted in this area made density estimates difficult (Barlow 2003; 2006). Barlow developed a method using detection probabilities of cetaceans from this study and previous line transect studies in Hawaiian waters to estimate cetacean density and abundance.

**Table 3-2. Summary Of Marine Mammal Densities For Mariana Islands. Densities In Bold Were Used In The Effects Modeling.**

| Common Name | Marine Mammal Densities (animals/km$^2$) | | | |
|---|---|---|---|---|
| | Navy 2007 Mariana Islands Survey | Hawaii Offshore | Eastern Tropical Pacific | Japan/Western Pacific |
| **ESA Listed Species** | | | | |
| Blue whale<br>*Balaenoptera musculus* | N/A | N/A | **0.0001<br>(CV = 0.43-1.00)** | N/A |
| Fin whale<br>*Balaenoptera physalus* | N/A | 0.0001<br>(CV = 0.72) | **0.0003<br>(CV = 0.72)** | N/A |
| Humpback whale<br>*Megaptera novaeangliae* | **0.0069<br>(CV = 1.00)** | N/A | 0.0001-0.0002<br>(CV = 1.00) | N/A |
| Sei whale<br>*Balaenoptera borealis* | **0.00029<br>(CV = 0.49)** | 0.0000<br>(CV = 1.06) | N/A | N/A |
| Sperm whale<br>*Physeter macrocephalus* | **0.00123<br>(CV = 0.60)** | 0.0029<br>(CV = 0.30) | 0.0001-0.0035<br>(CV = 0.47–1.00) | N/A |
| **Non ESA Listed Species** | | | | |
| Bryde's whale<br>*Balaenoptera edeni* | **0.00041<br>(CV = 0.45)** | 0.0002<br>(CV = 0.34) | 0.0001-0.0029<br>(CV = 0.47-1.00) | N/A |
| Minke whale<br>*Balaenoptera acutorostrata* | **N/A** | N/A | **0.0003<br>(CV = 0.71)** | N/A |
| Blainville’s beaked whale<br>*Berardius bairdii* | N/A | **0.0009<br>(CV = 0.77)** | 0.0013<br>(CV = 0.71) | N/A |
| Bottlenose dolphin<br>*Tursiops truncatus* | **0.00021<br>(CV = 0.99)** | 0.0013<br>(CV = 0.60) | 0.0001 -0.0311<br>(CV = 0.36-1.0) | 0.0146 |
| Cuvier's beaked whale<br>*Ziphius cavirostris* | N/A | **0.0052<br>(CV = 0.83)** | 0.0003-0.054<br>(CV = 0.55-1.00) | N/A |
| Dwarf sperm whale<br>*Kogia sima* | N/A | **0.0078<br>(CV = 0.66)** | 0.0017-0.0173<br>(CV = 0.52-1.00) | N/A |
| False killer whale<br>*Pseudorca crassidens* | **0.00111<br>(CV = 0.74)** | 0.0001<br>(CV = 1.08) | 0.0004-0.0147<br>(CV = 0.58-1.00) | N/A |

**Table 3-2. Summary Of Marine Mammal Densities For Mariana Islands. Densities In Bold Were Used In The Effects Modeling. (cont'd)**

| Common Name | Marine Mammal Densities (animals/km$^2$) | | | |
|---|---|---|---|---|
| | Navy 2007 Mariana Islands Survey | Hawaii Offshore | Eastern Tropical Pacific | Japan/Western Pacific |
| Fraser's dolphin *Lagenodelphis hosei* | N/A | **0.0069 (CV = 1.11)** | 0.005-0.1765 (CV = 0.58-1.00) | N/A |
| Ginkgo-toothed beaked whale *Mesoplodon ginkgodens* | N/A | **0.0005 (CV = 0.45-1.00)** | N/A | N/A |
| Killer whale *Orcinus orca* | N/A | **0.0002 (CV = 0.72)** | 0.0001-0.003 (CV = 0.58-1.00) | N/A |
| Longman's beaked whale *Indopacetus pacificus* | N/A | **0.0003 (CV = 1.05)** | 0.0002-0.0004 (CV = 1.00) | N/A |
| Melon-headed whale *Peponocephala electra* | **0.00428 (CV = 0.88)** | 0.0012 (CV = 1.10) | 0.0007-0.0167 (CV = 0.71-1.00) | N/A |
| Pantropical spotted dolphin *Stenella attenuata* | **0.0226 (CV = 0.70)** | 0.0042 (CV = 0.41) | 0.0574-0.4208 (CV = 0.24-0.95) | 0.0137 |
| Pygmy killer whale *Feresa attenuata* | **0.00014 (CV = 0.88)** | 0.0003 (CV = 1.12) | 0.0014-0.0156 (CV = 0.44-1.00) | N/A |
| Pygmy sperm whale *Kogia breviceps* | N/A | **0.0078 (CV = 0.77)** | 0.0018-0.0031 (CV = 0.71-1.00) | N/A |
| Risso's dolphin *Grampus griseus* | N/A | **0.0010 (CV = 0.65)** | 0.0006-0.0178 (CV = 0.39-1.0) | 0.0106 |
| Rough-toothed dolphin *Steno bredanensis* | **0.00029 (CV = 0.89)** | 0.0081 (CV = 0.52) | 0.0002-0.0576 (CV = 0.40-1.00) | N/A |
| Short-beaked common dolphin *Delphinus delphinus* | N/A | N/A | **0.0021 (CV = 0.28)** | N/A |
| Short-finned pilot whale *Globicephala macrorhynchus* | **0.00159 (CV = 0.68)** | 0.0036 (CV = 0.49) | 0.0007-0.0208 (CV = 0.36-1.00) | N/A |
| Spinner dolphin *Stenella longirostris* | **0.00314 (CV = 0.95)** | 0.0011 (CV = 0.66) | 0.0001-0.2191 (CV = 0.31-1.00) | N/A |
| Striped dolphin *Stenella coeruleoalba* | **0.00616 (CV = 0.54)** | 0.0042 (CV = 0.48) | 0.0019-0.3825 (CV = 0.24-1.46) | 0.0329 |

**Density Sources:**
Navy 2007 Mariana Islands Survey - DoN 2007b
Hawaii Offshore survey - Barlow 2006
Eastern Tropical Pacific - Ferguson and Barlow 2003
Japan/Western Pacific - Miyashita et al. 1993

CV = Coefficient of Variation

If no density estimates were available for a species from the MISTCS report then densities from the Hawaiian offshore survey (Barlow 2003; 2006) were primarily used because of its similarity to the MIRC Study Area habitat and species.

### Eastern Tropical Pacific - Water Areas (Ferguson and Barlow 2001, 2003)

The SWFSC within the NMFS has conducted marine mammal surveys in the Eastern Tropical Pacific (ETP) since the 1970s. During the last 30 years, SWFSC has refined the techniques for conducting visual observations from ships using line transect methods (Smith 1979; Holt and Powers 1982; Hiby and Hammond 1989; Buckland et al. 2001; 1993).

Ferguson and Barlow (2001, 2003) provide density estimates and associated coefficients of variation (CVs) for geographic regions within the ETP. Marine mammal density estimates from the offshore strata with similar sea surface temperatures to the MIRC Study Area were used in the MIRC analysis because these areas are oceanographically more similar to the Mariana Islands area. Areas adjacent to the coast were not used because of the higher productivity associated with coastal areas in the ETP (Hardy 1993; Burtenshaw et al. 2004).

### Western Pacific (Miyashita et al. 1993)

Miyashita et al. (1996) reported on the winter distribution and abundance of cetaceans in the western north Pacific. Data were collected using ship based surveys but were not conducted in the same systematic line transect manner as the NMFS surveys in Hawaii and the ETP. Ship surveys were conducted relative to the Japanese small cetacean drive fisheries (commercial cetacean fisheries) and occurred while searching for cetaceans.

# 4 ASSESSMENT OF MARINE MAMMAL SPECIES OR STOCKS THAT COULD POTENTIALLY BE AFFECTED

## 4.1 Marine Mammal Hearing and Vocalization Summary

### 4.1.1 Cetaceans

Cetaceans have an auditory anatomy that follows the basic mammalian pattern, with some changes to adapt to the demands of hearing in the sea. The typical mammalian ear is divided into an outer ear, middle ear, and inner ear. The outer ear is separated from the inner ear by a tympanic membrane, or eardrum. In terrestrial mammals, the outer ear, eardrum, and middle ear transmit airborne sound to the inner ear, where the sound waves are propagated through the cochlear fluid. Since the impedance of water is close to that of the tissues of a cetacean, the outer ear is not required to transduce sound energy as it does when sound waves travel from air to fluid (inner ear). Sound waves traveling through the inner ear cause the basilar membrane to vibrate. Specialized cells, called hair cells, respond to the vibration and produce nerve pulses that are transmitted to the central nervous system. Acoustic energy causes the basilar membrane in the cochlea to vibrate. Sensory cells at different positions along the basilar membrane are excited by different frequencies of sound (Pickles 1998). Baleen whales have inner ears that appear to be specialized for low-frequency hearing. Conversely, dolphins and porpoises have ears that are specialized to hear high frequencies.

Marine mammal vocalizations often extend both above and below the range of human hearing; vocalizations with frequencies lower than 18 Hertz (Hz) are labeled as infrasonic and those higher than 20 kHz as ultrasonic (National Research Council [NRC] 2003; Figure 4-1). Measured data on the hearing abilities of cetaceans are sparse, particularly for the larger cetaceans such as the baleen whales. The auditory thresholds of some of the smaller odontocetes have been determined in captivity. It is generally believed that cetaceans should at least be sensitive to the frequencies of their own vocalizations. Comparisons of the anatomy of cetacean inner ears and models of the structural properties and the response to vibrations of the ear’s components in different species provide an indication of likely sensitivity to various sound frequencies. The ears of small toothed whales are optimized for receiving high-frequency sound, while baleen whale inner ears are best in low to infrasonic frequencies (Ketten 1992; 1997; 1998).

Baleen whale vocalizations are composed primarily of frequencies below 1 kHz, and some contain fundamental frequencies as low as 16 Hz (Watkins et al. 1987; Richardson et al. 1995; Rivers 1997; Moore et al. 1998; Stafford et al. 1999; Wartzok and Ketten, 1999) but can be as high as 24 kHz (humpback whale; Au et al. 2006). Clark and Ellison (2004) suggested that baleen whales use low frequency sounds not only for long-range communication, but also as a simple form of echo ranging, using echoes to navigate and orient relative to physical features of the ocean. Information on auditory function in mysticetes is extremely lacking. Sensitivity to low-frequency sound by baleen whales has been inferred from observed vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system. Although there is apparently much variation, the source levels of most baleen whale vocalizations lie in the range of 150-190 dB re 1 µPa at 1 m. Low-frequency vocalizations made by baleen whales and their corresponding auditory anatomy suggest that they have good low-frequency hearing (Ketten 2000), although specific data on sensitivity, frequency or intensity discrimination, or localization abilities are lacking. Marine mammals, like all mammals, have typical U-shaped audiograms that begin with relatively low sensitivity (high threshold) at some specified low frequency with increased sensitivity (low threshold) to a species specific optimum followed by a generally steep rise at higher frequencies (high threshold) (Fay 1988).

The majority of blue and fin whales vocalizations are less than 222 Hz (Cummings and Thompson 1971; Thompson et al. 1992; Berchok et al. 2003a, 2003b; Mellinger and Clarke 2003; Clarke 2004; Rankin et al. 2004). Blue whales produce a variety of low-frequency sounds in a 10-100 Hz band (Cummings and Thompson 1971; Edds 1982; Thompson and Friedl 1982; Alling and Payne 1991; McDonald et al. 1995; Clark and Fristrup 1997; Rivers 1997; Stafford et al. 1998; Stafford et al. 1999; McDonald et al. 2001). Off California, the most typical blue whale signals are very long, patterned sequences of tonal infrasonic sounds in the 15-100 Hz range (Aburto et al. 1997; Teranishi et al. 1997; McDonald et al. 2001; Oleson et al. 2005), and are typically infrequently produced by a small subset of males (Calambokidis et al. 2004; Oleson et al. 2005).

Fin whales produce a variety of low frequency sounds, primarily in the 15-200 Hz band (Watkins 1981; Watkins et al. 1987; Edds 1988; Thompson et al. 1992; McDonald and Fox 1999). The most typical signals are long, patterned sequences of short duration (0.5-2 seconds) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964; Watkins et al. 1987).

Three sounds are produced by humpback whales: "songs" produced in late fall, winter, and spring by single animals; sounds produced by groups of humpback whales (possibly associated with aggressive behavior among males) on the winter breeding grounds; and sounds produced on the summer feeding grounds. Dominant frequencies of these songs range from 40 Hz to 4 kHz, with components of up to 8 kHz (Thompson et al. 1979; Richardson et al. 1995) and harmonics of the frequency fundamental measured up to 24 kHz (Au et al. 2001, 2006). Source levels average 155 dB re 1 µPa at 1 m and range from 144 to 174 dB re 1 µPa at 1 m (Thompson et al. 1979; Au et al. 2006). Sounds often associated with possible aggressive behavior by males are quite different from songs, extending from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz (Tyack and Whitehead 1983). Sounds are produced less frequently on summer feeding grounds and are at approximately 20-2000 Hz, with median durations of 0.2-0.8 sec and source levels of 175-192 dB re 1 µPa at 1 m (Thompson et al. 1986). Filter-bank models of the humpback whale’s ear have been developed from anatomical features of the humpback’s ear and optimization techniques (Houser et al. 2001a). The results suggest that humpbacks are sensitive to frequencies between 700 Hz and 10 kHz, but best sensitivity is likely to occur between 2 and 6 kHz.

Minke whales produce a variety of sounds, primarily in the 80-5,000 Hz range. In the Northern Hemisphere, sounds recorded include grunts, thumps, and ratchets from 80-850 Hz and pings and clicks from 3-20 kHz (Winn and Perkins 1976; Thompson et al. 1979; Stewart and Leatherwood 1985; Mellinger et al. 2000; Rankin and Barlow 2003).

The toothed whales produce a wide variety of sounds, which include species-specific broadband “clicks” with peak energy between 10 and 200 kHz, individually variable “burst pulse” click trains, and constant frequency or frequency-modulated (FM) whistles ranging from 4 to 16 kHz (Wartzok and Ketten 1999). The general consensus is that the tonal vocalizations (whistles) produced by toothed whales play an important role in maintaining contact between dispersed individuals, while broadband clicks are used during echolocation (Wartzok and Ketten 1999). Burst pulses have also been strongly implicated in communication, with some scientists suggesting that they play an important role in agonistic encounters (McCowan and Reiss 1995), while others have proposed that they represent “emotive” signals in a broader sense, possibly representing graded communication signals (Herzing 1996). Sperm whales, however, are known to produce only clicks, which are used for both communication and echolocation (Whitehead 2003). Most of the energy of toothed whales social vocalizations is concentrated near 10 kHz, with source levels for whistles as high as 100-180 dB re 1 µPa at 1 m (Richardson et al. 1995). No odontocete has been shown audiometrically to have acute hearing (<80 dB re 1 µPa) below 500 Hz (DoN 2001). Sperm whales produce clicks, which may be used to echolocate (Mullins et al. 1988), with a frequency range from less than 100 Hz to 30 kHz and source levels up to 230 dB re 1 µPa 1 m or greater (Møhl et al. 2000).

Southall et al (2007) has provided a comprehensive review of marine mammal acoustics including designating functional hearing groups. Table 4-1 presents the functional hearing groups and representative species or taxonomic groups for each although most species found in the MIRC fall in the first two groups, low frequency cetaceans (baleen whales) and mid frequency cetaceans (odontocetes).

**Table 4-1. Summary of the Five Functional Hearing Groups of Marine Mammals (Based on Southall et al. 2007)**

| Functional Hearing Group | Estimated Auditory Bandwidth | Species or Taxonomic Groups |
|---|---|---|
| **Low Frequency Cetaceans** (Mysticetes–Baleen whales) | 7 Hz to 22 kHz (best hearing is generally below 1000 Hz, higher frequencies result from humpback whales) | All baleen whales |
| **Mid/High Frequency Cetaceans**<br>(Odontocetes) | 150 Hz to 160 kHz (best hearing is from approximately 10-120 kHz) | Most delphinid species including rough-toothed, bottlenose, spinner, common, Fraser's, dusky, hourglass, Peale, white-beaked and white-sided, Risso's and right whale dolphins; medium and large odontocete whales including melon-headed pygmy killer, false killer, killer whale, pilot sperm whale, beluga whale, narwhal and beaked whales |
| **High-frequency cetaceans** (Odontocetes) | 200 Hz to 180 kHz (best hearing is from approximately 10-150 kHz) | Porpoise species including the harbor, finless, and Dall's porpoise; river dolphins including the Baiji, Ganges, Amazon river dolphins; the dwarf and pygmy sperm whales), and Commerson's, Heaviside and Hector's dolphins |
| **Pinnipeds in water** | 75 Hz to 75 kHz (best hearing is from approximately 1-30 kHz) | All seals, fur seals, sea lions and walrus |
| **Pinnipeds in air** | 75 Hz to 30 kHz (best hearing is from approximately 1-16 kHz) | All seals, fur seals, sea lions and walrus |

General reviews of cetacean and pinniped sound production and hearing may be found in Richardson et al. (1995), Edds-Walton (1997), Wartzok and Ketten (1999), and Au et al. (2000), May-Collado et al. (2007). For a discussion of acoustic concepts, terminology, and measurement procedures, as well as underwater sound propagation, Urick (1983) and Richardson et al. (1995) are recommended.

## 4.2 Endangered or Threatened Marine Mammal Species in the Action Area

The ESA-listed blue whale, fin whale, humpback whale, sei and sperm whale are expected to regularly occur, although seasonally, in the MIRC Study Area, and each species is described below. Species are also designated according to the ICUN Red List of Threatened Species using the following:

**Threatened:** a taxon is Endangered when the best available evidence indicates that it is facing a very high risk of extinction in the wild;

**Vulnerable:** considered to be facing a high risk of extinction in the wild;

**Near Threatened:** is close to qualifying for or is likely to qualify for a threatened category in the near future;

**Least Concern:** a taxon is Least Concern when it does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category;

**Data Deficient:** A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking;

**Blue whale (*Balaenoptera musculus*)** Western North Pacific Stock

*Listing Status*—In the North Pacific, the International Whaling Commission (IWC) began management of commercial whaling for blue whales in 1969; blue whales were fully protected from commercial whaling in 1976 (Allen 1980). Blue whales were listed as endangered under the ESA in 1973, therefore, they are considered depleted and strategic under the MMPA. They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA of 1972. Blue whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). Critical habitat has not been designated for blue whales.

*Population Status*—The blue whale was severely depleted by commercial whaling in the twentieth century (NMFS 1998). In the North Pacific, pre-exploitation population size is speculated to be approximately 4,900 blue whales and the current population estimate is a minimum of 3,300 blue whales (Wade and Gerrodette 1993, NMFS 2006c). No blue whales were visually or acoustically detected during the MISTCS winter survey cruise (DoN 2007b); however ship noise required the acoustic system to set a filter above the frequency of infrasonic calls. There are no density estimates for this species (Barlow 2006); therefore a density of 0.0001 animals per $km^2$ (CV = 0.43-1.00) was derived from the Eastern Tropical Pacific surveys (Ferguson and Barlow 2001, 2003).

A clear population trend for blue whales is difficult to detect under current survey methods. An increasing trend between 1979/80 and 1991 and between 1991 and 1996 was suggested by available survey data, but it was not statistically significant (Carretta et al. 2006). Although the population in the North Pacific is expected to have grown since being given protected status in 1966, the possibility of continued unauthorized takes by Soviet whaling vessels after 1966, and the existence of incidental ship strikes and gillnet mortality makes this uncertain (Yablokov 1994).

*Distribution*—The blue whale has a worldwide distribution in circumpolar and temperate waters. Blue whales undertake seasonal migrations and were historically hunted on their summer, feeding areas. It is assumed that blue whale distribution is governed largely by food requirements and that populations are seasonally migratory. Poleward movements in spring allow the whales to take advantage of high zooplankton production in summer. Movement toward the subtropics in the fall allows blue whales to reduce their energy expenditure while fasting, avoid ice entrapment in some areas, and engage in reproductive activities in warmer waters of lower latitudes. The timing varied, but whalers located few blue whales in wintering areas from December to February. The NMFS Biological Opinion for Valiant Shield (NMFS 2007) stated that observations made after whaling was banned revealed a similar pattern: blue whales spend most of the summer foraging at higher latitudes where the waters are more productive (Sears 1990; Calambokidis et al. 1990; Calambokidis 1995). Like the other baleen whales, individual blue whales might migrate south prematurely and occur in the MIRC, but it is highly improbable.

There are no occurrence records for the blue whale in the MIRC and vicinity, though this area is in the distribution range for this species. Blue whales would be most likely to occur in the Mariana Islands area during the winter (Jefferson, cited in DoN 2005) although none were observed during a recent marine mammal survey (January through April 2007) of the area (DoN 2007b).

*Reproduction/Breeding*—Blue whales move south in the fall and calving primarily occurs in the winter (Yochem and Leatherwood 1985).

*Diving Behavior*—Blue whales spend more than 94 percent of their time below the water's surface (Lagerquist et al. 2000). Croll et al. (2001) determined that blue whales dived to an average of 462 ft. (141 m) and for 7.8 minutes (min) when foraging and to 222 ft. (68 m) and for 4.9 min when not foraging. Calambokidis et al. (2003) deployed tags on blue whales and collected data on dives as deep as about 984 ft. (300 m). Lunge-feeding at depth is energetically expensive and likely limits the deeper diving capability of blue whales. Foraging dives are deeper than traveling dives; traveling dives were generally to ~ 100 ft (30 m). Typical dive shape is somewhat V-shaped, although the bottom of the V is wide to account for the vertical lunges at the bottom of the dive. Blue whales also have shallower foraging dives.

*Acoustics*—Blue whale vocalizations are long, patterned low-frequency sounds with durations up to 36 sec (Richardson et al. 1995) repeated every 1 to 2 min (Mellinger and Clark 2003). Their frequency range is 12 to 400 hertz (Hz), with dominant energy in the infrasonic range at 12 to 25 Hz (Ketten 1998; Mellinger and Clark 2003). Source levels (1 µPa @ 1 m) are up to 188 dB re 1 µPa-m (Ketten, 1998; McDonald et al. 2001). 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 (Aburto et al. 1997). Širović et al. (2007) reported that blue whales produced vocalizations with a source level of 189 ± 3 dB re:1 µPa-m over a range of 25 to 29 Hz and could be detected up to 124 miles away. A comparison of recordings between November 2003 and November 1964 and 1965, reveals a strong blue whale presence near San Nicolas Island (McDonald et al. 2006). McDonald et al. (2006) reported a long-term shift in the frequency of the blue whale calling is seen; in 2003 the spectral energy peak was 16 Hz, whereas in 1964-65 the energy peak was near 22.5 Hz, illustrating a more than 30% shift in call frequency over four decades.

Vocalizations of blue whales appear to vary among geographic areas (Rivers 1997), with clear differences in call structure suggestive of separate populations for the western and eastern regions of the North Pacific (Stafford et al. 2001). Stafford et al. (2005) recorded the highest calling rates when blue whale prey was closest to the surface during its vertical migration. Wiggins et al. (2005) reported the same trend of reduced vocalization during daytime foraging and then an increase in vocalizations at dusk as prey move up into the water column and disperse. Blue whales make seasonal migrations to areas of high productivity to feed and vocalize less in the feeding grounds than during the migration (Burtenshaw et al., 2004). Oleson et al. (2007) reported higher calling rates in shallow diving (<100 ft [30 m]) whales while deeper diving whales (> 165 ft [50 m]) were likely feeding and calling less.

As with other mysticete sounds, the function of vocalizations produced by blue whales is unknown. Hypothesized functions include: (1) maintenance of inter-individual distance, (2) species and individual recognition, (3) contextual information transmission (e.g., feeding, alarm, courtship), (4) maintenance of social organization (e.g., contact calls between females and offspring), (5) location of topographic features, and (6) location of prey resources (Thompson et al. 1992). Responses to conspecific sounds have been demonstrated in a number of mysticetes (Edds-Walton 1997), and there is no reason to believe that blue whales do not communicate similarly.

While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing. Although no recent studies have directly measured the sound sensitivity in blue whales, experts assume that blue whales are able to receive sound signals in roughly the same frequencies as the signals they produce (< 400 Hz;Croll et al. 2001; Stafford and Moore 2005; Oleson et al. 2007).

Blue whales continued foraging when exposed to LFA sonar sound at about 140 dB and changes in vocalizations were inconsistent and therefore could not be correlated to the LFA exposure (Croll et al. 2001).

In terms of functional hearing capability, blue whales belong to the low-frequency group, which have best hearing ranging from 7 Hz and 22 kHz (Southall et al. 2007; Table 4-1). Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of blue whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, blue whale behavioral exposures shown in Table 6-7 may be an overestimate.

*Impacts of human activity*—Historic Whaling- Blue whales were occasionally hunted by the sailing-vessel whalers of the 19th century (Scammon 1874). The introduction of steam power in the second half of that century made it possible for boats to overtake large, fast-swimming blue whales and other rorquals. From the turn of the century until the mid-1960s, blue whales from various stocks were intensely hunted in all the world’s oceans. Blue whales were protected in portions of the Southern Hemisphere beginning in 1939, but were not fully protected in the Antarctic until 1965. In 1955, they were given complete protection in the North Atlantic under the International Convention for the Regulation of Whaling; this protection was extended to the Antarctic in 1965 and the North Pacific in 1966 (Gambell 1979; Best 1993). The protected status of North Atlantic blue whales was not recognized by Iceland until 1960 (Sigurjonsson 1988). Only a few illegal kills of blue whales have been documented in the Northern Hemisphere, including three at Canadian east-coast whaling stations during 1966-69 (Mitchell 1974), some at shore stations in Spain during the late 1950s to early 1970s (Aguilar and Lens 1981; Sanpera and Aguilar 1992), and at least two by “pirate” whalers in the eastern North Atlantic in 1978 (Best 1992). Some illegal whaling by the form Soviet Union also occurred in the North Pacific (Yablokov 1994); it is likely that blue whales were among the species taken by these activities, but the extent of the catches is not known. Since gaining complete legal protection from commercial whaling in 1966, some populations have shown signs of recovery, while others have not been adequately monitored to determine their status (NMFS 1998). Removal of this significant threat has allowed increased recruitment in the population and, therefore, the blue whale population in the eastern North Pacific (ENP) is expected to have grown.

Fisheries Interactions- Because little evidence of entanglement in fishing gear exists, and large whales such as the blue whale may often die later and drift far enough not to strand on land after such incidents, it is difficult to estimate the numbers of blue whales killed and injured by gear entanglements. In addition, the injury or mortality of large whales due to interactions or entanglements in fisheries may go unobserved because large whales swim away with a portion of the net or gear. Fisherman have reported that large whales tend to swim through their nets without entangling and causing little damage to nets (Barlow et al. 1997).

Ship Strikes-Because little evidence of ship strikes exists, and large whales such as the blue whale may often die later and drift far enough not to strand on land after such incidents, it is difficult to estimate the numbers of blue whales killed and injured by ship strikes. In addition, a boat owner may be unaware of the strike when it happens. Ship strikes were implicated in the deaths of blue whales in 1980, 1986, 1987, 1993, and 2002 (Carretta et al. 2006). Additional mortality from ship strikes probably goes unreported because the whales do not strand or, if they do, they do not always have obvious signs of trauma (Carretta et al. 2006).

Major shipping lanes pass through, or near, whale watching areas, and underwater noise by commercial ship traffic may have a much greater impact than that produced by whale watching. However, little is known about whether, or how, vessel noise affects blue whales.

### Fin whale (*Balaenoptera physalus*)

*Listing Status*—In the North Pacific, the IWC began management of commercial whaling for fin whales in 1969; fin whales were fully protected from commercial whaling in 1976 (Allen 1980). Fin whales were listed as endangered under the ESA in 1973. They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA of 1972. Fin whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). Critical habitat has not been designated for fin whales.

*Population Status*—In the North Pacific, the total pre-exploitation population size of fin whales is estimated at 42,000 to 45,000 whales (Ohsumi and Wada 1974). The most recent abundance estimate (early 1970s) for fin whales in the entire North Pacific basin is between 14,620 and 18,630 whales (NMFS 2006c). Fin whales have a worldwide distribution with two distinct stocks recognized in the North Pacific: the East China Sea Stock and “the rest of the North Pacific Stock” (Donovan 1991). No fin whales were detected visually or acoustically during the winter MISTCS cruise (DoN 2007b); however ship noise required the acoustic system to set a filter above the frequency of infrasonic calls. There are no density estimates for this species (DoN 2007b; Barlow 2006); therefore a density estimate of 0.0003 animals per km$^2$ (CV = 0.72) was derived from the Eastern Tropical Pacific surveys (Ferguson and Barlow 2001, 2003).

*Distribution*—Fin whales occur in the oceans of both Northern and Southern Hemispheres between 20–75° N and S latitudes (NMFS 2006e). Fin whales are distributed widely in the world’s oceans. In the northern hemisphere, most migrate seasonally from high Arctic feeding areas in summer to low latitude breeding and calving areas in winter. The fin whale is found in continental shelf and oceanic waters (Gregr and Trites 2001; Reeves et al. 2002). Globally, it tends to be aggregated in locations where populations of prey are most plentiful, irrespective of water depth, although those locations may shift seasonally or annually (Payne et al. 1986, 1990; Kenney et al. 1997; Notarbartolo-di-Sciara et al. 2003). Fin whales in the North Pacific spend the summer feeding along the cold eastern boundary currents (Perry et al. 1999).

Miyashita et al. (1995) presents a compilation of at-sea whale sightings obtained from commercial fishing vessels in the Pacific Ocean from 1964-1990. This data did not show fin whales south of 20° N during the month of August; however, there was limited search effort. There were significantly more fin whale sightings north of 40° N. Fin whales are not expected south of 20° N or near Guam during the summer (Miyashita et al. 1995). Although fin whales are not expected there is a possibility of limited occurrence during the August exercise timeframe.

No fin whales were detected acoustically or visually during the winter MISTCS cruise (DoN 2007b).

*Life history information*- Fin whales become sexually mature between six to ten years of age, depending on density-dependent factors (Gambell, 1985b). Reproductive activities for fin whales occur primarily in the winter. Gestation lasts about 12 months and nursing occurs for 6 to 11 months (Perry et al. 1999). The age distribution of fin whales in the North Pacific is unknown. Natural sources and rates of mortality are largely unknown, but Aguilar and Lockyer (1987) suggest annual natural mortality rates may range from 0.04 to 0.06 (based on studies of northeast Atlantic fin whales). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in fin whales and may be preventing some fin whale stocks from recovering from whaling (Lambertsen 1992, as cited in Perry et al. 1999). Killer whale or shark attacks may result in serious injury or death in very young and sick whales (Perry et al. 1999). NMFS has no records of fin whales being killed or injured by commercial fisheries operating in the North Pacific (Ferrero et al. 2000).

*Reproduction/Breeding*—Reproductive activities for fin whales occur primarily in low latitude areas in the winter (Reeves 1998; Carretta et al. 2007).

*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 (Cetacean and Turtle Assessment Program 1982; Stone et al. 1992; Lafortuna et al. 2003). Kopelman and Sadove (1995) found significant differences in blow intervals, dive times, and blows per hour between surface feeding and non-surface-feeding fin whales. Croll et al. (2001)

determined that fin whales dived to 321 ft (98 m) (Standard Deviation [SD] = ± 106.8 ft) with a duration of 6.3 min (SD = ± 1.53 min) when foraging and to 168 ft (51 m) (SD = ± 97.3 ft) with a duration of 4.2 min (SD = ± 1.67 min) when not foraging. Goldbogen et al. (2006) reported that fin whales in California made foraging dives to a maximum of 748-889 ft (228-271 m)and dive durations of 6.2-7.0 min. Fin whale dives exceeding 492 ft (150 m) and coinciding with the diel migration of krill were reported by Panigada et al. (1999). Fin whales feed on planktonic crustaceans, including Thysanoessa sp and Calanus sp, as well as schooling fish including herring, capelin and mackerel (Aguilar 2002). Depth distribution data from the Ligurian Sea in the Mediterranean are the most complete (Panigada et al. 2003), and showed differences between day and night diving; daytime dives were shallower (<100m) and night dives were deeper (>400m), likely taking advantage of nocturnal prey migrations into shallower depths; this data may be atypical of fin whales elsewhere in areas where they do not feed on vertically-migrating prey.

Goldbogen et al. (2006) studied fin whales in southern California and found that 60% of total time was spent diving, with the other 40% near surface (<164 ft. [50m]); dives were to >738 ft. (225 m) and were characterized by rapid gliding ascent, foraging lunges near the bottom of dive, and rapid ascent with flukes. Dives were somewhat V-shaped although the bottom of the V is wide.

*Acoustics*—Underwater sounds produced by fin whales are one of the most studied *Balaenoptera* sounds. Fin whales produce calls with the lowest frequency and highest source levels of all cetaceans. Infrasonic (10-200 Hz), pattern sounds have been documented for fin whales (Watkins et al. 1987; Clark and Fristrup 1997; McDonald and Fox 1999). Charif et al. (2002) estimated source levels between 159 to 184 dB re:1 µPa-m for fin whales vocalizations recorded between Oregon and Northern California. Fin whales can also 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 (Croll et al. 2002). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18 to 35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB re:1 µPa-m (Patterson and Hamilton 1964; Watkins et al. 1987a; Thompson et al. 1992; McDonald et al. 1995). In temperate waters, intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald et al. 1995). Each pulse lasts on the order of one second and at 20 Hz (Tyack 1999). Particularly in the breeding season, fin whales produce series of pulses in a regularly repeating pattern. These bouts of pulsing may last for longer than one day (Tyack 1999). The seasonality and stereotype of the bouts of patterned sounds suggest that these sounds are male reproductive displays (Watkins et al. 1987a), while the individual counter-calling data of McDonald et al. (1995) suggest that the more variable calls are contact calls. Some researchers feel there are geographic differences in the frequency, duration, and repetition of the pulses (Thompson et al. 1992). As with other mysticete sounds, the function of vocalizations produced by fin whales is unknown. Hypothesized functions include: (1) maintenance of inter-individual distance, (2) species and individual recognition, (3) contextual information transmission (e.g., feeding, alarm, courtship), (4) maintenance of social organization (e.g., contact calls between females and offspring), (5) location of topographic features, and (6) location of prey resources (review by Thompson et al. 1992). Responses to conspecific sounds have been demonstrated in a number of mysticetes, and there is no reason to believe that fin whales do not communicate similarly (Edds-Walton 1997). The low-frequency sounds produced by fin whales have the potential to travel over long distances, and it is possible that long-distance communication occurs in fin whales (Payne and Webb 1971; Edds-Walton 1997). In addition, there is speculation that the sounds may function for long-range echolocation of large-scale geographic targets such as seamounts, which might be used for orientation and navigation (Tyack 1999).

The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an 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 (maximum up to 200) (Richardson et al., 1995; Charif et al., 2002). Croll et al. (2002) 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 162 ft (49 m) (Watkins et al. 1987).

Although no studies have directly measured the sound sensitivity of fin whales, experts assume that fin whales are able to receive sound signals in roughly the same frequencies as the signals they produce. This suggests fin whales, like other baleen whales, are more likely to have their best hearing capacities at low frequencies, including infrasonic frequencies, rather than at mid- to high-frequencies (Ketten 1997).

In terms of functional hearing capability, fin whales belong to the low-frequency group, which have best hearing ranging from 7 Hz and 22 kHz (Southall et al. 2007; Table 4-1). Fin whale calls generally cover the 10 to 15 Hz frequency band and are less than 1 second in duration (Sirovic 2006). Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of fin whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, fin whale behavioral exposures in Table 6-7 may be an overestimate.

*Impacts of human activity*-As early as the mid-seventeenth century, the Japanese were capturing fin, blue, and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen 1982, Cherfas 1989). In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. The North Pacific and Antarctic whaling operations soon added this modern' equipment to their arsenal. After blue whales were depleted in most areas, the smaller fin whale became the focus of whaling operations and more than 700,000 fin whales were landed in the twentieth century. The incidental take of fin whales in fisheries is extremely rare. Anecdotal observations from fishermen suggest that large whales swim through their nets rather than get caught in them (NMFS 2000). Because of their size and strength, fin whales probably swim through fishing nets which might explain why these whales are rarely reported as having become entangled in fishing gear.

Ship Strikes-Recent studies of ship strikes and fin whales suggest that it is predominately immature whales that are involved (Panigada et al. 2006; Douglas et al. 2008). Ship strikes on whales have increased since 1980 due to the increase in commercial cargo ships and increases in the speed of those ships (Laist et al. 2001; Douglas et al. 2008). Crews on large commercial ships are not always aware of the strike when it happens as evident by the several ships that have entered harbors with fin whales stuck on the ship's bow (Douglas et al. 2008). Suggestions have been proposed to increase the number of lookouts on commercial ships to avoid collisions with whales (Capoulade 2002). Additional mortality from ship strikes probably goes unreported because the whales do not strand or, if they do, they do not always have obvious signs of trauma (Carretta et al. 2006).

**Humpback whale (*Megaptera novaeangliae*)** Western North Pacific Stock

*Listing Status*—The IWC first protected humpback whales in the North Pacific in 1966. They are also protected under CITES. In the U.S., humpback whales were listed as endangered under the ESA in 1973 and are therefore classified as depleted and strategic stock under the MMPA.

*Population Status*—Humpback whales live in all major ocean basins from equatorial to sub-polar latitudes migrating from tropical breeding areas to polar or sub-polar feeding areas (Jefferson et al. 1993, NMFS 2006c). Three Pacific stocks of humpback whales are recognized in the Pacific Ocean and include the western North Pacific stock, central North Pacific stock, and ENP stock (Calambokidis et al. 1997; Baker et al. 1998). The Western North Pacific humpback whale stock is the one most likely to be encountered within Mariana Islands. In the entire North Pacific Ocean prior to 1905, it is estimated that there were 15,000 humpback whales basin-wide (Rice 1978). In 1966, after heavy commercial exploitation, humpback abundance was estimated at 1,000 to 1,200 whales (Rice 1978), although it is unclear if estimates were for the entire North Pacific or just the ENP. The current estimate for the entire north Pacific is 18,302 humpback whales in all feeding and wintering areas (Calambokidis et al. 2008). Humpback whale density was estimated at 0.0069 animals per $km^2$ (CV = 1.00; DoN 2007b).

*Distribution*—Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (Clapham and Mead 1999). Shallow banks or ledges with high sea-floor relief characterize feeding grounds (Payne et al. 1990; Hamazaki 2002). North Pacific humpback whales are distributed primarily in four more-or-less distinct wintering areas: the Ryukyu and Ogasawara (Bonin) Islands (south of Japan), Hawaii, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). The small winter aggregation of humpback whales observed by the Navy in 2007 (DoN 2007b), combined with acoustic detections of song indicate that there is at least a small wintering population in the Mariana Islands (DoN 2007b, Rivers et al 2007) as well. There is known to be some interchange of whales among different wintering grounds, and some matches between Hawaii and Japan, and between Hawaii and Mexico have been found (Salden et al. 1999; Calambokidis et al. 2000, 2001, 2008). During summer months, North Pacific humpback whales feed in a nearly continuous band from southern California to the Aleutian Islands, Kamchatka Peninsula, and the Bering and Chukchi seas (Calambokidis et al. 2001). Humpback whales summer throughout the central and western portions of the Gulf of Alaska, including Prince William Sound, around Kodiak Island (including Shelikof Strait and the Barren Islands), and along the southern coastline of the Alaska Peninsula. The northern Bering Sea, Bering Strait, and the southern Chukchi Sea along the Chukchi Peninsula appear to form the northern extreme of the humpback whale's range (Nikulin 1946, Berzin and Rovnin 1966).

Humpback whales were observed during the MISTCS cruise 2.7 and 7.6 nm north of Tinian in deep water (2,625 – 3,940 ft [800-1,200 m]) and in shallow water (1,227 ft [374 m]) 1.4 nm north of Tinian (DoN 2007b). Acoustic detections of humpback song were made during these sightings as well as on other occasions (DoN 2007b, Norris et al 2007).

*Life History*—Humpbacks primarily feed on small schooling fish and krill (Caldwell and Caldwell 1983). While in California waters, humpback prey includes euphausiids and small schooling fish like anchovies, sardines, and mackerel (Wynne and Folkens 1992). It is believed that minimal feeding occurs in wintering grounds, such as the Hawaiian Islands but feeding may occur opportunistically (Balcomb 1987; Salden 1989).

*Reproduction/Breeding*—Western North Pacific humpback whales have been observed in the Philippine Sea from the northern Philippines, Taiwan, southern Japan and Mariana Islands area during winter months although there is little information, and northern Mariana Islands may be south of the breeding areas (Mori et al. 1998; Yamaguchi et al. 2002).

*Diving Behavior*—Humpback whale diving behavior depends on the time of year (Clapham and Mead 1999). In summer, most dives last less than 5 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 (Clapham and Mead 1999). Although humpback whales have been recorded to dive as deep as about 1,638 ft (500 m) (Dietz et al. 2002), on the feeding grounds they spend the majority of their time in the upper 400 ft (122 m) of the water column (Dolphin 1987; Dietz et al. 2002). Humpback whales on the wintering grounds do dive deeply; Baird et al. (2000) recorded dives to 577 ft. (176 m).

Like other large mysticetes, they are a "lunge feeder" taking advantage of dense prey patches and engulfing as much food as possible in a single gulp. They also blow nets, or curtains, of bubbles around or below prey patches to concentrate the prey in one area, then lunge with mouths open through the middle. Dives appear to be closely correlated with the depths of prey patches, which vary from location to location. In the north Pacific, most dives were of fairly short duration (<4 min) with the deepest dive to 486 ft (140 m) (southeast Alaska; Dolphin 1987), while whales observed feeding on Stellwagen Bank in the North Atlantic dove to <131 ft (131 m) (Hain et al. 1995).

*Acoustics*—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 (Richardson et al. 1995). The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males (Helweg et al. 1992). Humpback songs were recorded off Tinian during the Navy 2007 survey (DoN 2007b, Norris et al 2007). Singing is most common on breeding grounds during the winter and spring months, but is occasionally heard outside breeding areas and out of season (Matilla et al. 1987; Clark and Clapham 2004). 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 (Payne et al. 1983). Social calls are from 50 Hz to over 10 kHz, with the highest energy below 3 kHz (Silber 1986). Female vocalizations appear to be simple; Simão and Moreira (2005) noted little complexity. The male song, however, is complex and changes between seasons. Components of the song range from under 20 Hz to 8 kHz and occasionally 24 kHz, with source levels of 144 to 174 dB re 1 µPa-m, with a mean of 155 dB re 1 µPa-m (Thompson et al. 1979; Payne and Payne 1985, Frazer and Mercado 2000; Au et al. 2006). Au et al. (2001) recorded high-frequency harmonics (out to 13.5 kHz) and source level (between 171 and 189 dB re 1 µPa-m) of humpback whale songs. Songs have also been recorded on feeding grounds (Mattila et al. 1987; Clark and Clapham 2004). Au et al. (2006) took recordings of whales off Hawaii and found high frequency harmonics of songs extending beyond 24 kHz, which may indicate that they can hear at least as high as this frequency.

"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 second in duration, and have source levels of 175 to 192 dB re 1 µPa-m (DoN 2006a). The main energy lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz. The fundamental frequency of feeding calls is approximately 500 Hz (D'Vincent et al. 1985).

Male calves were recorded in Hawaii producing sounds that were simple in structure, low frequency (mean of 220 Hz), brief in duration (mean duration of 170 ms and occurred over a narrow bandwidth of 2 kHz (Zoidis et al. 2008).

No tests on humpback whale hearing have been made. Houser et al. (2001) constructed a humpback audiogram using a mathematical model based on the internal structure of the ear and estimated sensitivity to frequencies from 700 Hz to 10 kHz, with maximum relative sensitivity between 2 and 6 kHz.

Research by Au et al., (2001, 2006) off Hawaii indicated the presence of high-frequency harmonics in humpback whale vocalizations at 24 kHz. While recognizing this was the upper limit of the recording equipment, it does not demonstrate that humpbacks can actually hear those harmonics, which may simply be correlated harmonics of the frequency fundamental in the humpback "song".. Maybaum (1989) reported that humpback whales showed a mild response to a hand held sonar marine mammal detection and location device (frequency of 3.3 kHz at 219 dB re 1µPa-m with a frequency sweep of 3.1-3.6 kHz) although this system is significantly different from the Navy's hull mounted sonars. In addition, the system had some low frequency components (below 1 kHz) which may be an artifact of the acoustic equipment. This may have affected the response of the whales to both the control and sonar playbacks.

In terms of functional hearing capability, humpback whales belong to low-frequency cetaceans which have best hearing ranging from 7 Hz and 22 kHz (Southall et al. 2007; Table 4-1). 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). Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of humpback whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, humpback whale behavioral exposures shown in Table 6-7 may be an overestimate.

*Impacts of human activity*-Historic whaling. Commercial whaling, the single most significant impact on humpback whales ceased in the North Atlantic in 1955 and in all other oceans in 1966. The humpback whale was the most heavily exploited by Soviet whaling fleets after World War II.

Fisheries Interactions-Entanglement in fishing gear poses a threat to individual humpback whales throughout the Pacific. Reports of entangled humpbacks whales found swimming, floating, or stranded with fishing gear attached, have been documented in the North Pacific. A number of fisheries based out of west coasts ports may incidentally take the ENP stock of humpback whale, and documented interactions are summarized in the U.S. Pacific Marine Mammal Stock Assessments: 2006 (Carretta et al. 2007). The estimated impact of fisheries on the ENP humpback whale stock is likely underestimated, since the serious injury or mortality of large whales due to entanglement in gear, may go unobserved because whales swim away with a portion of the net, line, buoys, or pots. According to Carretta et al. (2007) and the California Marine Mammal Stranding Network Database (Department of Commerce [DOC] 2006), 12 humpback whales and two unidentified whales have been reported as entangled in fishing gear (all crab pot gear, except for one of the unidentified whales) since 1997.

Ship Strikes-Humpback whales, especially calves and juveniles, are highly vulnerable to ship strikes and other interactions with non-fishing vessels. Younger whales spend more time at the surface, are less visible, and closer to shore (Herman et al. 1980; Mobley et al. 1999), thereby making them more susceptible to collisions. Humpback whale distribution overlaps significantly with the transit routes of large commercial vessels, including cruise ships, large tug and barge transport vessels, and oil tankers.

Ship strikes were implicated in the deaths of at least two humpback whales in 1993, one in 1995, and one in 2000 (Carretta et al. 2006). During 1999-2003, there were an additional five injuries and two mortalities of unidentified whales, attributed to ship strikes. Additional mortality from ship strikes probably goes unreported because the whales do not strand or, if they do, they do not have obvious signs of trauma.

Whale watching boats and boats from which scientific research is being conducted specifically direct their activities toward whales and may have direct or indirect impacts on humpback whales. The growth of the whale-watching industry has not increased as rapidly for the ENP stock of humpback whales, as it has for the Central North Pacific stock (wintering grounds in Hawaii and summering grounds in Alaska), but whale-watching activities do occur throughout the ENP stock's range. There is concern regarding the impacts of close vessel approaches to large whales, since harassment may occur, preferred habitats may be abandoned, and fitness and survivability may be compromised if disturbance levels are too high. While a 1996 study in Hawaii measured the acoustic noise of different whale-watching boats (Au and Green 2000) and determined that the sound levels were unlikely to produce grave effects on the humpback whale auditory system, the potential direct and indirect effects of harassment due to vessels cannot be discounted. Several investigators have suggested shipping noise may have caused humpback whales to avoid or leave feeding or nursery areas (Jurasz and Jurasz 1979; Dean et al. 1985), while others have suggested that humpback whales may become habituated to vessel traffic and its associated noise. Still other researchers suggest that humpback whales may become more vulnerable to vessel strikes once they habituate to vessel traffic (Swingle et al. 1993; Wiley et al. 1995).

Other Threats- Similar to fin whales, humpbacks are potentially affected by a resumption of commercial whaling, loss of habitat, loss of prey (for a variety of reasons including climate variability), underwater noise, and pollutants. Generally, very little is known about the effects of organochlorine pesticides, heavy metals, and polychlorinated biphenyl (PCB) and other toxins in baleen whales, although the impacts may be less than higher trophic level odontocetes due to baleen whales' lower levels of bioaccumulation from prey.

Anthropogenic sound may also affect humpback whales, as humpback whales seem to respond to moving sound sources, such as whale-watching vessels, fishing vessels, recreational vessels, and low-flying aircraft (Beach and Weinrich 1989; Clapham et al. 1993; Atkins and Swartz 1989). Their responses to sound are variable and have been correlated with the size, composition, and behavior of the whales when the sounds occurred (Herman et al. 1980; Watkins et al. 1981; Krieger and Wing 1986; Frankel and Clark 1998).

### **Sei whale (*Balaenoptera borealis*)** Western North Pacific Stock

*Listing Status*—Sei whales did not have meaningful protection at the international level until 1970, when catch quotas for the North Pacific began to be set on a species basis (rather than on the basis of total production, with six sei whales considered equivalent to one "blue whale unit"). Prior to that time, the kill was limited only to the extent that whalers hunted selectively for the larger species with greater return on effort (Allen 1980). The sei whale was given complete protection from commercial whaling in the North Pacific in 1976. In the late 1970's, some "pirate" whaling for sei whales took place in the eastern North Atlantic (Best 1992). There is no direct evidence of illegal whaling for this species in the North Pacific although the acknowledged misreporting of whaling data by Soviet authorities (Yablokov 1994) means that catch data are not wholly reliable. In the U.S., sei whales were listed as endangered under the ESA in 1973 and are therefore classified as depleted and strategic stock under the MMPA It is also classified as "endangered" by the IUCN (Baillie and Groombridge 1996) and is listed in CITES Appendix I. Critical habitat has not been designated for this species for the ENP stock.

*Population Status*—Prior to the MISTCS survey, sei whales were considered to be extralimital south of 20° N latitude and in the Mariana Islands area (DoN 2005). However, they were the second most commonly sighted species during the survey, resulting in an estimated population of 166 (CV = 48.7; 95% CI = 67-416) sei whales in the MISTCS Study Area. Sei whale density was estimated as 0.00029 animals per $km^2$ (DoN 2007b; Fulling et al. 2007).

The IWC groups all of sei whales in the entire North Pacific Ocean into one stock (Donovan 1991). However, some mark-recapture, catch distribution, and morphological research, indicated that more than one stock exists; one between 175°W and 155°W longitude, and another east of 155° W longitude (Masaki 1976; 1977). In the U.S. Pacific EEZ only the ENP stock is recognized. Worldwide, sei whales were severely depleted by commercial whaling activities. In the North Pacific, the pre-exploitation population estimate for sei whales is 42,000 whales and the most current population estimate for sei whales in the entire North Pacific (from 1977) is 9,110 (NMFS 2006e).

Application of various models to whaling catch and effort data suggests that the total population of adult sei whales in the North Pacific declined from about 42,000 to 8,600 between 1963 and 1974 (Tillman 1977). Since 500-600 sei whales per year were killed off Japan from 1910 to the late 1950s, the stock size presumably was already, by 1963, below its carrying capacity level (Tillman 1977).

*Distribution*—Sei whales live in temperate regions of all oceans in the Northern and Southern Hemispheres and are not usually associated with coastal features (NMFS 2006c). Sei whales are highly mobile, and there is no indication that any population remains in the same area year-round (i.e., are resident). Pole-ward summer feeding migrations occur, and sei whales generally winter in warm temperate or subtropical waters. Masaki 1976, 1977 reported that during the winter, sei whales are found from 20°- 23° N and during the summer from 35°-50° N, however, the MISTCS survey data appears to contradict this winter latitude restriction (DoN 2007b).

Sei whales are most often found in deep, oceanic waters of the cool temperate zone. They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins situated between banks and ledges (Kenney and Winn 1987; Schilling et al. 1992; Gregr and Trites 2001; Best and Lockyer 2002). These reports are consistent with what was observed during the MISTCS cruise, as sightings most often occurred in deep water 10,381 to 30,583 ft (3,164 to 9,322 m) deep. Most sei whale sightings were also associated with bathymetric relief (e.g., steeply sloping areas), including sightings adjacent to the Chamarro Seamounts east of CNMI (DoN 2007b). All confirmed sightings of sei whales were south of Saipan (approximately 15°N) with concentrations in the southeastern corner of the MISTCS Study Area (DoN 2007b). Sightings also often occurred in mixed groups with Bryde’s whales.

On feeding grounds, the distribution is largely associated with oceanic frontal systems (Horwood 1987). In the North Pacific, sei whales are found feeding particularly along the cold eastern currents (Perry et al. 1999).

*Reproduction/Breeding*—No breeding areas have been determined but calving is thought to occur from September to March (Rice 1977).

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

*Acoustics*—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 (Richardson et al. 1995). Sei whales in the Antarctic produced broadband “growls” and “whooshes” at frequency of 433 ±192 kHz and source level of 156 ±3.6 dB re 1 µPa -m (Mc Donald et al. 2005). Calls recorded off the Hawaiian Islands consisted of down sweeps from 100 Hz to 44 Hz over 1.0 seconds and low frequency calls with downs weeps from 39 Hz to 21 Hz over 1.3 seconds (Rankin and Barlow 2007a).

While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

In terms of functional hearing capability, sei whales belong to low-frequency cetaceans which have best hearing ranging from 7 Hz and 22 kHz (Southall et al. 2007; Table 4-1). There are no tests or modeling estimates of specific sei whale hearing ranges. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of sei whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, sei whale behavioral exposures in Table 6-7 may be an overestimate.

*Impact of human activity*—Historic Whaling. Several hundred sei whales in the North Pacific were taken each year by whalers based at shore stations in Japan and Korea between 1910 and the start of World War II (Committee for Whaling Statistics 1942). From 1910 to 1975, approximately 74,215 sei whales were caught in the entire North Pacific Ocean (Perry et al. 1999). The species was taken less regularly and in much smaller numbers by pelagic whalers elsewhere in the North Pacific during this period (Committee for Whaling Statistics 1942). Small numbers were taken sporadically at shore stations in British Columbia from the early 1900s until the 1950s, when their importance began to increase (Pike and MacAskie 1969).

More than 2,000 were killed in British Columbia waters between 1962 and 1967, when the last whaling station in western Canada closed (Pike and MacAskie 1969). Small numbers were taken by shore whalers in Washington (Scheffer and Slipp 1948) and California (Clapham et al. 1997) in the early twentieth century, and California shore whalers took 386 from 1957 to 1971 (Rice 1977). Heavy exploitation by pelagic whalers began in the early 1960s, with total catches throughout the North Pacific averaging 3,643 per year from 1963 to 1974 (total 43,719; annual range 1,280-6,053; Tillman 1977). The total reported kill of sei whales in the North Pacific by commercial whalers was 61,500 between 1947 and 1987 (Barlow et al. 1997).

A major area of discussion in recent years has been IWC member nations issuing permits to kill whales for scientific purposes. Since the moratorium on commercial whaling came into effect Japan, Norway, and Iceland have issued scientific permits as part of their research programs. For the last five years, only Japan has issued permits to harvest sei whales although Iceland asked for a proposal to be reviewed by the IWC SC in 2003. The Government of Japan has captured minke, Bryde’s, and sperm whales (*Physeter macrocephalus*) in the North Pacific (JARPN II). The Government of Japan extended the captures to include 50 sei whales from pelagic areas of the western North Pacific.

Fisheries Interactions- Sei whales, because of their offshore distribution and relative scarcity in U.S. Atlantic and Pacific waters, probably have a lower incidence of entrapment and entanglement than fin whales. Data on entanglement and entrapment in non-U.S. waters are not reported systematically. Heyning and Lewis (1990) made a crude estimate of about 73 rorquals killed per year in the southern California offshore drift gillnet fishery during the 1980's. Some of these may have been fin whales and some of them sei whales. Some balaenopterids, particularly fin whales, may also be taken in the drift gillnet fisheries for sharks and swordfish along the Pacific coast of Baja California, Mexico (Barlow et al. 1997). Heyning and Lewis (1990) suggested that most whales killed by offshore fishing gear do not drift far enough to strand on beaches or to be detected floating in the nearshore corridor where most whale-watching and other types of boat traffic occur. Thus, the small amount of documentation should not be interpreted to mean that entanglement in fishing gear is an insignificant cause of mortality. Observer coverage in the Pacific offshore fisheries has been too low for any confident assessment of species-specific entanglement rates (Barlow et al. 1997). Sei whales, similar to other large whales, may break through or carry away fishing gear. Whales carrying gear may die later, become debilitated or seriously injured, or have normal functions impaired, but with no evidence recorded.

Ship Strikes-The decomposing carcass of a sei whale was found on the bow of a container ship in Boston harbor, suggesting that sei whales, like fin whales, are killed at least occasionally by ship strikes (Waring et al. 1997). Sei whales are observed from whale-watching vessels in eastern North America only occasionally (Edds et al. 1984) or in years when exceptional foraging conditions arise (Weinrich et al. 1986; Schilling et al. 1992). There is no comparable evidence available for evaluating the possibility that sei whales experience significant disturbance from vessel traffic.

Other Threats- No major habitat concerns have been identified for sei whales in either the North Atlantic or the North Pacific. However, fishery-caused reductions in prey resources could have influenced sei whale abundance. The sei whale’s strong preference for copepods and euphausiids (i.e., low trophic level organisms), at least in the North Atlantic, may make it less susceptible to the bioaccumulation of organochlorine and metal contaminants than, for example, fin, humpback, and minke whales, all of which seem to feed more regularly on fish and euphausiids (O’Shea and Brownell 1995). Since sei whales off California often feed on pelagic fish as well as invertebrates (Rice 1977), they might accumulate contaminants to a greater degree than do sei whales in the North Atlantic. There is no evidence that levels of organochlorines, organotins, or heavy metals in baleen whales generally (including fin and sei whales) are high enough to cause toxic or other damaging effects (O'Shea and Brownell 1995). It should be emphasized, however, that very little is known about the possible long-term and trans-generational effects of exposure to pollutants.

### Sperm whale (*Physeter macrocephalus*)

*Listing Status*—Sperm whales have been protected from commercial harvest by the IWC since 1981, although the Japanese continued to harvest sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). Sperm whales were listed as endangered under the ESA in 1973. They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA of 1972. Critical habitat has not been designated for sperm whales.

*Population Status*—The sperm whale was the most frequently sighted cetacean (21 sightings) during the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) with acoustic detections three times higher than visual detections (DoN 2007b). There are an estimated 705 (CV = 60.4; 95% CI = 228-2,181) sperm whales in the MISTCS study area and density was estimated as 0.0012 animals per km$^2$ (95% CI = 0.40-3.8) (DoN 2007b).

Approximately 258,000 sperm whales in the North Pacific were harvested by commercial whalers between 1947 and 1987 (Hill and DeMaster 1999). However, this number may be negatively biased by as much as 60% because of under-reporting by Soviet whalers (Brownell et al. 1998). In particular, the Bering Sea population of sperm whales (consisting mostly of males) was severely depleted (Perry et al. 1999). Catches in the North Pacific continued to climb until 1968, when 16,357 sperm whales were harvested. Catches declined after 1968, in part through limits imposed by the IWC (Rice 1989). Reliable estimates of current and historical sperm whale abundance across each ocean basin are not available (NMFS 2006c). Five stocks of sperm whales are recognized in U.S. waters: the North Atlantic stock, the northern Gulf of Mexico stock, the Hawaiian stock, the California/Oregon/Washington stock, and the North Pacific stock (NMFS 2006z). Sperm whales are widely distributed across the entire North Pacific Ocean and into the southern Bering Sea in summer, but the majority are thought to occur south of 40°N in winter. Estimates of pre-whaling abundance in the North Pacific are considered somewhat unreliable, but may have totaled 1,260,000 sperm whales. Whaling harvests between 1800 and the 1980s took at least 436,000 sperm whales from the entire North Pacific Ocean (NMFS 2006c).

Several researchers have proposed population structures that recognize at least three sperm whales populations in the North Pacific for management purposes (Kasuya 1991; Bannister and Mitchell 1980). At the same time, the IWC's Scientific Committee designated two sperm whale stocks in the North Pacific: a western and eastern stock or population (Donovan 1991). The line separating these populations has been debated since their acceptance by the IWC's Scientific Committee. Stock structure for sperm whales in the North Pacific is not known (Dufault et al. 1999). For management purposes, the IWC has divided the North Pacific into two management regions defined by a zig-zag line which starts at 150$^o$ W at the equator, is at 160$^o$ W between 40$^o$ to 50$^o$ N, and ends up at 180$^o$ W north of 50$^o$ N (Donovan 1991).

*Distribution*—Sperm whales occur throughout all ocean basins from equatorial to polar waters, including the entire North Atlantic, North Pacific, northern Indian Ocean, and the southern oceans. Sperm whales are found throughout the North Pacific and are distributed broadly from tropical and temperate waters to the Bering Sea as far north as Cape Navarin. Mature, female, and immature sperm whales of both sexes are found in more temperate and tropical waters from the equator to around 45˚N throughout the year. These groups of adult females and immature sperm whales are rarely found at latitudes higher than 50˚N and 50˚S (Reeves and Whitehead 1997). Sexually mature males join these groups throughout the winter. During the summer, mature male sperm whales are thought to move north into the Aleutian Islands, Gulf of Alaska, and the Bering Sea. Sperm whales are rarely found in waters less than 984 ft (300 m) in depth. They are often concentrated around oceanic islands in areas of upwelling, and along the outer continental shelf and mid-ocean waters. Sperm whales show a strong preference for deep waters (Rice, 1989), especially areas with high sea-floor relief. Sperm whale distribution is associated with waters over the continental shelf edge, over the continental slope, and into deeper waters (Hain et al. 1985; Kenney and Winn 1987; Waring and Finn 1995; Gannier 2000; Gregr and Trites 2001; Waring et al. 2001). However, in some areas, such as off New England, on the southwestern and eastern Scotian Shelf, and in the northern Gulf of California, adult males are reported to quite consistently use waters with bottom depths <328 ft (100 m) and as shallow as 131 ft (40 m) (Whitehead et al. 1992; Scott and Sadove 1997; Croll et al. 1999; Garrigue and Greaves 2001; Waring et al. 2002).

Whaling records demonstrate sightings year-round around the Marianas (Townsend 1935), with group size ranging from 1 to 25 individuals (DoN 2007b). During the Navy funded survey in 2007, sperm whales were observed in waters (2,654 to 32,395 ft [809 to 9,874 m) deep, however, in some locales, sperm whales also may be found in waters less than 328 ft (100 m)deep (Scott and Sadove 1997; Croll et al. 1999). There are two stranding records for this area (Kami and Lugan 1976; Eldredge 1991, 2003). The 2007 Navy survey had multiple sightings that included young calves and large bulls, supporting an earlier sighting of a group of sperm whales that included a newborn calf off the west coast of Guam (Eldredge 2003). Sperm whale occurrence patterns are assumed to be similar throughout the year (DoN 2005).

Sightings collected by Kasuya and Miyashita (1988) suggest that there are two stocks of sperm whales in the western North Pacific, a northwestern stock with females that summer off the Kuril Islands and winter off Hokkaido and Sanriku, and the southwestern North Pacific stock with females that summer in the Kuroshio Current System and winter around the Bonin Islands. The males of these two stocks are found north of the range of the corresponding females (i.e., in the Kuril Islands/Sanriku/Hokkaido and in the Kuroshio Current System, respectively, during the winter).

*Life history information*—Female sperm whales become sexually mature at about nine years of age (Kasuya 1991). Male sperm whales take between 9 and 20 years to become sexually mature, but will require another 10 years to become large enough to successfully compete for breeding rights (Kasuya 1991). Adult females give birth after about 15 months gestation and nurse their calves for 2 to 3 years. The calving interval is estimated to be about four to six years (Kasuya 1991). The age distribution of the sperm whale population is unknown, but sperm whales are believed to live at least 60 years (Rice 1978). Estimated annual mortality rates of sperm whales are thought to vary by age, but previous estimates of mortality rate for juveniles and adults are now considered unreliable (IWC 1980).

*Reproduction/Breeding*—Calving generally occurs in the summer at lower latitudes and the tropics (DoN 2005).

*Diving Behavior*—Sperm whales forage during deep dives that routinely exceed a depth of 1,314 ft (410 m) and 30 min duration (Watkins et al. 2002). Sperm whales are capable of diving to depths of over 6,564 ft (2,001 m) with durations of over 60 min (Watkins et al. 1993). Sperm whales spend up to 83 percent of daylight hours underwater (Jaquet et al. 2000; Amano and Yoshioka 2003). Males do not spend extensive periods of time at the surface (Jaquet et al. 2000). In contrast, females spend prolonged periods of time at the surface (1 to 5 hours daily) without foraging (Whitehead and Weilgart 1991; Amano and Yoshioka 2003). The average swimming speed is estimated to be 0.7 m/sec (Watkins et al. 2002). Dive descents averaged 11 min at a rate of 1.52 m/sec, and ascents averaged 11.8 min at a rate of 1.4 m/sec (Watkins et al. 2002).

*Acoustics*—Sperm whales produce short-duration (generally less than 3 sec), broadband clicks from about 0.1 to 30 kHz (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995; Thode et al. 2002) with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). The source levels can be up to 236 dB re 1 µPa-m (Møhl et al. 2003). Thode et al. (2002) suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region. The clicks of neonate sperm whales are very different from usual clicks of adults in that they are of low directionality, long duration, and low-frequency (centroid frequency between 300 and 1,700 Hz) with estimated source levels between 140 and 162 dB re 1 µPa-m (Madsen et al. 2003). Clicks are heard most frequently when sperm whales are engaged in diving/foraging behavior (Whitehead and Weilgart 1991; Miller et al. 2004; Zimmer et al. 2005). These may be echolocation clicks used in feeding, contact calls (for communication), and orientation during dives. When sperm whales are socializing, they tend to repeat series of clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared between individuals of a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead 1997; Rendell and Whitehead 2004). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins and Schevill 1975; Watkins et al. 1985). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

The anatomy of the sperm whale's ear indicates that it hears high-frequency sounds (Ketten 1992). Anatomical studies also suggest that the sperm whale has some ultrasonic hearing, but at a lower maximum frequency than many other odontocetes (Ketten 1992). The sperm whale may also possess better low-frequency hearing than some other odontocetes, although not as extraordinarily low as many baleen whales (Ketten 1992). The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1991). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz and the highest sensitivity to frequencies was between 5 and 20 kHz (Ridgway and Carder 2001).

Sperm whales functional hearing range is estimated to occur between approximately 150 Hz and 160 kHz, placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1). No direct tests on sperm whale hearing have been made, although the anatomy of the sperm whale's inner and middle ear indicates an ability to best hear high frequency to ultrasonic frequency sounds. The lower end of the sperm whale functional hearing range is of lower frequency than the lowest MFA sonar frequency analyzed. However, the overall sperm whale hearing range generally intersects Atlantic Fleet Active Sonar Training (AFAST) mid- and high-frequency sonars. The intersection of common frequencies between sperm whale functional hearing and mid and high frequency sonars suggests that more often than not there is a potential for a behavioral response. But as a result of having a functional range lower than the MFA sonars, there are still some likelihood low frequency vocalizations and sound dependent behaviors may not be disrupted or may only be partially disrupted or masked. Behavioral observations have been made whereby during playback experiments off the Canary Islands, André et al. (1997) reported that foraging whales exposed to a 10 kHz pulsed signal did not exhibit any general avoidance reactions. When resting at the surface in a compact group, sperm whales initially reacted strongly, and then ignored the signal completely (André et al. 1997). Additionally, even though the sperm whales may exhibit a reaction when initially exposed to active acoustic energy, the exposures are not expected to be long-term due to the likely low received level of acoustic energy and relatively short duration of potential exposures.

In the event that sperm whales are exposed to MFA/HFA sonar, the available data suggests that the response to mid-frequency (1 kHz to 10 kHz) sounds is variable (Richardson et al. 1995a). In the Caribbean, Watkins et al. (1985) observed that sperm whales exposed to 3.25 kHz to 8.4 kHz pulses interrupted their activities and left the area. The pulses were surmised to have originated from submarine sonar signals given that no vessels were observed. The authors did not report receive levels from these exposures, and also got a similar reaction from artificial noise they generated by banging on their boat hull. It was unclear if the sperm whales were reacting to the sonar signal itself or to a potentially new unknown sound in general. Other studies involving sperm whales indicate that, after an initial disturbance, the animals return to their previous activity. During playback experiments off the Canary Islands, André et al. (1997) reported that foraging whales exposed to a 10 kHz pulsed signal did not exhibit any general avoidance reactions. When resting at the surface in a compact group, sperm whales initially reacted strongly, then ignored the signal completely (André et al. 1997).

*Impacts of human activity*-In U.S. waters in the Pacific, sperm whales are known to have been incidentally taken only in drift gillnet operations, which killed or seriously injured an average of nine sperm whales per year from 1991-1995 (Barlow et al. 1997). Of the eight sperm whales observed taken by the California/Oregon drift gillnet fishery, three were released alive and uninjured (37.5 percent), one was released injured (12.5 percent), and four were killed (50 percent) (NMFS 2000). Therefore, approximately 63 percent of captured sperm whales could be killed accidentally or injured (based on the mortality and injury rate of sperm whales observed taken by the U.S. Navy from 1990-2000). Based on past fishery performance, sperm whales are not observed taken in every year; they were observed taken in four out of the last ten years (NMFS 2000). During the three years the Pacific Coast Take Reduction Plan has been in place, a sperm whale was observed taken only once (in a set that did not comply with the Take Reduction Plan; NMFS 2000).

Interactions between longline fisheries and sperm whales in the Gulf of Alaska have been reported over the past decade (Rice 1989, Hill and DeMaster 1999). Observers aboard Alaskan sablefish and halibut longline vessels have documented sperm whales feeding on longline-caught fish in the Gulf of Alaska (Hill and Mitchell 1998) and in the South Atlantic (Ashford and Martin 1996). During 1997, the first entanglement of a sperm whale in Alaska's longline fishery was recorded, although the animal was not seriously injured (Hill and DeMaster 1998). The available evidence does not indicate sperm whales are being killed or seriously injured as a result of these interactions, although the nature and extent of interactions between sperm whales and long-line gear is not yet clear. Ashford and Martin (1996) suggested that sperm whales pluck, rather than bite, the fish from the long-line.

In 2000, the Japanese Whaling Association announced that it planned to kill 10 sperm whales and 50 Bryde's whales in the Pacific Ocean for research purposes, which would be the first time sperm whales would be taken since the international ban on commercial whaling took effect in 1987. Despite protests from the U.S. government and members of the IWC, the Japanese government harvested 5 sperm whales and 43 Bryde's whales in the last six months of 2000. According to the Japanese Institute of Cetacean Research (Institute of Cetacean Research undated), another five sperm whales were killed for research in 2002–2003. The consequences of these deaths on the status and trend of sperm whales remains uncertain; however, the renewal of a program that intentionally targets and kills sperm whales before we can be certain the population has recovered from earlier harvests places this species at risk in the foreseeable future.

## 4.3 Non-Endangered and Non-Threatened Species

Other marine mammal species occurring within Mariana Islands are described below. All of these species, while protected under the MMPA, are not listed as endangered under the ESA, and nor are they considered depleted or strategic under the MMPA

### 4.3.1 Baleen Whales (Sub-Order Mysticeti)

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

*Population Status*—There were an estimated 233 (CV = 45.0; 95% CI = 99-546) Bryde's whales in the MISTCS Study Area and density was estimated as 0.00041 animals per km$^2$ (95% CI = 0.17-0.95; DoN 2007b).

The IWC recognizes three management stocks of Bryde's whales in the North Pacific: Western North Pacific, ENP, and East China Sea (Donovan 1991). The Bryde's whale is designated as "data deficient" on the IUCN Red List (Reeves et al. 2003).

*Distribution*—Bryde's whale is found year-round in tropical and subtropical waters, generally not moving poleward of 40° in either hemisphere (Jefferson et al. 1993; Kato 2002). They have been reported to occur in both deep and shallow waters globally. Long migrations are not typical of Bryde's whales, though limited shifts in distribution toward and away from the equator, in winter and summer, respectively, have been observed (Cummings 1985). Bryde's whales have a broad, overlapping winter and summer distribution in the Central Pacific from 5°S to 40°N, and are the most common baleen whales likely to occur in the Mariana Islands from May to July, and possibly August (Eldredge 1991, 2003; Kishiro 1996; Okamura and Shimada 1999; Miyashita et al. 1996).

Historical records show a consistent presence of Bryde’s whales in the Mariana Islands. Miyashita et al. (1996) sighted Bryde’s whales in the Mariana Islands during a 1994 survey, commenting that in the western Pacific these whales are typically only seen when surface water temperature was greater than 20°C although Yoshida and Kato (1999) reported a preference for water temperatures between approximately 15° and 20°C. A single Bryde’s whale washed ashore on Masalok Beach on Tinian in February, 2005. There was one sighting in July 1999, approximately 9.3 to 18.5 km west of FDM. Additionally, there was a sighting 195 km southeast of Guam made during December 1996, which was reported to the NMFS for their Platforms of Opportunity Program. There is also one reported stranding for this area that occurred in August 1978 (Eldredge 1991, 2003). Occurrence patterns are expected to be the same throughout the year.

Bryde’s whales were observed at least 18 times during the three month Navy survey in 2007 (DoN 2007b). They were observed in groups of one to three, with several sightings including calves. Bryde’s whales were sighted in deep waters, ranging from 8,363 to 24,190 ft in bottom depth. There were several sightings in waters over and near the Mariana Trench. Most sightings though were associated with bathymetric relief (e.g., steeply sloping areas and seamounts), including sightings adjacent to the Chamarro Seamounts east of CNMI and over the West Mariana Ridge. There were also concentrations in the southeast corner of the MISTCS study area. Multi-species aggregations with sei whales were also observed on several occasions (DoN 2007b)

While 25°N may represent the northernmost extent of Bryde’s whale winter distribution (5°S to 25°N; Kishiro 1996), they can range from 5°N to 40°N during summer, suggesting that winter and summer ranges overlap (Okamura and Shimada 1997; Ohizumi et al. 2002). Miyashita et al. (1995) report the majority of August sightings in the Western Pacific for Bryde’s whales between 20-40°N, although there was no reported sighting effort south of 20°N. Bryde’s whales are sometimes seen very close to shore and even inside enclosed bays (Best et al. 1984).

*Reproduction/Breeding*—Breeding and calving occur in warm temperate and tropical areas but regularly used sites have not been identified.

*Diving Behavior*—Bryde’s whales are lunge-feeders, feeding on fish and krill (Nemoto and Kawamura 1977). Cummings (1985) reported that Bryde’s whales might dive as long as 20 min.

*Acoustics*—Bryde’s whales produce low frequency tonal and swept calls similar to those of other rorquals (Oleson et al. 2003). Calls vary regionally, yet all but one of the call types have a fundamental frequency below 60 Hz; they last from 0.25 sec to several seconds; and they are produced in extended sequences (Oleson et al. 2003). Heimlich et al. (2005) recently described five tone types.

While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

In terms of functional hearing capability, Bryde’s whales belong to low-frequency cetaceans which have best hearing ranging from 7 Hz and 22 kHz (Southall et al. 2007; Table 4-1). There are no tests or modeling estimates of specific Bryde’s whale hearing ranges. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of Bryde’s whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, Bryde's whale behavioral exposures in Table 6-7 may be an overestimate.

**Minke whale (*Balaenoptera acutorostrata*)**

*Population Status*—The minke whale is designated as "near threatened" on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for this species in the Mariana Islands area; Horwood (1990) noted that densities of minke whales throughout the North Pacific are low, however, frequent acoustic detections suggest that this may be due to their cryptic nature (Rankin et al 2007, Rankin and Barlow 2003). The IWC recognizes three stocks of minke whales in the North Pacific, one of which is in the western Pacific west of 180ºW (Donovan 1991). The minke whale was frequently detected acoustically (29 detections) during the MISTCS cruise but was not visually detected therefore no abundance or density could be calculated for this species from the available sighting data (DoN 2007b). A density of 0.0003 animals per km$^2$ was derived from the Eastern Tropical Pacific surveys (Ferguson and Barlow 2003).

*Distribution*—The minke whale generally occupies waters over the continental shelf, including inshore bays and estuaries (Mitchell and Kozicki 1975; Ivashin and Vitrogov 1981; Murphy 1995; Mignucci-Giannoni 1998; Calambokidis et al. 2004). However, based on whaling catches and surveys worldwide, there is also a deep-ocean component to the minke whale's distribution (Slijper et al. 1964; Horwood,1990; Mitchell 1991; Mellinger et al. 2000; Roden and Mullin 2000). During August in the North Pacific, minke whales are more common in the Bering and Chukchi seas and in the Gulf of Alaska (Miyashita et al. 1995).

Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 1993); they are less common in the tropics than in cooler waters. Minke whales are present in the North Pacific from near the equator to the Arctic (Horwood 1990). In the winter, minke whales are found south to within 2° of the equator (Perrin and Brownell 2002). There is no obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations in the western North Pacific, as there is in the North Atlantic (Horwood 1990); however, there are some monthly changes in densities in both high and low latitudes (Okamura et al. 2001). Some coastal minke whales restrict their summer activities to exclusive home ranges (Dorsey et al. 1983) and exhibit site fidelity to these areas between years (Borggaard et al. 1999).

Minke whales were the most frequently acoustically detected species of baleen whale during the Navy's 2007 survey and were mostly found in the southwestern area of the MIRC near the Mariana Trench (DoN 2007b). It is not unusual to have acoustic sightings with no visual confirmation (DoN 2007b, Rankin 2007) due to the cryptic behavior of this species in tropical waters. Minke whale vocalizations in the Pacific Islands have only been reported during the winter months, however, it is not known if this is indicative of a seasonal migration.

*Reproduction/Breeding*—Stewart and Leatherwood (1985) suggested that mating occurs in winter or early spring although it had never been observed.

*Diving Behavior*—Stern (1992) described a general surfacing pattern of minke whales 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. Minke whales are "gulpers," like the other rorquals (Pivorunas 1979). Hoelzel et al. (1989) reported on different feeding strategies used by minke whales. In the North Pacific, major food items include krill, Japanese anchovy, Pacific saury, and walleye Pollock (Perrin and Brownell 2002).

*Acoustics*—Recordings in the presence of minke whales have included both high-and low-frequency sounds (Beamish and Mitchell 1973; Winn and Perkins 1976; Mellinger et al. 2000). Mellinger et al., (2000) described two basic forms of pulse trains that were attributed to minke whales: a "speed up" pulse train with energy in the 200 to 400 Hz band, with individual pulses lasting 40 to 60 msec, and a less-common "slow-down" pulse train characterized by a decelerating series of pulses with energy in the 250 to 350 Hz band. Recorded vocalizations from minke whales have dominant frequencies of 60 Hz to greater than 12,000 Hz, depending on vocalization type (Richardson et al. 1995). Recorded source levels, depending on vocalization type, range from 151 to 175 dB re 1 µPa-m (Ketten 1998). Gedamke et al. (2001) recorded a complex and stereotyped sound sequence ("star-wars vocalization") in the Southern Hemisphere 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 (Anonymous 2002; Rankin and Barlow 2003). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

In terms of functional hearing capability, minke whales belong to low-frequency cetaceans which have best hearing ranging from 7 Hz and 22 kHz (Southall et al. 2007; Table 4-1). There are no tests or modeling estimates of specific minke whale hearing ranges. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of minke whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, minke whale behavioral exposures shown in Table 6-7 may be an overestimate.

### 4.3.2 Toothed whales (Sub-Order Odontoceti)

**Blainville's Beaked Whale (*Mesoplodon densirostris*)**

*Population Status*—The Blainville's beaked whale is designated as "data deficient" on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for the Blainville's beaked whale in this area. There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0013 animals per km$^2$ (CV = 0.71) was derived from the offshore Hawaii area (Barlow 2006).

*Distribution*—Beaked whales may be expected to occur in the area including, and seaward of, the shelf break. Two *Mesopolodon* spp. were observed during the Navy's 2007 survey, over the West Mariana Ridge, but were not identified to the species level (DoN 2007b). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year.

Recent information suggests that other beaked whale species (Blainville's and Cuvier's beaked whales, and northern bottlenose whales) show site fidelity and can be sighted in the area over many years (Hooker et al. 2002; Wimmer and Whitehead 2005; McSweeney et al. 2007).

*Reproduction/Breeding*—Mating for beaked whales generally occurs in October and November but little else is known of their reproductive behavior (Balcomb 1989).

*Diving Behavior*—Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction (Heyning and Mead 1996). Another species of beaked whales, the Baird's beaked whale, feeds mainly on benthic fishes and cephalopods, but occasionally on pelagic fish such as mackerel, sardine, and saury (Kasuya 2002; Walker et al. 2002; Ohizumi et al. 2003). Baird et al. (2006) reported on the diving behavior of four Blaineville's beaked whales off the west coast of Hawaii. The four beaked whales foraged in deep ocean areas (2,270-9,855ft) with a maximum dive to 4,619 ft. Dives ranged from at least 13 min (lost dive recorder during the dive) to a maximum of 68 min (Baird et al. 2006).

*Acoustics*—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Blainville's beaked whales echolocation clicks were recorded at frequencies from 20 to 40 kHz (Johnson et al. 2004). Recently, an acoustic recording tag was attached to two Blainville's beaked whales in the Ligurian Sea (Johnson et al. 2004). This species was found to be highly vocal, producing high frequency echolocation clicks with no significant energy below 20 kHz (Johnson et al. 2004). The source level of these clicks ranges from 200 to 220 dB re 1 µPa-m (Johnson et al. 2004). Blainville's beaked whales produce whistles and pulsed sounds between 6 and 16 kHz (Rankin and Barlow 2007b).

MacLeod (1999) suggested that beaked whale species use frequencies of between 300 Hz and 129 kHz for pulse sounds, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication and Cuvier's beaked whales echolocation clicks were recorded at frequencies from 20 to 70 kHz (Zimmer et al. 2005).

No hearing data is available for Blainville's beaked whales but Cook et al. (2006) reported that the Gervais beaked whale (*Mesoplodon europeus*) could hear in the range of 5 to 80 kHz although no measurements were attempted above 80 kHz). The Gervais beaked whale was most sensitive from 40 to 80 kHz (Cook et al. 2006).

Beaked whales functional hearing range is estimated to occur between approximately 150 Hz and 160 kHz, placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1) though best hearing is presumed to occur at ultrasonic frequencies (MacLeod 1999; Ketten 2000). However, due to their physiology, they may be more sensitive than other cetaceans to low-frequency sounds as well (MacLeod 1999; Ketten 2000). Some have proposed a potential association between beak whale strandings and Navy activities, noting five recurring factors in common with each stranding event: use of MFA sonar, beaked whale presence, surface ducts, steep bathymetry, and constricted channels with limited egress. These five factors would not occur simultaneously within the MIRC Study Area. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of beaked whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, beaked whale behavioral exposures shown in Table 6-7 may be an overestimate.

### Bottlenose dolphin, Coastal (*Tursiops truncatus*)

*Population Status*—There were an estimated 122 (CV = 99.2; 95% CI = 5.0-2,943) bottlenose dolphins in the MISTCS study area and density was estimated as 0.00021 animals per km$^2$ (95% CI = 0.001-5.1; DoN 2007b). Bottlenose dolphin group size ranged from 3 to 10 individuals and calves were seen during several sightings.

Bottlenose dolphins are designated as "data deficient" on the IUCN Red List (Reeves et al. 2003). Nothing is known of stock structure around the Marianas. The only estimate of abundance of bottlenose dolphins for the region is an estimate of 31,700 animals for the Western North Pacific area north of the Marianas (Miyashita 1993), which may possibly coincide with the stock of offshore bottlenose dolphins that occurs around the Marianas.

*Distribution*—Bottlenose dolphins are expected to occur from the coastline to the 6,562 ft isobath, which takes into consideration the known habitat preferences of *Tursiops* globally. Individuals are expected to occur in both harbors and lagoons, based on observations worldwide in similar habitats. There is a low or unknown occurrence of the bottlenose dolphin seaward of the 6,562 ft isobath. This pattern takes into account possible movement by bottlenose dolphins between the Mariana Islands chain, as well as sightings globally in deep waters. Occurrence patterns are expected to be the same throughout the year. There are no stranding records available for this species in the Marianas area and vicinity, and only a mention by Trianni and Kessler (2002) that bottlenose dolphins are seen in coastal waters of Guam. It is possible that bottlenose dolphins do not occur in great numbers in this island chain. Gannier (2002) attributed the fact that large densities of bottlenose dolphins do not occur at the Marquesas Islands to the fact that the area does not have a significant shelf component. A similar situation could be occurring in the Marianas MRA study area and vicinity.

Bottlenose dolphins were sighted three times during the Navy's 2007 MISTCS survey, two of the sightings were in the vicinity of Challenger Deep, while the other sighting was east of Saipan near the Mariana Trench in deep waters ranging from 13,914 to 16,440 ft (DoN 2007b). One of the sightings near the Challenger Deep was a mixed-species aggregation that included sperm whales (with calves) logging at the surface. Another mixed-species aggregation involved bottlenose dolphins with short-finned pilot whales and rough-toothed dolphins.

*Reproduction/Breeding*—Newborn calves are observed through out the year and may be influenced by productivity and food abundance (Urian et al. 1996). Miyashita (1993) reported that all his sightings of bottlenose dolphins in the western Pacific were of a larger, unspotted type (presumably the bottlenose dolphin, as opposed to the similar Indo-Pacific bottlenose dolphin). The Indo-Pacific bottlenose dolphin is considered to be a species associated with continental margins, as it does not appear to occur around offshore islands great distances from a continent, such as the Marianas (DoN 2005). However, since the Indo-Pacific bottlenose dolphin occurs directly west and to the south of the Marianas area, there is the possibility of extralimital occurrences of this species.

Bottlenose dolphins are expected to occur from the coastline to the 6,562 ft isobath, which takes into consideration the known habitat preferences of *Tursiops* globally. Individuals are expected to occur in both harbors and lagoons, based on observations worldwide in similar habitats. There is a low or unknown occurrence of the bottlenose dolphin seaward of the 6,562 ft isobath. This pattern takes into account possible movement by bottlenose dolphins between the Mariana Islands chain, as well as sightings globally in deep waters. Occurrence patterns are expected to be the same throughout the year.

There are no stranding records available for this species in the Marianas area and vicinity, and only a mention by Trianni and Kessler (2002) that bottlenose dolphins are seen in coastal waters of Guam. It is possible that bottlenose dolphins do not occur in great numbers in this island chain. Gannier (2002) attributed the fact that large densities of bottlenose dolphins do not occur at the Marquesas Islands to the fact that the area does not have a significant shelf component. A similar situation could be occurring in the Marianas MRA study area and vicinity.

*Diving Behavior*—Pacific coast bottlenose dolphins feed primarily on surf perches (Family Embiotocidae) and croakers (Family Sciaendae) (Norris and Prescott 1961; Walker 1981; Schwartz et al. 1992; Hanson and Defran 1993), and also consume squid (*Loligo opalescens*) (Schwartz et al. 1992). Navy bottlenose dolphins have been trained to reach maximum diving depths of about 984 ft. (Ridgway et al. 1969). Reeves et al. (2002) noted that the presence of deep-sea fish in the stomachs of some offshore individual bottlenose dolphins suggests that they dive to depths of more than 1,638 ft. Dive durations up to 15 min have been recorded for trained individuals (Ridgway et al. 1969). Typical dives, however, are more shallow and of a much shorter duration.

Offshore bottlenose dolphins in the Bahamas dove to depths below 1,76 ft and for over 5 min during the night but dives were shallow (<50m) during the day (Klatsky et al. 2007). In contrast, the dives of offshore bottlenose dolphins off the east coast of Australia were mostly within 16 ft of the surface (approximately 67% of dives) with the deepest dives to only 164 ft (Corkeron and Martin 2004). A comparison of hemoglobin concentration and hematocrit, important to oxygen storage for diving, between Atlantic coastal and offshore bottlenose dolphins shows higher levels of both in offshore dolphins (Hersh and Duffield 1990). The increase in hemoglobin and hematocrit suggest greater oxygen storage capacity in the offshore dolphin which may allow it to dive longer in the deep offshore areas that they inhabit.

*Acoustics*—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 (FM). Clicks and whistles have a dominant frequency range of 110 to 130 kHz and a peak to peak source level of 218 to 228 dB re 1 µPa-m (Au 1993) and 3.5 to 14.5 kHz and 125 to 173 dB re 1 µPa-m, respectively (Ketten 1998). Generally, whistles range in frequency from 0.8 to 24 kHz (Richardson et al. 1995).

The bottlenose dolphin has a functional high-frequency hearing limit of 160 kHz (Au 1993) and can hear sounds at frequencies as low as 40 to 125 Hz (Turl 1993). Inner ear anatomy of this species has been described (Ketten 1992). Electrophysiological experiments suggest that the bottlenose dolphin brain has a dual analysis system: one specialized for ultrasonic clicks and the other for lower-frequency sounds, such as whistles (Ridgway 2000). The audiogram of the bottlenose dolphin shows that the lowest thresholds occurred near 50 kHz at a level around 45 dB re 1 µPa (Nachtigall et al. 2000; Finneran and Houser 2006; Houser and Finneran 2007). Below the maximum sensitivity, thresholds increased continuously up to a level of 137 dB at 75 Hz. Above 50 kHz, thresholds increased slowly up to a level of 55 dB at 100 kHz, then increased rapidly above this to about 135 dB at 150 kHz. Scientists have reported a range of best sensitivity between 25 and 70 kHz, with peaks in sensitivity occurring at 25 and 50 kHz at levels of 47 and 46 dB re 1 µPa (Nachtigall et al. 2000).

TTS in hearing have been experimentally induced in captive bottlenose dolphins (Ridgway et al. 1997; Schlundt et al. 2000, 2006; Nachtigall et al. 2003; Finneran et al. 2002, 2005, 2007b). Ridgway et al. (1997) observed changes in behavior at the following minimum source levels for 1 sec tones: 186 dB at 3 kHz, 181 dB at 20 kHz, and 178 dB at 75 kHz (all re 1 µPa-m). TTS levels were 194 to 201 dB at 3 kHz, 193 to 196 dB at 20 kHz, and 192 to 194 dB at 75 kHz (all re 1 µPa). Schlundt et al. (2000) exposed bottlenose dolphins to intense tones (0.4, 3, 10, 20, and 75 kHz); the animals demonstrated altered behavior at levels of 178 to 193 dB re 1 µPa, with TTS after exposures generally between 192 and 201 dB re 1 µPa-m (though one dolphin exhibited TTS after exposure at 182 dB re 1 µPa). Nachtigall et al. (2003) determined threshold for a 7.5 kHz pure tone stimulus. No shifts were observed at 165 or 171 dB re 1 µPa, but when the sound level reached 179 dB re 1 µPa, the animal showed the first sign of TTS. Recovery apparently occurred rapidly, with full recovery within 45 min following sound exposure. TTS was measured between 8 and 16 kHz (negligible or absent at higher frequencies) after 30 min of sound exposure (4 to 11 kHz) at 160 dB re 1 µPa (Nachtigall et al. 2004).

Further details of TTS in bottlenose dolphins are described in section 6.2.

Functional hearing for bottlenose dolphins is estimated to occur between approximately 150 Hz and 160 kHz placing them in the mid-frequency cetacean group (Southall, 2007; Table 4-1) with peaks in sensitivity at 25 and 50 kHz (Nachtigall et al. 2000). Bottlenose dolphins communicate via clicks and whistles at frequency ranges that overlap MFA sonar though best hearing sensitivity aligns more with that of high frequency sonar. Signature whistles, which identify individual dolphins and are a dominant characteristic of communications between mothers and calves, range from 3.4 to 14.5 kHz, comparable to the 1 to 10 kHz range of MFA sonar. Potential Level B exposures from MFA sonar could therefore result in impaired communication between mother and calf pairs. In addition, experiments support the likelihood that some HFA sonar frequencies could result in a behavioral response. Observed changes in behavior in one bottlenose dolphin were induced with an exposure to a 75 kHz one-second pulse at 178 dB re 1 µPa-m (Ridgway et al. 1997; Schlundt et al. 2000). Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of bottlenose dolphins may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, bottlenose dolphin behavioral exposures shown in Table 6-7 may be an overestimate. Any behavioral responses that do occur are not expected to be long-term due to the likely low received level of acoustic energy and relatively short duration of potential exposures. Thus, interruptions in communication and other activities would be temporary.

**Cuvier's beaked whale (*Ziphius cavirostris*)**

*Population Status*—There are no density estimates for the Cuvier's beaked whale in this area. The Cuvier's beaked whale is designated as "data deficient" on the IUCN Red List (Reeves et al. 2003). There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0052 animals per $km^2$ (CV = 0.83) was derived using density estimates from the offshore Hawaii area (Barlow 2006).

*Distribution*—Beaked whales may be expected to occur in the area mostly seaward of the shelf break. One ziphiid whale was observed during the Navy's 2007 survey in deep water, but was not identified to the species level (DoN 2007b). As noted previously, on 30 August 2007, a live Cuvier's beaked whale stranded at Piti, Guam and was coaxed back to sea (NMFS 2007o). There is a low or unknown occurrence of beaked whales on the shelf between the 164 ft isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year.

Little is known about the habitat preferences of any beaked whale. Based on current knowledge, beaked whales normally inhabit deep ocean waters (>6,562 ft) or continental slopes (656 to 6,562 ft), and only rarely stray over the continental shelf (Pitman 2002). Cuvier's beaked whale generally is sighted in waters >656 ft deep, and is frequently recorded at depths >3,281 ft (Gannier 2000; MacLeod et al. 2004). They are commonly sighted around seamounts, escarpments, and canyons. MacLeod et al. (2004) reported that Cuvier's beaked whales occur in deeper waters than Blainville's beaked whales in the Bahamas. In Hawaii Cuvier's beaked whales showed a high degree of site fidelity in a study spanning 21 years and showed that there was an offshore population and an island associated population (McSweeney et al. 2007). The site fidelity in the island associated population was hypothesized to take advantage of the influence of islands on oceanographic conditions that may increase productivity (McSweeney et al. 2007). Based on those that were identified, Cuvier's beaked whale appears to be the most abundant beaked whale in the area, representing almost 80% of the identified beaked whale sightings (Barlow and Gerrodette 1996).

*Reproductive/Breeding*—Little is known of beaked whale reproductive behavior.

*Diving Behavior*—Cuvier's beaked whales are generally sighted in waters with a bottom depth greater than about 650 ft and are frequently recorded at depths of 3,282 ft or more (Gannier 2000; MacLeod, et al. 2004). They are commonly sighted around seamounts, escarpments, and canyons. In the eastern tropical Pacific Ocean, the mean bottom depth for Cuvier's beaked whales is approximately 11,154 ft, with a maximum depth of over 16,732 ft. (Ferguson 2005). Recent studies by Baird et al., (2006) show that Cuvier's beaked whales dive deeply (maximum of 4,757 ft) and for long periods (maximum dive duration of 68.7 min) but also spent time at shallow depths. Tyack et al. (2006b) has also reported deep diving for Cuvier's beaked whales with mean depth of 3,510 ft and mean duration of 58 min. Gouge marks were observed on mud volcanoes on the sea floor at 5,580 to 6,564, and Woodside et al. (2006) speculated that they were caused by Cuvier's beaked whales foraging on benthic prey.

*Acoustics*—MacLeod (1999) suggested that beaked whale species use frequencies between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Cuvier's beaked whales use frequencies from 20 to 70 kHz (Zimmer et al. 2005). Soto et al. (2006) reported changes in vocalizations during diving on close approaches of large cargo ships which may have masked their vocalizations. Cuvier's beaked whales only echolocated below 656 ft (Tyack et al. 2006a). Echolocation clicks are produced in trains (interclick intervals near 0.4 sec and individual clicks are frequency modulated pulses with durations of 200-300 µsec, the center frequency was around 40 kHz with no energy below 20 kHz (Tyack et al. 2006a).

Cook et al. (2006), in the only hearing study of a beaked whale, reported that the Gervais beaked whale (*Mesoplodon europeus*) could hear in the range of 5 to 80 kHz although no measurements were attempted above 80 kHz). The Gervais beaked whale was most sensitive from 40 to 80 kHz (Cook et al. 2006).

Beaked whales functional hearing range is estimated to occur between approximately 150 Hz and 160 kHz, placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1) though best hearing is presumed to occur at ultrasonic frequencies (MacLeod 1999; Ketten 2000). However, due to their physiology, they may be more sensitive than other cetaceans to low-frequency sounds as well (MacLeod 1999; Ketten 2000). Some have proposed a potential association between beak whale strandings and Navy activities, noting five recurring factors in common with each stranding event: use of mid-frequency sonar, beaked whale presence, surface ducts, steep bathymetry, and constricted channels with limited egress. These five factors would not occur simultaneously within the MIRC Study Area. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of beaked whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, beaked whale behavioral exposures shown in Table 6-7 may be an overestimate.

**Dwarf Sperm Whale (*Kogia sima*)**

*Population Status*—The dwarf sperm whale is not listed as endangered under the ESA and is not a depleted or strategic stock under the MMPA (Carretta et al. 2005). There is no information on the population trend of dwarf sperm whales or their abundance in the Marianas area. There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0078 animals per km$^2$ (CV = 0.66) was derived using density estimates from the Hawaii offshore area (Barlow 2006).

The dwarf sperm whale is designated as least concern on the IUCN Red List (Reeves et al. 2003).

The difficulty in identifying pygmy and dwarf sperm whales is exacerbated by their avoidance reaction towards ships and change in behavior towards approaching survey aircraft (Würsig et al. 1998). Based on the cryptic behavior of these species and their small group sizes (much like that of beaked whales), as well as similarity in appearance, it is difficult to identify these species in sightings at sea.

*Distribution*—Both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope (Baumgartner et al. 2001; McAlpine 2002; Baird 2005b). The primary occurrence for *Kogia* is seaward of the shelf break and in deep water with a mean depth of 4,674 ft (Baird 2005b). There is a rare occurrence for *Kogia* inshore of the area of primary occurrence. Occurrence is expected to be the same throughout the year.

There are only two stranding records for the dwarf sperm whale in the MIRC area and vicinity (Kami and Lujan 1976; Reeves et al. 1999; Eldredge 1991, 2003).

*Reproduction/Breeding*—There is no information on the breeding behavior in the Mariana Islands area. .

*Diving Behavior*—*Kogia* feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998; Wang et al. 2002). Willis and Baird (1998) reported that *Kogia* make dives of up to 25 min. Median dive times of around 11 min have been documented for *Kogia* (Barlow 1999). A satellite-tagged pygmy sperm whale released off Florida was found to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al. 2001). Most sightings of *Kogia* are brief; these whales are often difficult to approach, and they actively avoid aircraft and vessels (Würsig et al. 1998).

*Acoustics*—Pygmy sperm whale clicks range from 60 to 200 kHz, with a dominant frequency of 120 kHz (Richardson et al. 1995a). There is no information available on dwarf sperm whale vocalizations or hearing capabilities. An auditory brainstem response study indicates that pygmy sperm whales have their best hearing between 90 and 150 kHz (Ridgway and Carder 2001).

In terms of functional hearing capability, pygmy and dwarf sperm whales belong to high-frequency cetaceans which have best hearing ranging from 200 Hz to 180 kHz (Southall et al. 2007; 4-1). There are no tests or modeling estimates of specific pygmy and dwarf sperm whale hearing ranges. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of pygmy or dwarf sperm whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, pygmy or dwarf sperm whale behavioral exposures shown in Table 6-7 may be an overestimate.

### False killer whale (*Pseudorca crassidens*)

*Population Status*—There were an estimated 637 (CV = 74.3; 95% CI = 164-2,466) false killer whales in the MISTCS Study Area and density was estimated as 0.00111 animals per 1,000 $km^2$ (95% CI = 0.29-4.3 DoN 2007b). False killer whale group size ranged from 2 to 26 individuals and several sightings contained calves.

This species is designated as “least concern” on the IUCN Red List (Reeves et al. 2003). Nothing is known of the stock structure of false killer whales in the North Pacific Ocean. There are estimated to be about 6,000 false killer whales in the area surrounding the Mariana Islands (Miyashita 1993).

*Distribution*—The false killer whale is an oceanic species, occurring in deep waters, and is known to occur close to shore near oceanic islands (Baird 2002; Jefferson, cited in DoN, 2005). They are found in tropical and temperate waters, generally between 50°S and 50°N latitude with a few records north of 50°N in the Pacific and the Atlantic (Odell and McClune 1999). False killer whales were sighted in waters with a bottom depth ranging from 10,036 to 26,437 ft during the Navy’s 2007 survey, with groups ranging from 2 to 26 individuals (DoN 2007b). Several sightings were made over the Mariana Trench and the southeast corner of the study area, in waters with a bottom depth greater than 16,404 ft. There was also a sighting in deep waters west of the West Mariana Ridge.

Several sightings contained calves. There are two additional unpublished sightings and no reported strandings of the false killer whale in the Marianas. Seasonal movements in the western North Pacific may be related to prey distribution (Odell and McClune 1999). Baird et al. (2005) noted considerable inter-island movements of individuals in the Hawaiian Islands.

False killer whales are commonly sighted in offshore waters from small boats and aircraft, as well as offshore from long-line fishing vessels (e.g., Mobley et al. 2000; Baird et al. 2003; Walsh and Kobayashi 2004).

*Reproduction/Breeding*—Little is known of their reproductive behavior.

*Diving Behavior*—False killer whales primarily eat deep-sea cephalopods and fish (Odell and McClune 1999), but they have been known to attack other cetaceans, including dolphins (Perryman and Foster 1980; Stacey and Baird 1991), sperm whales (Palacios and Mate 1996), and baleen whales.

*Acoustics*—The dominant frequencies of false killer whale whistles are 4 to 9.5 kHz; those of their clicks are 25 to 30 kHz and 95 to 130 kHz (Thomas et al. 1990; Richardson et al. 1995). The source level for echolocation clicks is 220 to 228 dB re 1 µPa-m (Ketten 1998). Best hearing sensitivity measured for a false killer whale was around 16 to 64 kHz (Thomas et al. 1988, 1990).

Yuen et al. (2005) tested a stranded false killer whale using auditory evoke potentials to produce an audiogram in the range of 4 to 44 kHz and with best sensitivity at 16 to 24 kHz, but it may have had age related hearing loss. Nachtigall and Supin (2008) showed that false killer whales are able to adjust their hearing of echolocation signals to compensate for distance and size (i.e. more sensitive hearing for smaller returning echos).

### Fraser's Dolphin (*Lagenodelphis hosei*)

*Population Status*—This species is designated as "data deficient" on the IUCN Red List (Reeves et al. 2003). There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0069 animals per km$^2$ (CV = 1.11) was derived using density estimates from the Hawaii offshore area (Barlow 2006).

*Distribution*—The Fraser's dolphin is an oceanic species. In the Gulf of Mexico, this species has been seen in waters over the abyssal plain (Leatherwood et al. 1993). In some locales, as noted earlier, Fraser's dolphins do approach closer to shore, particularly in locations where the shelf is narrow and deep waters are nearby, so there is also a low or unknown occurrence from the 328 ft isobath to the shelf break. In the offshore eastern tropical Pacific, this species is distributed mainly in upwelling-modified waters (Au and Perryman 1985). Occurrence patterns are assumed to be the same throughout the year.

*Reproduction/Breeding*—Very little is known of the natural history of this species, including reproduction. Available data do not show strong evidence of calving seasonality (Jefferson and Leatherwood 1994).

*Diving Behavior*—Fraser's dolphins feed on mid-water fishes, squids, and shrimps (Jefferson and Leatherwood 1994; Perrin et al. 1994). There is no information available on depths to which Fraser's dolphins dive, but they are thought to be capable of deep dives.

*Acoustics*—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 (Leatherwood et al. 1993) and recent data extended that range 6.6 to 23.5 kHz with durations of 0.06 to 0.93 sec (Oswald et al. 2008). There are no hearing data for this species.

### Ginkgo-toothed Whale (*Mesoplodon ginkgodens*)

*Population Status*—There was no density estimate for Ginkgo-toothed beaked whales available from the Mariana Islands (DoN 2007b), therefore, a density estimate of 0.0005 animals per km$^2$ (CV = 0.45 – 1.00) that was derived from the Hawaii offshore area was used (Barlow 2006). The ginkgo-toothed beaked whale is designated as data deficient in the North Pacific on the IUCN Red List (Reeves et al. 2003).

*Distribution*—Beaked whales normally inhabit deep ocean waters (>6,562 [2,000 m]) or continental slopes (656 to 6,562 ft), and only rarely stray over the continental shelf (Pitman 2002). Palacios (1996) suggested based on stranding records in the eastern Pacific Ocean, that this species may select relatively cool, upwelling-modified habitats, such as those found in the California and Perú Currents and along the equatorial front. Beaked whales may be expected to occur in the area including, and seaward of, the shelf break. There is a low or unknown occurrence of beaked whales on the shelf between the 164 ft isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year. Very little is known about the distribution of this species. What is known of its range suggests any records in the Marianas area and vicinity would be rare (DoN 2005).

The ginkgo-toothed whale is known only from strandings (there are no confirmed live sightings) in temperate and tropical waters of the Pacific and Indian Oceans (Mead 1989; Palacios 1996). There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species.

*Reproduction/Breeding*—There is no information the reproductive behavior of Mesoplodont whales in this area.

*Diving Behavior*—Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction (Heyning and Mead 1996). Another species of beaked whales, the Baird's beaked whale, feeds mainly on benthic fishes and cephalopods, but occasionally on pelagic fish such as mackerel, sardine, and saury (Kasuya 2002; Walker et al. 2002; Ohizumi et al. 2003). Baird et al. (2006) reported on the diving behavior of four Blaineville's beaked whales off the west coast of Hawaii. The four beaked whales foraged in deep ocean areas (2,270-9,855ft) with a maximum dive to 4,619 ft. Dives ranged from at least 13 min (lost dive recorder during the dive) to a maximum of 68 min (Baird et al. 2006). Tyack et al. (2006b) reported a mean depth of 2,740 ft and mean duration of 46.5 min for Baird's beaked whales.

*Acoustics*—Little is known of the acoustics of Ginkgo-tooth beaked whales but information is available for other beaked whale species. MacLeod (1999) suggested that beaked whale species use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Rankin and Barlow (2007b) reported on the vocalizations of Blainville's beaked whales in Hawaii that included four mid frequency sounds: a frequency-modulated whistle and three frequency and amplitude modulated pulsed sounds within the range of 6 and 16 kHz. Vocalizations recorded from two juvenile Hubbs' beaked whales consisted of low and high frequency click trains ranging in frequency from 300 Hz to 80 kHz and whistles with a frequency range of 2.6 to 10.7 kHz and duration of 156 to 450 msec (Lynn and Reiss 1992; Marten 2000). Cuvier's beaked whales echolocation clicks were recorded at frequencies from 20 to 70 kHz (Zimmer et al. 2005).

Cook et al. (2006), in the only hearing study of a beaked whale, reported that the Gervais beaked whale (*Mesoplodon europeus*) could hear in the range of 5 to 80 kHz although no measurements were attempted above 80 kHz). The Gervais beaked whale was most sensitive from 40 to 80 kHz (Cook et al. 2006).

Beaked whales functional hearing range is estimated to occur between approximately 150 Hz and 160 kHz, placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1) though best hearing is presumed to occur at ultrasonic frequencies (MacLeod 1999; Ketten 2000). However, due to their physiology, they may be more sensitive than other cetaceans to low-frequency sounds as well (MacLeod 1999; Ketten 2000). Some have proposed a potential association between beak whale strandings and Navy activities, noting five recurring factors in common with each stranding event: use of MFA sonar, beaked whale presence, surface ducts, steep bathymetry, and constricted channels with limited egress. These five factors would not occur simultaneously within the MIRC Study Area. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of beaked whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, beaked whale behavioral exposures shown in Table 6-7 may be an overestimate.

### Killer whale (*Orcinus orca*)

*Population Status*—This species is designated as "lower risk" on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates available for the killer whale in the Mariana Islands area. Little is known of stock structure of killer whales in the North Pacific, with the exception of the northeastern Pacific where resident, transient, and offshore stocks have been described for coastal waters of Alaska, British Columbia, and Washington to California (Carretta et al. 2004). There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0002 animals per km$^2$ (CV = 0.72) was derived using density estimates from the offshore Hawaii area (Barlow 2006).

*Distribution*—Killer whales in general are uncommon in most tropical areas (Jefferson, cited in DoN 2005). The distinctiveness of this species would lead it to be reported more than any other member of the dolphin family, if it occurs in a certain locale. Rock (1993) reported that killer whales have been reported in the tropical waters around Guam, Yap, and Palau "for years". There is, however; a paucity of sighting documentation to substantiate this claim (Reeves et al. 1999; Visser and Bonoccorso 2003). There are a few sightings (most are unconfirmed) of killer whales off Guam (Eldredge 1991), including a sighting 27 km west of Tinian during January 1997 reported to the NMFS Platforms of Opportunity Program. There was also a badly decomposed killer whale found stranded on Guam in August 1981 (Kami and Hosmer 1982).

*Reproduction/Breeding*—There is no information the reproductive behavior of killer whales in this area.

*Diving Behavior*—The maximum depth recorded for free-ranging killer whales diving off British Columbia is about 864 ft (Baird et al. 2005). On average, however, for seven tagged individuals, less than 1 percent of all dives examined were to depths greater than about 98 ft (Baird et al. 2003). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min (Dahlheim and Heyning 1999).

*Acoustics*—The killer whale produces a wide variety of clicks and whistles, but most of its sounds are pulsed from 1 to 6 kHz (Richardson et al. 1995). Peak to peak source levels of echolocation signals range between 195 and 224 dB re 1 µPa-m (Au et al. 2004). The source level of social vocalizations ranges between 137 to 157 dB re 1 µPa-m (Veirs 2004). Acoustic studies of resident killer whales in British Columbia have found that there are dialects, in their highly stereotyped, repetitive discrete calls, which are group-specific and shared by all group members (Ford 2002). These dialects likely are 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 (Ford 2002). Dialects also have been documented in killer whales occurring in northern Norway, and likely occur in other locales as well (Ford 2002).

The killer whale has the lowest frequency of maximum sensitivity and one of the lowest high frequency hearing limits known among toothed whales (Szymanski et al. 1999). The upper limit of hearing is 100 kHz for this species. The most sensitive frequency, in both behavioral and in auditory brainstem response audiograms, has been determined to be 20 kHz (Szymanski et al. 1999).

### Longman's beaked whale (*Indopacetus pacificus*)

*Population Status*—Longman's beaked whale is considered to be a relatively rare beaked whale species (Pitman et al. 1999; Dalebout et al. 2003). This species is listed as data deficient on the IUCN Red List. There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0003 animals per km$^2$ (CV = 1.05) was derived using density estimates from the Hawaii offshore area (Barlow 2006).

*Distribution*—Longman's beaked whale appears to have a preference for warm tropical water, with most sightings occurring in waters with a SST warmer than 26ºC (Pitman et al. 1999). Beaked whales normally inhabit deep ocean waters (>6,562 ft) or continental slopes (656 to 6,562 ft), and only rarely stray over the continental shelf (Pitman 2002). Longman's beaked whale is known from tropical waters of the Pacific and Indian Oceans (Pitman et al. 1999; Dalebout et al. 2003). Ferguson and Barlow (2001) reported that all Longman's beaked whale sightings were south of 25ºN.Beaked whales may be expected to occur in the area including around seaward of the shelf break.

There is a low or unknown occurrence of beaked whales on the shelf between the 162 ft isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here.

Longman's beaked whale is not as rare as previously thought but is not as common as the Cuvier's and Mesoplodon beaked whales (Ferguson and Barlow 2001). Recent information shows that Cuvier's and Mesoplodon beaked whales may not always inhabit deep ocean areas and may be found over the continental slope (Ferguson et al. 2006).

*Reproduction/Breeding*—There is no information the reproductive behavior of Longman's beaked whales in this area.

*Diving Behavior*—Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction (Heyning and Mead, 1996). Another species of beaked whale, the Baird's beaked whale, feed mainly on benthic fishes and cephalopods, but occasionally on pelagic fish such as mackerel, sardine, and saury (Kasuya 2002; Walker et al. 2002; Ohizumi et al. 2003). Prolonged dives by the Baird's beaked whales for periods of up to 67 min have been reported (Kasuya 2002), though dives of about 84 to 114 ft are typical, and dives of 45 min are not unusual (Balcomb 1989; Von Saunder and Barlow 1999). Tyack et al. (2006b) reported a mean depth of 2,740 ft and mean duration of 46.5 min for Baird's beaked whales.

*Acoustics*—Little is known of the acoustics of Longman's beaked whale but information is available for other beaked whale species. MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Blainville's beaked whales echolocation clicks were recorded at frequencies from 20 to 40 kHz (Johnson et al. 2004) and Cuvier's beaked whales at frequencies from 20 to 70 kHz (Zimmer et al. 2005).

Cook et al. (2006), in the only hearing study on beaked whales, reported that the Gervais beaked whale (*Mesoplodon europeus*) could hear in the range of 5 to 80 kHz although no measurements were attempted above 80 kHz). The Gervais beaked whale was most sensitive from 40 to 80 kHz (Cook et al. 2006).

Beaked whales functional hearing range is estimated to occur between approximately 150 Hz and 160 kHz, placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1) though best hearing is presumed to occur at ultrasonic frequencies (MacLeod 1999; Ketten 2000). However, due to their physiology, they may be more sensitive than other cetaceans to low-frequency sounds as well (MacLeod 1999; Ketten 2000). Some have proposed a potential association between beak whale strandings and Navy activities, noting five recurring factors in common with each stranding event: use of mid-frequency sonar, beaked whale presence, surface ducts, steep bathymetry, and constricted channels with limited egress. These five factors would not occur simultaneously within the MIRC Study Area. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of beaked whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, beaked whale behavioral exposures shown in Table 6-7 may be an overestimate.

**Melon-headed Whale (*Peponocephala electra*)**

*Population Status*—There were an estimated 2,455 (CV = 70.2; 95% CI = 695-8,677) melon-headed whales in the MISTCS Study Area and density was estimated as 0.00428 animals per km$^2$ (95% CI = 1.2-15.1; DoN 2007b). Melon-headed whale group size ranged from 80 to109 individuals.

This species is designated as "least concern" on the IUCN Red List (Reeves et al. 2003).

*Distribution*—The melon-headed whale is an oceanic species. Occurrence patterns are assumed to be the same throughout the year. There were two sightings of melon-headed whales during the Navy's 2007 survey, with group sizes of 80 to 109 individuals (DoN 2007b). Additionally, there was a live stranding on the beach at Inarajan Bay, Guam in April 1980 (Kami and Hosmer 1982; Donaldson 1983), and there have been some sightings at Rota and Guam (Jefferson et al. 2006; DoN 2005). There are records of its occurrence for the Marianas area and vicinity. There was a live stranding on the beach at Inarajan Bay, Guam in April 1980 (Kami and Hosmer 1982; Donaldson 1983). Melon-headed whales are expected to occur from the shelf break (656 ft isobath) to seaward of the Marianas area and vicinity. There is also a low or unknown occurrence from the coastline to the shelf break which would take into account any sightings that could occur closer to shore since deep water is very close to shore at these islands. For example, on 4 July 2004, there was a sighting of an estimated 500-700 melon-headed whales and an undetermined smaller number of rough-toothed dolphins at Sasanhayan Bay (Rota) in waters with a bottom depth of 249 ft. (77 m) (Jefferson et al. 2006).

Melon-headed whales were sighted in waters with a bottom depth, ranging from 10,577to 12,910 ft. One of the two sightings was in the vicinity of the West Mariana Ridge.

*Reproduction/Breeding*—Breeding behavior is unknown and it is unclear whether there is significant seasonality in calving (Jefferson and Barros 1997).

*Diving Behavior*—Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mesopelagic forms found in waters up to 4,921 ft deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros 1997). There is no information on specific diving depths for melon-headed whales.

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

### Pantropical spotted dolphin (*Stenella attenuata*)

*Population Status*—There were an estimated 12,981 (CV = 70.4; 95% CI = 3,446-48,890) pantropical spotted dolphins in the MISTCS Study Area and density was estimated as 0.0226 animals per km$^2$ (95% CI = 6.0-85.3; DoN 2007b). Pantropical spotted dolphin group size ranged from 1 to 115 individuals. There were multiple sightings that included young calves, and one mixed species aggregation with melon-headed whales and another with an unidentified *Balaenoptera* spp. These pantropical spotted dolphins were identified as the offshore morphotype.

Pantropical spotted dolphins may have several stocks in the western Pacific (Miyashita 1993), although this is not confirmed at present. There were an estimated 127,800 spotted dolphins in the waters surrounding the Mariana Islands (Miyashita 1993). This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). Three subspecies are recognized in the Pacific Ocean. One inhabits nearshore waters around the Hawaiian Islands, another occurs in offshore waters of the eastern tropical Pacific, and a third occurs in coastal waters between Baja California and the northwestern coast of South America (Reeves et al. 2002).

*Distribution*—The pantropical spotted dolphin can be found throughout tropical and some subtropical oceans of the world (Perrin and Hohn 1994). Pantropical spotted dolphins are associated with warm tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). Pantropical spotted dolphins usually occur in deeper waters, and rarely over the continental shelf or continental shelf edge

(Davis et al. 1998; Waring et al. 2002). They are extremely gregarious, forming groups of hundreds or even thousands of individuals. Range in the central Pacific is from the Hawaiian Islands in the north to at least the Marquesas in the south (Perrin and Hohn 1994). The pantropical spotted dolphin is primarily an oceanic species (Jefferson et al. 1993). Based on the known habitat preferences of the pantropical spotted dolphin, this species is expected to occur seaward of the shelf break (656 ft isobath). Low or unknown occurrence of the pantropical spotted dolphin from the coastline (except in harbors and lagoons) to the shelf break is based on sightings of pantropical spotted dolphins being reported in coastal waters of Guam by Trianni and Kessler (2002).

Pantropical spotted dolphins were sighted throughout the study area in waters with a variable bottom depth, ranging from 374 to 18,609 ft. The vast majority of the sightings (65%; 11 of 17 sightings) were in deep waters (>10,000 ft); these findings match the known preference of this species for oceanic waters. There was only one shallow-water sighting 2.5 km north of Tinian during the humpback whale focal study, in waters with a bottom depth of 374 ft.

*Reproduction/Breeding*—In the Eastern Tropical Pacific there are two calving peaks, one in spring and one in fall (Perrin and Hohn 1994).

*Diving Behavior*—Results from various tracking and food habit studies suggest that pantropical spotted dolphins in the eastern tropical Pacific and off Hawaii feed primarily at night on epipelagic species and on mesopelagic species which rise towards the water's surface after dark (Robertson and Chivers 1997; Scott and Cattanach 1998; Baird et al. 2001). Dives during the day generally are shorter and shallower than dives at night; rates of descent and ascent are higher at night than during the day (Baird et al. 2001). Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the eastern tropical Pacific and off Hawaii (Baird et al. 2001).

*Acoustics*—Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz (Ketten, 1998). Click source levels between 197 and 220 dB re 1 µPa-m (peak to peak levels),within the range of 40-140 kHz, have been recorded for pantropical spotted dolphins (Schotten et al. 2004). Data from Atlantic spotted dolphins are provided to fill in the gaps of acoustic information for pantropical spotted dolphins. Echolocation clicks measured in wild Atlantic spotted dolphins showed bimodal ranges of 40 and 50 kHz and a high-frequency peak between 110 and 130 kHz, with a source level of 210 dB re 1 µPa-m (Au and Herzing 2003).

There are no published hearing data for pantropical spotted dolphins (Ketten, 1998). Anatomy of the ear of the pantropical spotted dolphin has been studied; Ketten (1992, 1997) found that they have a Type II cochlea, like other delphinids.

Functional hearing for pantropical spotted dolphins is estimated to occur between approximately 150 Hz and 160 kHz placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1). Pantropical spotted dolphins communicate, feed and socialize via clicks and whistles at frequency ranges that overlap MFA sonar though best hearing sensitivity aligns more with that of HFA sonar. Pantropical spotted dolphin whistles have a frequency range of 3.1 to 21.4 kHz (Richardson et al. 1995) which overlaps well with MFA sonar, while clicks are bimodal with peaks at 40 to 60 kHz and 120 to 140 kHz and more aligned with HFA sonar (Schotten et al., 2004). Potential Level B exposures from MFA and HFA sonar could therefore result in impaired communication, changes in foraging and social interaction. However, any behavioral responses are not expected to be long-term due to the likely low received level of acoustic energy and relatively short duration of potential exposures. Thus, interruptions in communication and other activities would be temporary.

### Pygmy killer whale (*Feresa attenuata*)

*Population Status*—There was only one sighting of the pygmy killer whale with a group size of six animals (DoN 2007b). Based on this one sighting, the best estimate of abundance was 78 individuals (CV = 88.1; 95% CI = 17-353) and density was estimated as 0.00014 animals per km$^2$ (DoN 2007b).

This species is designated as data deficient on the IUCN Red List (Reeves et al. 2003).

*Distribution*—The pygmy killer whale is an oceanic species. This species has a worldwide distribution in deep tropical and subtropical oceans. Pygmy killer whales generally do not range north of 40°N or south of 35°S (Jefferson et al. 1993). Reported sightings suggest that this species primarily occurs in equatorial waters, at least in the eastern tropical Pacific (Perryman et al. 1994). Most of the records outside the tropics are associated with strong, warm western boundary currents that effectively extend tropical conditions into higher latitudes (Ross and Leatherwood 1994).

The sighting was made near the Mariana Trench, south of Guam, where the bottom depth was 14,564 ft. This is consistent with the known habitat preferences of the species for deep, oceanic waters.

*Reproduction/Breeding*—There is no information on the breeding behavior in this area.

*Diving Behavior*—There is no information on the diving behavior of pygmy killer whales.

*Acoustics*—The pygmy killer whale produces clicks in the range of 45 to 117 kHz, with the main energy in the range of 70 to 85 kHz (Madsen et al. 2004). Peak to peak source levels were 197 to 223 dB re 1 µPa-m. There is no information on the hearing of pygmy killer whales.

### Pygmy sperm whale (*Kogia breviceps*)

*Population Status*—Pygmy sperm whales are designated as “least concern” on the IUCN Red List (Reeves et al 2003). There are no density estimates available for the Kogiidae family, including this species, in the Mariana Islands area (DoN 2007b); therefore a density estimate of 0.0078 animals per km$^2$ (CV = 0.77) was derived using density estimates from the Hawaii offshore area (Barlow 2006).

*Distribution*—Both Kogia species have a worldwide distribution in tropical and temperate waters (Jefferson et al. 1993). Both species of Kogia generally occur in waters along the continental shelf break and over the continental slope (e.g., Baumgartner et al. 2001; McAlpine 2002; Baird 2005). This takes into account their preference for deep waters. There is only one stranding record available for this specie in the Marianas study area and vicinity (Kami and Lujan 1976; Reeves et al 1999; Eldredge 1991, 2003). Identification to species level for this genus is difficult, particularly at sea. There is a rare occurrence for Kogia inshore of the area of primary occurrence. Occurrence is expected to be the same throughout the year.

*Reproduction/Breeding*—In the Eastern Tropical Pacific there are two calving peaks, one in spring and one in fall (Perrin and Hohn 1994).

*Diving Behavior*—Kogia feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998; Wang et al. 2002). Willis and Baird (1998) reported that Kogia make dives of up to 25 min. Median dive times of around 11 min have been documented for Kogia (Barlow 1999). A satellite-tagged pygmy sperm whale released off Florida was found to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al. 2001). Most sightings of Kogia are brief; these whales are often difficult to approach and they actively avoid aircraft and vessels (Würsig et al. 1998).

*Acoustics*—Pygmy sperm whale clicks range from 60 to 200 kHz, with a dominant frequency of 120 kHz (Richardson et al. 1995). An auditory brainstem response study indicates that pygmy sperm whales have their best hearing between 90 and 150 kHz (Ridgway and Carder 2001).

In terms of functional hearing capability, pygmy and dwarf sperm whales belong to high-frequency cetaceans which have best hearing ranging from 200 Hz to 180 kHz (Southall et al. 2007; 4-1). There are no tests or modeling estimates of specific pygmy and dwarf sperm whale hearing ranges. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of pygmy or dwarf sperm whales may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, pygmy or dwarf sperm whale behavioral exposures shown in Table 6-7 may be an overestimate.

### Risso’s dolphin (*Grampus griseus*)

*Population Status*—This species is designated as “data deficient” on the IUCN Red List (Reeves et al. 2003). Essentially nothing is known of stock structure of Risso’s dolphins in the western Pacific. Assuming that several stocks may occur there, Miyashita (1993) used Japanese survey data to estimate that about 7,000 Risso’s dolphins occur in the area to the north of the Mariana Islands. There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0010 animals per km$^2$ (CV = 0.65) was derived using density estimates from the Hawaii offshore area (Barlow 2006).

*Distribution*—Risso’s dolphins are expected to occur in the Marianas area from the shelf break to seaward of the Marianas area and vicinity. While there is a predominance of Risso’s dolphin sightings worldwide in areas with steep bottom topography, this species is also found in deeper waters. The largest numbers for this species will likely be in the vicinity of the shelf break and upper continental slope (Jefferson, cited in DoN 2005). There is an area of low or unknown occurrence from the 50 m isobath to the shelf break. This takes into consideration also the possibility that this species, with a preference for waters with steep bottom topography, might swim into areas where deep water is close to shore. Leatherwood et al. (1979) and Shane (1994) reported on sightings of Risso’s dolphins in shallow waters in the northeastern Pacific, including near oceanic islands. These sites are in areas where the continental shelf is narrow and deep water is closer to the shore (Leatherwood et al. 1979, Gannier 2000, 2002). Occurrence patterns are assumed to be the same throughout the year. A comprehensive study of the distribution of Risso’s dolphin in the Gulf of Mexico found that they used the steeper sections of the upper continental slope in waters 1,150 to 3,200 ft deep (Baumgartner 1997). Risso’s dolphins occur individually or in small to moderate-sized groups, normally ranging in numbers from 2 to nearly 250.

*Reproduction/Breeding*—There is no information on the breeding behavior in this area.

*Diving Behavior*—Risso’s dolphins may remain submerged on dives for up to 30 min (Kruse et al. 1999). Cephalopods are the primary prey (Clarke 1996).

*Acoustics*—Risso’s dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and simultaneous whistle and burst-pulse sounds (Corkeron and Van Parijs 2001). The combined whistle and burst pulse sound appears to be unique to Risso’s dolphin (Corkeron and Van Parijs 2001). Corkeron and Van Parijs (2001) recorded five different whistle types, ranging in frequency from 4 to 22 kHz. Broadband clicks had a frequency range of 6 to greater than 22 kHz. Low-frequency narrowband grunt vocalizations had a frequency range of 0.4 to 0.8 kHz. A recent study established empirically that Risso’s dolphins echolocate; estimated source levels were up to 216 to 225 dB re 1 µPa-m (peak to peak levels) with two prominent peaks in the range of 30-50 kHz and 80 to 100 kHz (Philips et al. 2003; Madsen et al. 2004).

The range of hearing in two Risso’s dolphins (one infant and one adult was 1.6 to 150 kHz with maximum sensitivity occurring between 8 and 64 kHz (Nachtigall et al. 1995, 2005).

### Rough-toothed dolphin (*Steno bredanensis*)

*Population Status*—There were only two sightings of the rough-toothed dolphin made during the MISTCS cruise. There were an estimated 166 (CV = 89.2; 95% CI = 36-761) rough toothed dolphins in the MISTCS Study Area and density was estimated as 0.0029 animals per km$^2$ (DoN 2007b). Rough-toothed dolphin group size averaged nine individuals. A mixed-species aggregation involved common bottlenose dolphins with short finned pilot whales and rough-toothed dolphins. There was one sighting of rough-toothed dolphin that included calves (DoN 2007b).

The rough-toothed dolphin is designated as “data deficient” on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for this species in this area. Rough-toothed dolphins are common in tropical areas, but not nearly as abundant as some other dolphin species (Reeves et al. 2002). Nothing is known about stock structure for the rough-toothed dolphin in the North Pacific (Carretta et al. 2004).

*Distribution*—Rough-toothed dolphins are typically found in tropical and warm temperate waters (Perrin and Walker 1975 in Bonnell and Dailey 1993), rarely ranging north of 40°N or south of 35°S (Miyazaki and Perrin 1994). Occurrence patterns are expected to be the same throughout the year. Rough-toothed dolphins occur in low densities throughout the ETP where surface water temperatures are generally above 25°C (Perrin and Walker 1975). Sighting and stranding records in the ENP are rare (e.g., Ferrero et al. 1994).

There were two sightings of rough-toothed dolphins during the MISTCS (DoN 2007b), both in groups of nine individuals with calves present in one sighting. As an oceanic species, the rough-tooth dolphin is expected to occur from the shelf break to seaward in this area. There is also a low or unknown occurrence of rough-toothed dolphins from the coastline (including harbors and lagoons) to the shelf break, which takes into consideration the possibility of encountering this species in more shallow waters, based on distribution patterns for this species in other tropical locales. In July 2004, there was a sighting of an undetermined smaller number of rough-toothed dolphins mixed in with a school of an estimated 500 to 700 melon-headed whales at Sasanhayan Bay (Rota) in waters with a bottom depth of 249 ft (Jefferson et al. 2006).

Rough-toothed dolphins usually form groups of 10 to 20 (Reeves et al. 2002), but aggregations of hundreds can be found (Leatherwood and Reeves, 1983). In the ETP, they have been found in mixed groups with spotted, spinner, and bottlenose dolphins (Perrin and Walker 1975). Reeves et al. (2002) suggested that they are deep divers, and can dive for up to 15 min. They usually inhabit deep waters (Davis et al. 1998), where they prey on fish and cephalopods (Reeves et al. 2002).

Rough-toothed dolphins were sighted in deep waters, ranging from 3,343 to 14731 ft in bottom depth. One sighting was off the island of Guguan, while the other was at the southern edge of the study area (DoN 2007b).

*Reproduction/Breeding*—There is no information on the breeding behavior in this area.

*Diving Behavior*—Rough-toothed dolphins are deep divers and can stay under for up to 15 min (Reeves et al. 2002). They usually inhabit deep waters (Davis et al. 1998), where they prey on fish and cephalopods (Reeves et al. 2002). Rough-toothed dolphins may stay submerged for up to 15 min and are known to dive as deep as 230 ft, but can probably dive much deeper (Miyazaki and Perrin 1994).

*Acoustics*—The vocal repertoire of the rough-toothed dolphin includes broad-band clicks, barks, and whistles (Yu et al. 2003). Echolocation clicks of rough-toothed dolphins are in the frequency range of 0.1 to 200 kHz, with a peak of about 25 kHz (Miyazaki and Perrin 1994; Yu et al. 2003). Whistles show a wide frequency range: 0.3 to >24 kHz (Yu et al. 2003).

There is little published information on hearing ability of this species. Preliminary data from Cook et al. (2005) showed that rough-tooth dolphins hear from 5to 80 kHz (80 kHz was the upper limit tested) and probably higher frequencies.

Functional hearing for rough-toothed dolphins is estimated to occur between approximately 150 Hz and 160 kHz placing them in the mid-frequency cetacean group (Southall 2007; Table 4-1). Scientists have determined the rough-toothed dolphin can detect sounds between 5 and 80 kHz and probably much higher (Cook et al. 2005). The echolocation frequency range (0.1 to 200 kHz) of this species has some overlap with MFA and HFA sonar. However, lower echolocation ranges of rough-toothed dolphins are below that of AFAST MFA sonar, and disruption of communication in Level B exposure zones may be moderated. Exposure to MFA sonar that is below or HFA sonar that is above the functional hearing capability of rough-toothed dolphins may not elicit a behavioral response since the respective frequencies are outside the functional hearing range of the animal. If the animal does react to sound outside their functional hearing range, their response may be less severe when compared to their response to a sound that is within their functional hearing range. Because risk function methods do not necessarily exclude sonar frequencies that are outside a species functional hearing range, rough-toothed dolphin behavioral exposures shown in Table 6-7 may be an overestimate.

### Short-beaked common dolphin (*Delphinus delphis*)

*Population Status*—There are no abundance estimates for the short-beaked common dolphin in Mariana Islands area. This species is designated as least concern on the IUCN Red List (Reeves et al. 2003). There are no density estimates for this species in the Mariana Islands (DoN 2007b); therefore a density estimate of 0.0021 animals per $km^2$ (CV = 0.28) was derived using density estimates from the Eastern Tropical Pacific surveys (Ferguson and Barlow 2001, 2003).

*Distribution—Delphinus* is a widely distributed genus of cetacean. It is found worldwide in temperate, tropical, and subtropical seas. The range of the short-beaked common dolphin may extend entirely across the tropical and temperate North Pacific (Heyning and Perrin 1994). There is a low or unknown occurrence of the short-beaked common dolphin from the shelf break to seaward of the Marianas area and vicinity. Short-beaked common dolphins are thought to be more common in cool temperate waters of the North Pacific, although there are populations in cooler, upwelling modified waters of the eastern tropical Pacific (Au and Perryman 1985). The absence of known areas of major upwelling in the western tropical Pacific suggests that common dolphins will not be found there, although there have been some reports of sightings of this species (Masaki and Kato 1979). However, the species identification of these records is not confirmed, and therefore is in doubt. Occurrence patterns are assumed to be the same throughout the year.

*Reproduction/Breeding*—The peak calving season occurs from spring and early summer (Forney 1994).

*Diving Behavior*—There are limited direct measurements but dives to >656 ft are possible. Most were in the range of 30 to 164 ft based on a study on one tagged individual tracked off San Diego (Evans 1971, 1994). Stomach contents of *Delphinus* from California waters revealed 19 species of fish and two species of cephalopods; *Delphinus* feeds primarily on organisms in the vertically migrating DSL (Evans 1994). Diel fluctuations in vocal activity of this species (more vocal activity during late evening and early morning) appear to be linked to feeding on the DSL as it rises during the same time (Goold 2000).

*Acoustics*—Recorded *Delphinus* vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998). Maximum source levels echolocation clicks were approximately 180 dB re 1 µPa-m (Fish and Turl 1976). Oswald et al. (2003) found that short-beaked common dolphins in the ETP have whistles with a mean frequency range of 6.3 kHz, mean maximum frequency of 13.6 kHz, and mean duration of 0.8 sec.

Popov and Klishin (1998) recorded auditory brainstem responses from a common dolphin. The audiogram was U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz.

### Short-finned pilot whale (*Globicephala macrorhynchus*)

*Population Status*—There were an estimated 909 (CV = 67.7; 95% CI = 230-3,590) short-finned pilot whales in the MISTCS study area and density was estimated as 0.00159 animals per km$^2$ (DoN 2007b).

This species is designated as "lower risk" on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for the short-finned pilot whale in this area. Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters, where two stocks have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). The southern stock of short-finned pilot whales (Kasuya et al. 1988), which is probably the one associated with the Mariana Islands area, has been estimated to number about 18,700 whales in the area south of 30°N latitude (Miyashita 1993).

*Distribution*—Miyashita et al. (1996) reported sightings in the vicinity of the Northern Mariana Islands during February through March 1994, but did not provide the actual sighting coordinates. A group of more than 30 individuals was sighted in late April 1977 near Uruno Point, off the northwest coast of Guam (Birkeland 1977). A stranding occurred on Guam in July 1980 (Kami and Hosmer 1982; Donaldson 1983; Schulz 1980).

Expected occurrence of the short-finned pilot whale in the MIRC and vicinity is seaward of the 328 ft isobath. The known preference of this species globally for steep bottom topography, which is most probably related to distribution of squid, was considered. With a narrow shelf and deep waters in close proximity to the shore, there is also a low or unknown occurrence of pilot whales in waters over the shelf from the coastline to the 328 ft isobath, not including any lagoons. Occurrence patterns are assumed to be the same throughout the year.

Short-finned pilot whale group size ranged from 5 to 43 individuals. A mixed-species aggregation involved bottlenose dolphins with short-finned pilot whales and rough-toothed dolphins. No calves were seen. Short-finned pilot whales were sighted in waters with a bottom depth, ranging from 3,041 to 14,731 ft (DoN 2007b). Three sightings were over the West Mariana Ridge (an area of seamounts), another sighting was 7 nm off the northeast corner of Guam, just inshore of the 9,843 ft isobath. There was also an off-effort sighting of a group of 6 to 10 pilot whales near the mouth of Apra Harbor (DoN 2007b).

*Reproduction/Breeding*—Calving and breeding peaks occurs in the spring and summer or spring and autumn depending on the population (Jefferson et al. 1993).

*Diving Behavior*—Pilot whales are deep divers; the maximum dive depth measured is about 3,186 ft (Baird et al. 2002). Pilot whales feed primarily on squid, but also take fish (Bernard and Reilly, 1999). Pilot whales are not generally known to prey on other marine mammals; however, records from the eastern tropical Pacific suggest that the short-finned pilot whale does occasionally chase, attack, and may eat dolphins during fishery operations (Perryman and Foster 1980), and they have been observed harassing sperm whales in the Gulf of Mexico (Weller et al. 1996).

*Acoustics*—Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and a source level of 180 dB re 1 µPa-m for whistles (Fish and Turl 1976; Ketten 1998). There are no published hearing data available for this species.

### Spinner dolphin (*Stenella longirostris*)

*Population Status*—During the MISTCS there was only one sighting of spinner dolphins with a group size of 98 animals. There were an estimated 1,803 (CV = 95.8; 95% CI = 361-9,004) spinner dolphins in the MISTCS Study Area and density was estimated as 0.00314 animals per km$^2$ (DoN 2007b).

This species is designated as "lower risk" on the IUCN Red List (Reeves et al. 2003).

*Distribution*—The spinner dolphin is found in tropical and subtropical waters worldwide. Limits are near 40°N and 40°S (Jefferson et al. 1993). The spinner dolphin is expected to occur throughout the entire

Marianas area and vicinity, except within Apra Harbor, where there is a low or unknown occurrence for this species. Spinner dolphins are behaviorally sensitive and avoid areas with much anthropogenic usage, which is why it is unknown whether this species would occur in Apra Harbor. Lagoons are high-usage habitat for resting by spinner dolphins; spinner dolphin occurrence in at least Saipan and Cocos Lagoons would be concentrated, with animals congregating during the day to rest. In the Mariana Islands, dolphins are reported in Saipan Lagoon at Saipan nearly every year (Trianni and Kessler 2002), and they were observed off Saipan during the MISTCS survey (DoN 2007b) in 1,398 ft of water. Typically, sightings are from the northern part of the lagoon, referred to as Tanapag Lagoon (Trianni and Kessler 2002). Spinner dolphins travel among the Mariana island chain (Trianni and Kessler 2002). Spinner dolphins are seen at FDM (DoN) 2001; Trianni and Kessler 2002), Guam (Trianni and Kessler 2002), and at Rota (Jefferson et al. 2006).

Spinner dolphins at islands and atolls rest during daytime hours in shallow, wind-sheltered nearshore waters and forage over deep waters at night (Norris et al. 1994; Östman 1994; Poole 1995; Gannier 2000, 2002; Lammers 2004; Östman-Lind et al. 2004). Spinner dolphins are expected to occur in shallow water (about 162 ft or less) resting areas throughout the middle of the day, moving into deep waters offshore during the night to feed. Data collected on spinner dolphins in Hawaii indicates that preferred resting habitat is usually more sheltered from prevailing tradewinds than adjacent areas and the bottom substrate is generally dominated by large stretches of white sand bottom rather than the prevailing reef and rock bottom along most other parts of the coast (Norris et al. 1994; Lammers 2004). These clear, calm waters and light bottom substrates provide a less cryptic backdrop for predators like tiger sharks (Norris et al. 1994; Lammers 2004). High-use areas at Guam include Bile Bay, Tumon Bay, Double Reef, north Agat Bay, and off Merizo (Cocos Lagoon area) (Eldredge 1991; Amesbury et al. 2001; DoN 2005). During the MISTCS cruise spinner dolphins were sighted northeast of Saipan in waters with a bottom depth of 1,398 ft (DoN 2007b).

*Reproductive/Breeding*—There is no information on the breeding behavior in this area.

*Diving Behavior*—Spinner dolphins feed primarily on small mesopelagic fishes, squids, and sergestid shrimp and they dive to at least 654 ft (199 m) to 984 ft (300 m) (Perrin and Gilpatrick 1994). Foraging can begin in the late afternoon (Lammers 2004), but takes place primarily at night when the mesopelagic prey migrates vertically towards the surface and also horizontally towards the shore (Benoit-Bird et al. 2001; Benoit-Bird and Au 2004; Dollar and Grigg 2003).

*Acoustics*—Spinner dolphins produce whistles in the range of 1 to 22.5 kHz with the dominant frequency being 6.8 to 17.9 kHz, above that of the active sonar frequencies, although their full range of hearing may extend down to 1 kHz or below as reported for other small odontocetes (Richardson et al. 1995; Nedwell et al. 2004). Spinner dolphins consistently produce whistles with frequencies as high as 16.9 to 17.9 kHz, with a maximum frequency for the fundamental component at 24.9 kHz (Bazúa-Durán and Au 2002; Lammers et al. 2003). Clicks have a dominant frequency of 60 kHz (Ketten 1998). The burst pulses are predominantly ultrasonic, often with little or no energy below 20 kHz (Lammers et al. 2003). Peak to peak source levels between 195 and 222 dB have been recorded for spinner dolphin clicks (Schotten et al. 2004). Their echolocation clicks range up to at least 65 kHz (Richardson et al. 1995).

The full range of hearing may extend down to 1 kHz or below as reported for other small odontocetes (Richardson et al. 1995a; Nedwell et al. 2004; Bazúa-Durán and Au 2002).

### Striped dolphin (*Stenella coeruleoalba*)

*Population Status*—There were an estimated 3,531 (CV = 54.0; 95% CI = 1,250-9,977) striped dolphins in the MISTCS Study Area and density was estimated as 0.00616 animals per km$^2$ (DoN 2007b). Striped dolphin group size ranged from 7 to 44 individuals and several sightings contained calves.

This species is designated as "lower risk" on the IUCN Red List (Reeves et al. 2003). The stock structure of striped dolphins in the western Pacific is poorly known, although there is evidence for more than one stock (Miyashita 1993). A putative population south of 30°N in the western Pacific was estimated to number about 52,600 dolphins, and this is probably the group from which any striped dolphins around the Marianas would come.

*Distribution*—Striped dolphins have a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994a). Their preferred habitat seems to be deep water (Davis et al. 1998) along the edge and seaward of the continental shelf, particularly in areas influenced by warm currents (Waring et al. 2002). This species is well documented in both the western and eastern Pacific off the coasts of Japan and North America (Perrin et al. 1994); the northern limits are the Sea of Japan, Hokkaido, Washington state, and along roughly 40°N across the western and central Pacific (Reeves et al. 2002).

Prior to the MISTCS survey (DoN 2007b), striped dolphins were only known from one stranding that occurred in July 1985 (Wilson et al. 1987; Eldredge 1991, 2003). However, several striped dolphin sightings were made in waters ranging from 7,749 to 24,836 ft of water (DoN 2007b). Group size ranged from 7 to 44 individuals. None were observed south of Guam.

Striped dolphins are gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Wade and Gerrodette (1993) noted a mean group size of 61 in the ETP, and Smith and Whitehead (1999) reported a mean group size of 50 in the Galápagos.

Striped dolphins were sighted throughout the study area in waters with a variable bottom depth, ranging from 7,749 to 24,835 ft in bottom depth. There was at least one sighting over the Mariana Trench, southeast of Saipan. There were no sightings south of Guam (approximately 13°N).

*Reproduction/Breeding*—Off Japan, where their biology has been best studied, there are two calving peaks: one in summer, another in winter (Perrin et al. 1994).

*Diving Behavior*—Striped dolphins often feed in pelagic or benthopelagic zones along the continental slope or just beyond oceanic waters. A majority of the prey possess luminescent organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to about 654 to 2,298 ft to reach potential prey (Archer and Perrin 1999). Striped dolphins may feed at night, in order to take advantage of the deep scattering layer's diurnal vertical movements. Small, mid-water fishes (in particular, myctophids or lanternfish) and squids are the dominant prey (Perrin et al. 1994).

*Acoustics*—Striped dolphin whistles range from 6 to at least 24 kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Richardson et al. 1995).

The striped dolphin's range of most sensitive hearing (defined as the frequency range with sensitivities within 10 dB of maximum sensitivity) was determined to be 29 to 123 kHz using standard psycho-acoustic techniques; maximum sensitivity occurred at 64 kHz (Kastelein et al. 2003).

# 5 HARASSMENT AUTHORIZATION REQUESTED

The Navy requests a Letter of Authorization (LOA) pursuant to Section 101 (a)(5)(A) of the MMPA for harassment of marine mammals incidental to training in the MIRC. It is understood that an LOA is applicable for up to 5 years, and is appropriate where authorization for serious injury or mortality of marine mammals is requested. The Navy requests the take, by serious injury or mortality, of 10 beaked whales, although the Navy does not anticipate that marine mammal strandings or mortality will result from conducting MIRC training activities within the study area. The request is for mid- and high frequency active sonar (does not include low frequency active), underwater detonation and training events within the MIRC Study Area (Figure 1.1). The request is for a 5-year period commencing in January 2010.

The acoustic modeling approach taken in the MIRC EIS/OEIS and this LOA request attempts to quantify potential exposures to marine mammals resulting from the use of MFA and HFA sonar and underwater detonations. Results from this modeling approach are presented without consideration of mitigation measures employed per Navy standard operating procedures. For example, securing or turning off an active sonar when an animal approaches closer than a specified distance reduces potential exposure since the sonar is no longer transmitting; and range clearance procedures and safety requirements having long set-up times for events using explosives make it very unlikely any marine mammals will be in the vicinity undetected.

Modeling results predict no marine mammal mortalities or exposure to active sonar or underwater detonations in excess of the permanent threshold shift (PTS) threshold indicative of Level A harassment.

The history of Navy activities in the MIRC Study Area and analysis in this document indicate that military readiness activities are not expected to result in any sonar or underwater detonation –induced Level A harassment or mortalities to marine mammals.

There are natural and manmade sources of mortality other than active sonar and underwater detonation that may contribute to stranding events as described in the Cetacean Stranding Section (Section 6.5). The actual cause of a particular stranding may not be immediately apparent when there is little evidence of physical trauma, especially in the case of disease or age-related mortalities. These events require careful scientific investigation by a collaborative team of subject matter experts to determine actual cause of death.

Given the frequency of naturally occurring marine mammal strandings (e.g., the 30 August 2007 live stranding of a single Cuvier’s beaked whale at Piti, Guam [NMFS 2007o]), it is conceivable that a stranding could co-occur with a Navy exercise even though the stranding is actually unrelated to and not caused by Navy activities. In a letter from NMFS to Navy dated October 2006, NMFS indicated that Section 101(a)(5)(A) authorization is appropriate for mid-frequency active sonar activities because it allows NMFS to consider the potential for incidental mortality. NMFS’ letter indicated; "Because mid-frequency sonar has been implicated in several marine mammal stranding events including some involving serious injury and mortality, and because there is no scientific consensus regarding the causal link between sonar and stranding events, NMFS cannot conclude with certainty the degree to which mitigation measures would eliminate or reduce the potential for serious injury of mortality." Accordingly, the Navy’s LOA application will include requests for take, by mortality, of 10 beaked whales.

Evidence from five beaked whale strandings, all of which have taken place outside of the MIRC Study Area, and have occurred over approximately a decade, suggests that the exposure of beaked whales to mid-frequency sonar in the presence of certain conditions (e.g., multiple units using tactical sonar, steep bathymetry, constricted channels, strong surface ducts, etc.) may result in strandings, potentially leading to indirectly caused mortality. Although these physical factors believed to contribute to the likelihood of beaked whale strandings are not present, in their aggregate, in the MIRC Study Area, scientific uncertainty exists regarding what other factors, or combination of factors, may contribute to beaked whale strandings.

Neither NMFS nor the Navy anticipates that marine mammal strandings or indirectly caused mortality will result from the use of mid- or high-frequency sonar during Navy exercises within the MIRC Study Area. However, during the MMPA process (which allows for adaptive management), NMFS and the Navy will determine the appropriate way to proceed in the unlikely event that a causal relationship were to be found between Navy activities and a future stranding. The Navy’s LOA application requests the take, by serious injury or mortality, of nine beaked whales and one pantropical spotted dolphin for a total of 10 mortality takes. These numbers may be modified through the MMPA process based on the available of new data and/or emergent science.

# 6 NUMBERS AND SPECIES EXPOSED

The NMFS application 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 NDAA, and Section 6.1.3.2 defines MMPA Level A and Level B as applicable to military readiness activities. Section 6.2 presents how the Level A and Level B harassment definitions were relied on to develop the quantitative acoustic analysis methodologies used to assess the potential for the Proposed Action to affect marine mammals.

## 6.1 Acoustic Effects

**Ship Noise**

Increased number of ships operating in the area will result in increased sound from vessel traffic. Marine mammals react to vessel-generated sounds in a variety of ways. Some respond negatively by retreating or engaging in antagonistic responses while other animals ignore the stimulus altogether (Watkins 1986; Terhune and Verboom 1999).

Most studies have ascertained the short-term response to vessel sound and vessel traffic (Watkins, et al. 1981; Baker et al. 1983; Magalhães et al. 2002); however, the long-term implications of ship sound on marine mammals is largely unknown (NMFS 2007a). Anthropogenic sound has increased in the marine environment over the past 50 years (Richardson et al. 1995; NRC 2003). This sound increase can be attributed to increases in vessel traffic as well as sound from marine dredging and construction, oil and gas drilling, geophysical surveys, sonar, and underwater explosions (Richardson et al. 1995).

Given the current ambient sound levels in the marine environment, the amount of sound contributed by the use of Navy vessels in the proposed exercises and training is very low. It is anticipated that any marine mammals exposed would exhibit only short-term reactions and would not suffer any long-term consequences from ship sound.

**Acoustic Sources Analyzed**

The following mid and high frequency active sonar sources were analyzed for the MIRC. Details of the modeling of these acoustic sources can be found in Appendix A.

- AN/SQS-53: Surface ship sonar - mid frequency active sonar source
- AN/SQS-56: Surface ship sonar - mid frequency active sonar source
- AN/SSQ-62: Sonobuoy sonar - mid frequency active sonar source
- AN/SSQ-125: Sonobuoy sonar - mid frequency active sonar source
- AN/AQS-22: Helicopter-dipping sonar - mid frequency active sonar source
- BQQ-10: Submarine sonar - mid frequency active sonar source
- MK-48: Torpedo sonar. High frequency active sonar source

### 6.1.1 Analytical Framework for Assessing Marine Mammal Response to Active Sonar

Marine mammals respond to various types of man-made sounds introduced in 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 (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.

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 respective areas during active sonar activities.
- Applied the applicable acoustic threshold criteria to the predicted sound exposures from the proposed activity. The results of this effort are 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 6-1) is a representation of the general analytical frame work utilized in applying the 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 are those items, which "will" happen, dotted lines are those which "might" happen, but which 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 in the Marine Mammal Protection Act (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 part of Level B harassment (Level B harassment includes both TTS and non-TTS). Boxes that are shaded from red to yellow have the potential for injury (Level A harassment) and behavioral disturbance (Level B harassment).

The analytical framework outlined within the flow-chart acknowledges that physiological responses must always precede behavioral responses (i.e., there can be no behavioral response without first some physiological effect of the sound) and an organization where each functional block only occurs once and all relevant inputs/outputs flow to/from a single instance.

### 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 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 nonauditory system tissues. These are not independent pathways and both must be considered since the same sound could affect both auditory and non-auditory 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.

#### 6.1.1.1 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 of the exposed animals. Some of these assessments can be numerically based (e.g., TTS, PTS, and 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 occurring at the bottom (the sound is not perceived).

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 after, 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. Sounds with sufficient amplitude and duration to be detected among the background ambient sound 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. Conversely a recent study by Nachtigall and Supin (2008) shows that false killer whales adjust their hearing sensitivity in response to ambient sounds and the intensity of the returning echolocation signal.

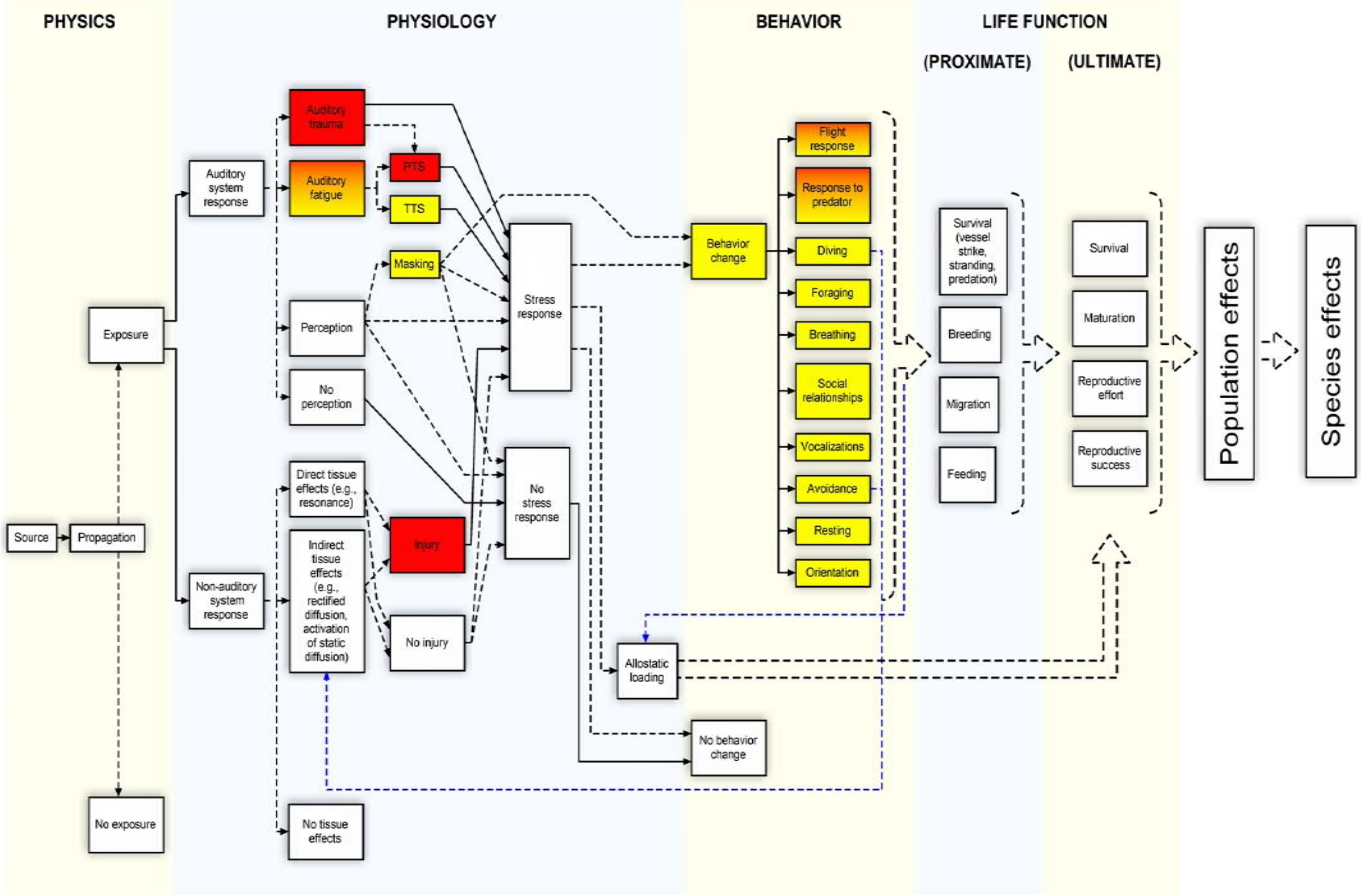


**Figure 6-1. Conceptual model for assessing the effects of sound exposures on marine mammals (from the US Navy: CNO N45 and SPAWAR**

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).

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 (not perceived).

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

#### 6.1.1.2 The Stress Response

The acoustic source is considered a potential stressor if, by its action on the animal, using 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 3-1 and the later discussions of allostasis and allostatic loading, the 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.

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 6-1 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 6-1) is assumed to also produce a stress response and contribute to the allostatic load.

#### 6.1.1.3 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. The 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 6-1 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 use, 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.

#### 6.1.1.4 Life Function

#### 6.1.1.5 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 effect 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 which is sexually immature will suffer relatively little consequence to disruption of breeding behavior when compared to an actively displaying adult of prime reproductive age.

#### 6.1.1.6 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 effect, 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.

### 6.1.2 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 model for estimating potential acoustic effects from MIRC ASW training activities on cetacean species makes use of the methodology that was developed in cooperation with the 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). By way of a response comment letter to Undersea Warfare Training Range (USWTR) received from NMFS dated January 30, 2006, NMFS concurred with the use of Energy Flux Density Level (EL) for the determination of physiological effects to marine mammals. Therefore, this methodology is used to estimate the annual exposure of marine mammals that may be considered Level A harassment as a result of PTS shift in hearing or tissue injury or Level B harassment as a result of temporary, recoverable physiological effects.

In addition, the approach for estimating potential acoustic effects from MIRC training activities on marine mammal makes use of the comments received on previous National Environmental Policy Act (NEPA) documents. NMFS and other commenter's recommended the use of an alternate methodology to evaluate when sound exposures might result in behavioral effects without corresponding physiological effects. As a result of these comments, this analysis uses a risk function approach to evaluate the potential for MMPA Level B harassment from behavioral effects. The risk-function is further explained in Section 6.2.

A number of Navy actions and NOAA rulings have helped to qualify possible events deemed as "harassment" under the MMPA. As stated previously, "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). NMFS also includes mortality as a possible outcome to consider in addition to Level A and Level B harassment. The acoustic effects analysis and exposure calculations are based on the following premises:

- Harassment that may result from Navy training activities described in the MIRC EIS/OEIS is unintentional and incidental to those training activities.
- This MIRC LOA request uses an unambiguous definition of injury as defined in the Rim of the Pacific (RIMPAC) OEA (DoN 2006) and in previous rulings (NOAA 2001; 2002a): injury occurs when any biological tissue is destroyed or lost as a result of the action.
- Consistent with prior ruling (NOAA 2001; 2006b), this MIRC LOA request assumes that Level A and B do not overlap so as to preclude circular definitions of harassment.
- An individual animal predicted to experience simultaneous multiple injuries, multiple disruptions, or both, is counted as a single take (NOAA 2001; 2006b). NMFS has defined a 24-hour "refresh rate," or amount of time in which an individual can be harassed no more than once. The Navy has determined that, in a 24-hour period, all sonar training activities in MIRC transmit for a subset of that time. Additional model assumptions account for ship movement, multiple ships, animal movement, and presence of land shadows.
- The acoustic effects analysis is based on primary exposures only. Secondary, or indirect, effects, such as susceptibility to predation following injury and injury resulting from disrupted behavior or physiology, while possible, can only be reliably predicted in circumstances where the responses have been well documented. Consideration of secondary effects would result in much 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.

### 6.1.3 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 Sections 6.1.4 and 6.1.5 is used to develop specific numerical exposure thresholds and risk curves. Exposure thresholds and risk function curves are combined with sound propagation models and species distribution data to estimate the potential exposures, as presented in Appendix A.

#### 6.1.3.1 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 the MMPA. Effects that address behavioral disruption are considered Level B harassment under MMPA.

The biological framework proposed 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.
- Components of other biological traits that may be relevant.
- 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 impact may not be observable over short periods of observation. Ecological information is considered in the analysis of the effects of individual species (Section 6.7).

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 operations of organs and tissues within an animal. A physiological effect may range from the most significant of impacts (i.e., mortality and serious injury) to lesser effects that would define the lower end of the physiological impact range, such as the non-injurious distortion of auditory tissues. This latter effect is important to the integration of the biological and regulatory frameworks.

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.

In this LOA request 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 acoustic sources. As a result, this LOA request uses the following definitions:

- A **physiological effect** is a variation in an animal's respiratory, endocrine, hormonal, circulatory, neurological, or reproductive activity and processes, beyond the animal's normal range of variability, in response to human activity or to an exposure to a stimulus such as active sonar.
- A **behavioral effect** is a variation in the pattern of an animal's breathing, feeding, resting, migration, intraspecific behavior (such as reproduction, mating, territorial, rearing, and agonistic behavior), and interspecific behavior beyond the animal's normal pattern of variability in response to human activity or to an exposure to a stimulus such as active sonar.

The definitions of physiological effect and behavioral effect used here are specific to this LOA request and should not be confused with more global definitions applied to the field of biology or to existing Federal law. 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 6-2 shows the relationship between severity of effects, source distance, and exposure level, as defined in this LOA request.

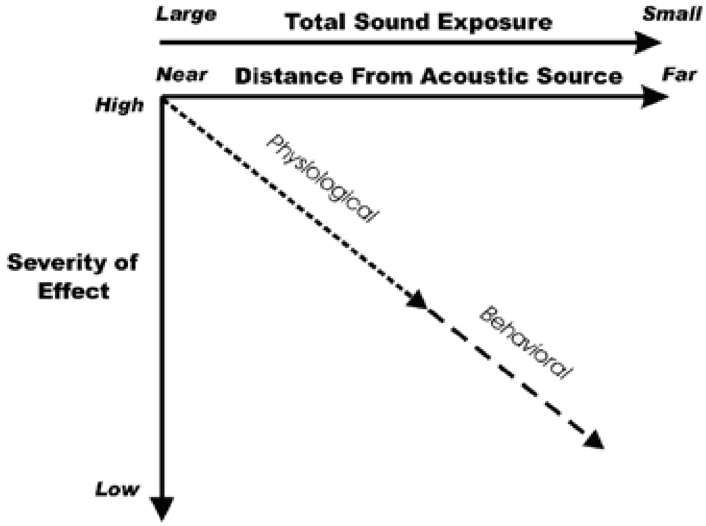


**Figure 6-2. Relationship Between Severity of Effects, Source Distance, and Exposure Level**

### 6.1.3.2 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, as defined in MIRC EIS/OEIS and previous rulings (NOAA 2001, 2002a), is the destruction or loss of biological tissue. 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, this LOA request assumes that all injury is qualified as a physiological effect and, to be consistent with prior actions and rulings (NOAA, 2001), all injuries (slight to severe) are considered Level A harassment.

Public Law 108-136 (2004) amended the MMPA definitions of Level B harassment for military readiness activities, which applies to this action. For military readiness activities, Level B harassment is defined as "any act that disturbs or is likely to disturb a marine mammal or marine mammal stock by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behaviors 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.

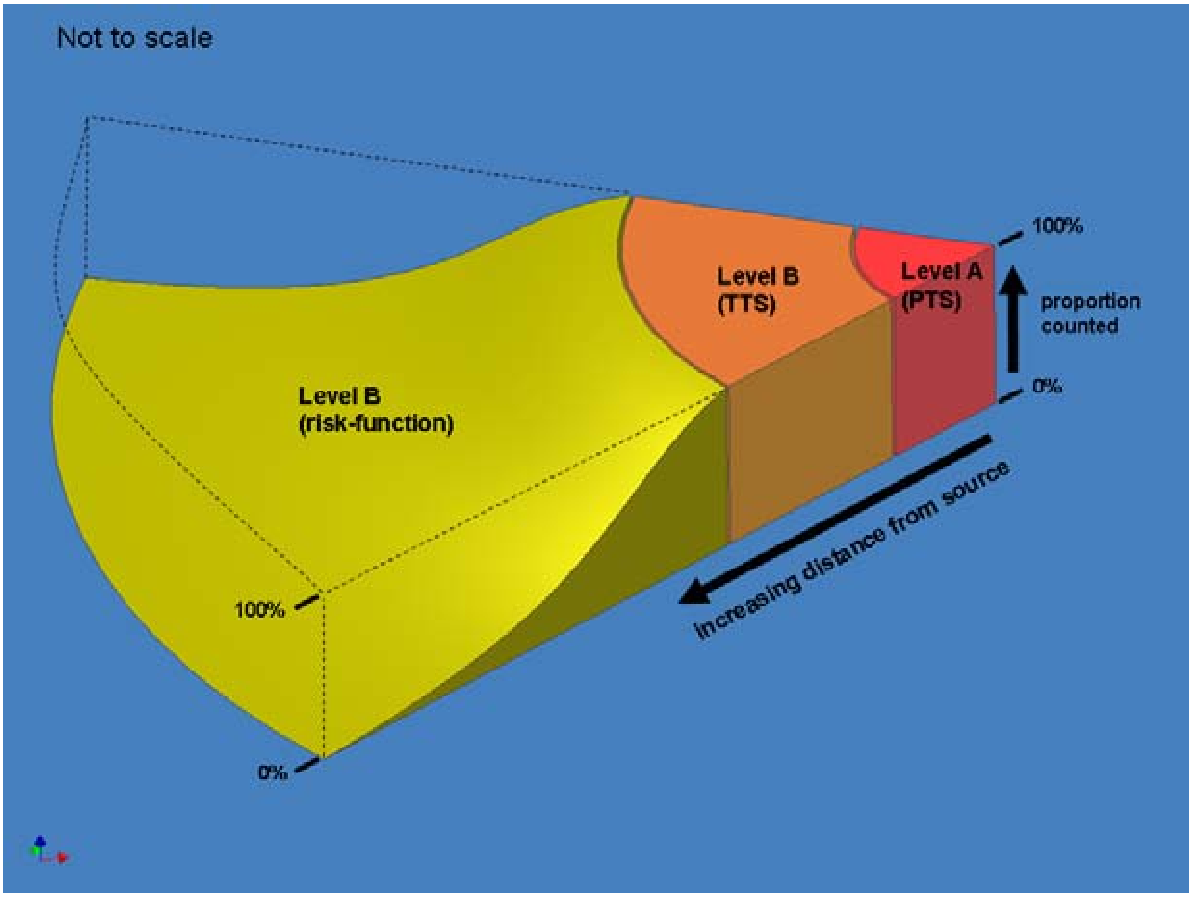
Some physiological effects can occur that are non-injurious but can potentially disrupt the behavior of a marine mammal. These include temporary distortions in sensory tissue that alter physiological function, but that are fully recoverable without the requirement for tissue replacement or regeneration. 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 harassment status of slight behavior disruption has been addressed in workshops, previous actions, and rulings (NOAA 2001; DoN 2001a). The conclusion is that a 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 rulings (NOAA, 2002a).

Although the temporary lack of response discussed above may not result in abandonment or significant alteration of natural behavioral patterns, the acoustic effect inputs used in the acoustic model assume that temporary hearing impairment (slight to severe) is considered Level B harassment. Although modes of action are appropriately considered, as outlined in Figure 6-1, the conservative assumption used here is to consider all hearing impairment as harassment. As a result, the actual incidental harassment of marine mammals associated with this action may be less than predicted using the analytical framework.

#### 6.1.3.3 MMPA Exposure Zones

Two acoustic modeling approaches are used to account for both physiological and behavioral effects to marine mammals. This subsection of harassment zones is specific to the modeling of total energy (EL) for the onset of TTS (part of Level B harassment) and sound pressure level for behavioral responses or non-TTS (part of Level B harassment). When using a threshold of accumulated energy (EL) the volumes of ocean in which Level A and Level B harassment from TTS are predicted to occur are described as exposure zones. As a conservative estimate, all marine mammals predicted to be in a zone are considered exposed to accumulated sound levels that may result in harassment within the applicable Level A or Level B harassment categories. Figure 6-3 illustrates exposure zones extending from a hypothetical, directional active sonar sound source and is not to scale. The exposure zones presented in Figure 6-3 that represents the estimated Level B harassment using the risk function (or non-TTS) is approximately 98 percent of all Level B harassments (2 percent associated with TTS).



This figure is for illustrative purposes only and does not represent the sizes or shapes of the actual exposure zones.

**Figure 6-3. Exposure Zones Extending from a Hypothetical, Directional Sound Source**

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 account of all more serious injuries by inclusion within the Level A harassment zone. The threshold used to define the outer limit of the Level A exposure zone is given as the onset PTS in Figure 6-3.

The **Level B exposure zone** begins just beyond the point of slightest injury and extends outward from that point to include animals that may possibly experience Level B harassment (non-TTS and TTS). Approximately 98 percent of the estimated harassments are non-TTS (risk function). 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 (such as occurs with inner ear hair cells subjected to TTS). The animals predicted to be in this zone are assumed to experience Level B harassment from TTS by virtue of temporary impairment of sensory function (altered physiological function) that can disrupt behavior. The criterion and threshold used to define the outer limit of the Level B exposure zone for the on-set of certain physiological effects are given in Figure 6-3.

#### 6.1.3.4 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. 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 over-stimulation 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 noise-induced threshold shift, or simply a threshold shift (TS) (Miller 1974). A TS may be either permanent, in which case it is called a PTS, or temporary, in which case it is called a TTS. Still lower levels of sound may result in auditory masking, which may interfere with an animal’s ability to hear other concurrent sounds.

The tissues of the ear appear to be the most susceptible to the physiological effects of sound and TSs occur at lower exposures than other more serious auditory effects, therefore, PTS and TTS are used here as the biological indicators of physiological effects. TTS is the first indication of physiological non-injurious change and is not physical injury. Therefore, this section focused on TSs, including PTSs and TTSs. Masking (without a resulting TS) is not associated with abnormal physiological function, therefore, it is not considered a physiological effect in this LOA request, but rather a potential behavioral effect. Descriptions of other potential physiological effects, including acoustically mediated bubble growth and air cavity resonance, are described in Section 6.2.5.

#### 6.1.3.5 Noise-Induced Threshold Shifts

The amount of TS depends on the amplitude, duration, frequency, 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) (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 eventually 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 6-4 shows two hypothetical TSs: one that completely recovers, a TTS, and one that does not completely recover, leaving some PTS.

#### 6.1.3.6 PTS, TTS, and Exposure Zones

PTS is non-recoverable and, by definition, must result from the destruction of tissues within the auditory system. PTS therefore qualifies as an injury and is classified as Level A harassment under the wording of the MMPA. In the MIRC, 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, non-injurious distortion of hearing-related tissues. In the MIRC, the smallest measurable amount of TTS (onset-TTS) is taken as the best indicator for slight temporary sensory impairment. Because it is considered non-injurious, 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 the MIRC, the potential for TTS is considered as a Level B harassment that is mediated by physiological effects on the auditory system.

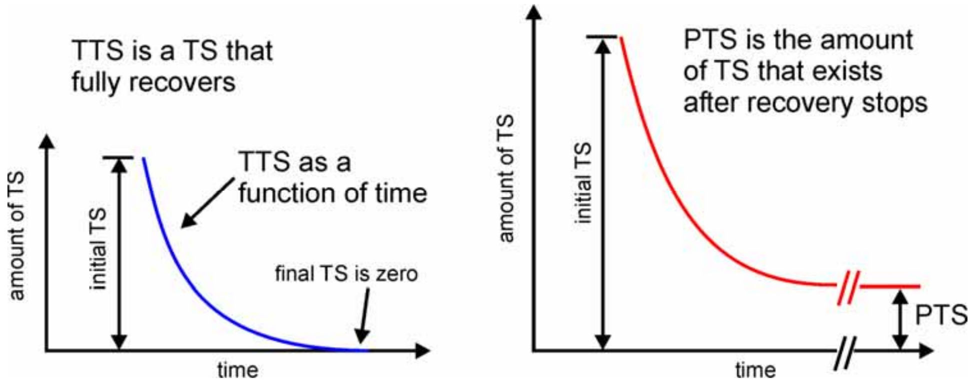


**Figure 6-4. Hypothetical TTS and PTS**

### 6.1.4 Criteria and Threshold for Explosive Source Effects

The criterion for mortality for marine mammals used in the CHURCHILL Final Environmental Impact Statement (FEIS) (DoN 2001) is "onset of severe lung injury." This 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-ms." 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 pounds-per-square-inch (psi) -ms index is a complicated calculation. Again, to be conservative, CHURCHILL used the mass of a calf dolphin (at 12.2 kg), so that the threshold index is 30.5 psi-ms (Table 6.1).

The dual criteria are used for injury: onset of slight lung hemorrhage and 50 percent eardrum rupture (tympanic membrane [TM] rupture). These criteria are considered indicative of the onset of injury (Table 6-1).

- The threshold for onset of slight lung injury is calculated for a small animal (a dolphin calf weighing 27 lb), and is given in terms of the "Goertner modified positive impulse," indexed to 13 psi-ms in the (DoN 2001a). This threshold is conservative since the positive impulse needed to cause injury is proportional to animal mass, and therefore, larger animals require a higher impulse to cause 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 rupture); this is stated in terms of an EL value of 205 dB re 1 µPa$^2$-s. The criterion reflects the fact 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).

**Table 6-1. Effects Analysis Criteria for Underwater Detonations for Explosives < 2000 lbs Net Explosive Weight**

| | Criterion | Metric | Threshold | Comments | Source |
|---|---|---|---|---|---|
| **Mortality & Injury** | **Mortality**<br>**Onset of extensive lung hemorrhage** | **Shock Wave**<br>Goertner modified positive impulse | **30.5 psi-msec** | All marine mammals<br>(dolphin calf) | Goertner 1982 |
| | **Slight Injury**<br>**Onset of slight lung hemorrhage** | **Shock Wave**<br>Goertner modified positive impulse | **13.0 psi-msec** | All marine mammals<br>(dolphin calf) | Goertner 1982 |
| | **Slight Injury**<br>**50% TM Rupture** | **Shock Wave**<br>Energy Flux Density (EFD) | **205 dB re:1µPa$^2$-sec** | All marine mammals | DoN 2001 |
| **Harassment** | **Temporary Auditory Effects**<br>**TTS** | **Noise Exposure**<br>greatest EFD in any 1/3-octave band *over all exposures* | **182 dB re:1µPa$^2$-sec** | For odontocetes greatest EFD for frequencies >100 Hz and for mysticetes ≥10 Hz | NMFS 2005,<br>NMFS 2006 |
| | **Temporary Auditory Effects**<br>**TTS** | **Noise Exposure**<br>Peak Pressure for *any single exposure* | **23 psi** | All marine mammals | DoN 2001 |
| | **Behavioral Modification (sub TTS)** | **Noise Exposure**<br>greatest EFD in any 1/3-octave band *over multiple exposures* | **177 dB re:1µPa$^2$-sec** | For odontocetes greatest EFD for frequencies >100 Hz and for mysticetes ≥10 Hz | NMFS |

Notes:

Goertner, J.F. 1982. Prediction of underwater explosion safe ranges for sea mammals. Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, MD. NSWC/WOL TR-82-188. 25 pp.

DoN. 2001. USS Churchill Shock Trail FEIS- February 2001. Department of the Navy.

NMFS. 2005. Notice of Issuance of an Incidental Harassment Authorization, Incidental to Conducting the Precisions Strike Weapon (PSW) Testing and Training by Eglin Air Force Base in the Gulf of Mexico. Federal Register,70(160):48675-48691.

NMFS. 2006. Incidental Takes of Marine Mammals Incidental to Specified Activities; Naval Explosive Ordnance Disposal School Training Operations at Eglin Air Force Base, Florida, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Federal Register 71(199):60693-60697

Two criteria are considered for non-injurious harassment TTS, which is a temporary and recoverable loss of hearing sensitivity (NMFS 2001; DoN 2001a).

- The first criterion for TTS is 182 dB re 1 µPa$^2$-s maximum EL level in any 1/3-octave band at frequencies >100 hertz (Hz) for marine mammals.
- A second criterion for estimating TTS threshold has also been developed. A threshold of 12 pounds per square inch (psi) peak pressure was developed for 10,000 pound charges as part of the CHURCHILL Final EIS (DoN 2001a, [Federal Regulation (FR) 70/160, 19 Aug 05; FR 71/226, 24

Nov 06]). It was introduced to provide a more conservative safety zone for TTS when the explosive or the animal approaches the sea surface (for which case the explosive energy is reduced but the peak pressure is not). Navy policy is to use a 23 psi criterion for explosive charges less than 2,000 lb. This is below the level of onset of TTS for an odontocete (Finneran et al. 2002). All explosives modeled for the MIRC EIS/OEIS are less than 1,500 lbs.

- The third criterion is used for estimation of behavioral disturbance before TTS (sub-TTS) for cases with multiple successive explosions. The threshold is 177 dB re 1 µPa$^2$-s (EL) to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS.

#### 6.1.4.1 Harassment Threshold for Multiple Successive Explosions (MSE)

There may be rare occasions when MSE are part of a static location event such as during MINEX, MISSILEX, BOMBEX, SINKEX, GUNEX, and Naval Surface Fire Support (NSFS) (when using other than inert weapons). For these events, the Churchill FEIS approach was extended to cover MSE events occurring at the same location. For MSE exposures, accumulated energy over the entire training time is the natural extension for energy thresholds since energy accumulates with each subsequent shot; this is consistent with the treatment of multiple arrivals in Churchill. For positive impulse, it is consistent with Churchill FEIS to use the maximum value over all impulses received.

For MSE, the acoustic criterion for sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. The sub-TTS threshold is derived following the approach of the Churchill FEIS for the energy-based TTS threshold.

The research on pure-tone exposures reported in Schlundt et al. (2000) and Finneran and Schlundt (2004) provided a threshold of 192 dB re 1 µPa$^2$-s as the lowest TTS value. This value for pure-tone exposures is modified for explosives by (a) interpreting it as an energy metric, (b) reducing it by 10 dB to account for the time constant of the mammal ear, and (c) measuring the energy in 1/3 octave bands, the natural filter band of the ear. The resulting TTS threshold for explosives is 182 dB re 1 µPa$^2$-s in any 1/3 octave band. As reported by Schlundt et al. (2000) and Finneran and Schlundt (2004), instances of altered behavior in the pure-tone research generally began five dB lower than those causing TTS. The sub-TTS threshold is therefore derived by subtracting five dB from the 182 dB re 1 µPa2-s in any 1/3 octave band threshold, resulting in a 177 dB re 1 µPa$^2$-s (EL) sub-TTS behavioral disturbance threshold for MSE.

Preliminary modeling undertaken for other Navy compliance documents using the sub-TTS threshold of 177 dB has demonstrated that for events involving MSE using small net explosive weight (NEW) explosives (MINEX, GUNEX, NSFS, and UNDET), the footprint of the threshold for explosives onset TTS criteria based on the 23 psi pressure component dominates and supersedes any exposures at a received level involving the 177 dB EL threshold. Restated in another manner, modeling for the sub-TTS threshold should not result in any estimated impacts that are not already quantified under the larger footprint of the 23 psi criteria for small MSE. Given that modeling for sub-TTS should not, therefore, result in any additional harassment takes for MINEX, GUNEX, NSFS, and UNDET, analysis of potential for behavioral disturbance using the sub-TTS criteria was not undertaken for these events (MINEX, GUNEX, NSFS, and UNDET).

For the remainder of the MSE events (BOMBEX, SINKEX, and MISSILEX) where the sub-TTS exposures may need to be considered, these potential behavioral disturbances were estimated by extrapolation from the acoustic modeling results for the explosives TTS threshold (182 dB re 1 mPa$^2$-s in any 1/3 octave band). In absence of modeling, to account for the 5 dB lower sub-TTS threshold, a factor of 3.17 was applied to the TTS modeled numbers in order to extrapolate the number of sub-TTS exposures estimated for MSE events. This multiplication factor is used calculate the increased area represented by the difference between the 177 dB sub-TTS threshold and the modeled 182 dB threshold.

The factor is based on the increased range 5 dB would propagate (assuming spherical spreading), where the range increases by approximately 1.78 times, resulting in a circular area increase of approximately 3.17 times that of the modeled results at 182 dB. Acoustic modeling for the sub-TTS exposures associated with BOMBEX, SINKEX, and MISSILEX will be conducted and provided at a later date as an addendum to this LOA.

Potential overlap of exposures from multiple explosive events within a 24-hour period was not taken into consideration in the modeling resulting in the potential for some double counting of exposures. However, because an animal would generally move away from the area following the first explosion, the overlap is likely to be minimal.

It should be emphasized that there is a lead time for set up and clearance of any area before an event using explosives takes place (this may be 30 minutes to several hours). There will, therefore, be a long period of area monitoring before any detonation or live-fire event begins. Ordnance cannot be released until the target area is determined clear. Many events, such as GUNNEX, may involve only inert rounds. In addition, live rounds are generally expended are immediately halted if sea turtles are observed within the target area. Training is delayed until the animal clears the target area. These mitigation factors to determine if the area is clear, serve to minimize the risk of harming sea turtles and marine mammals.

### 6.1.5 Criteria and Thresholds for Physiological Effects (Sensory Impairment)

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. Section 6.2.4 identified the tissues of the ear as being 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 as a result of physiological effects), respectively. Therefore, this section is focused on criteria and thresholds to predict PTS and TTS in marine mammals as described above.

Marine mammal ears are functionally and structurally similar to terrestrial mammal ears; however, there are important differences (Ketten 1998). The most appropriate information from which to develop TTS/PTS criteria for marine mammals would be experimental measurements of TTS and PTS 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 because of the ethical issues presented and therefore, must be extrapolated using 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 request 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**

Energy Flux Density Level (EL) is 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.

Sound Pressure Level (SPL) is a measure of the root-mean square, or “effective,” sound pressure in dB. SPL is expressed in dB re 1 µPa for underwater sound and dB re 20 µPa for airborne sound.

#### 6.1.5.1 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). Existing cetacean TTS data are summarized in the following bullets.

- Schlundt et al. (2000) reported the results of TTS experiments conducted with bottlenose dolphins and white whales exposed to 1-second tones. This paper also includes a reanalysis of preliminary TTS data released in a technical report by Ridgway et al. (1997). At frequencies of 3, 10, and 20 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 white whales) make the Schlundt et al. (2000) data the most directly relevant TTS information for the scenarios described in the MIRC EIS/OEIS.

- 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. (2003) 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. (2003b) 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 white whales exposed to impulsive sounds similar to those produced by distant underwater explosions and seismic water guns. These studies showed that, for very short-duration impulsive sounds, higher sound pressures were required to induce TTS than for longer-duration tones.

Figure 6-5 shows the existing TTS data for cetaceans (dolphins and white 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. (2003b).

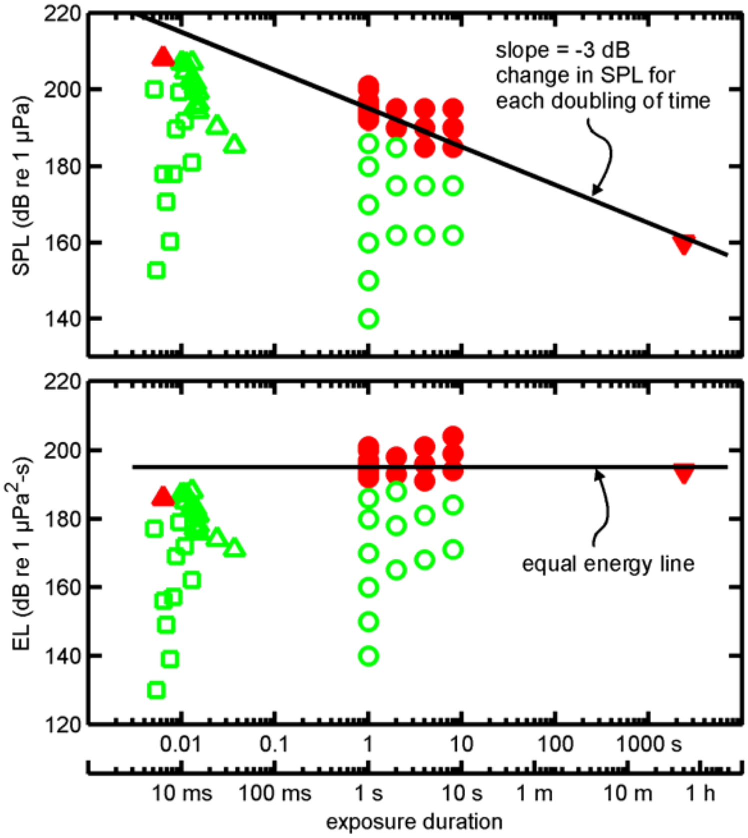
Figure 6-5 illustrates that the effects of the different sound exposures depend on the SPL and duration. As the duration decreases, higher SPLs are required to cause TTS. In contrast, the ELs required for TTS do not show the same type of variation with exposure duration.

The solid line in the upper panel of Figure 6-5 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 + 10log10 (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* – 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 non-impulsive data) very well, despite differences in exposure duration, SPL, experimental methods, and subjects.

In summary, the existing cetacean TTS data show that, for the species studied and sounds (non-impulsive) of interest, the following is true:

- **The growth and recovery of TTS are analogous 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) (Kryter et al., 1965; 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 energy flux density level of 195 dB re 1 µPa$^2$-s is the most appropriate predictor for onset-TTS from a single, continuous exposure.
- For the purposes of this LOA application a measurable amount of 6 dB is considered the onset of TTS.



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. (2003), and Inverted triangle: Data from Nachtigall et al., 2003b

**Figure 6-5. Existing TTS Data for Cetaceans**

#### 6.1.5.2 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 – 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 does 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 6-6 shows results from Ward et al. (1958, 1959) plotted as the amount of $TTS_2$ versus the exposure EL. The data in Figure 6-6(a) are from broadband (75 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 ($R^2 = 0.95$). 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 in additional amount of TTS produced by an increase in exposure. For example, the slope of the line in Figure 6-7(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 $TTS_2$.

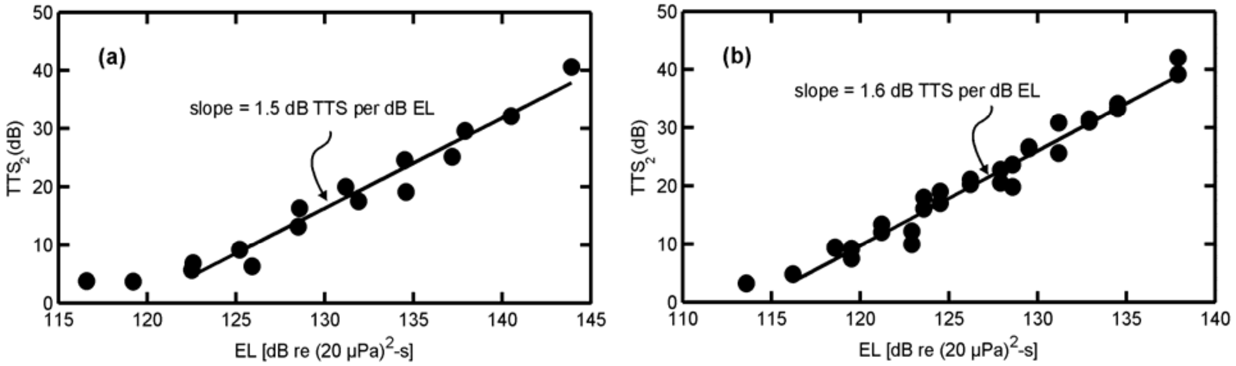


**Figure 6-6. Growth of TTS versus the Exposure EL (from Ward et al. [1958, 1959])**

The data in Figure 6-6(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 6-6(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 – 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 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 $TTS_2$ and exposure EL. A value of 1.6 dB $TTS_2$ 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.

#### 6.1.5.3 Threshold Levels for Harassment from Physiological Effects

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

**195 dB re 1 $\mu Pa^2$-s received EL for TTS**

**215 dB re 1 $\mu Pa^2$-s received EL for PTS**

Marine mammals predicted to receive a sound exposure with EL of 215 dB re 1 $\mu Pa^2$-s or greater are assumed to experience PTS and are counted as Level A harassment. Marine mammals predicted to receive a sound exposure with EL greater than or equal to 195 dB re 1 $\mu Pa^2$-s but less than 215 dB re 1 $\mu Pa^2$-s are assumed to experience TTS and are counted as Level B harassment from TTS. Analyses for each individual species are presented in Sections 6.8.2 and 6.8.3.

#### 6.1.5.4 Derivation of Effect Threshold

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, 2003) and the long-duration sound data from Nachtigall et al. (2003a, b). 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).

#### 6.1.5.5 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:

$$EL = SPL + 10\log10(\text{duration})$$

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.
- A single ping with SPL = 192 dB re 1 µPa and duration = 2 seconds.
- Two pings with SPL = 192 dB re 1 µPa and duration = 1 second.
- Two pings with SPL = 189 dB re 1 µPa and duration = 2 seconds.

#### 6.1.5.6 Comparison to SURTASS LFA Risk Functions

The physiological effect thresholds described in this LOA request should not be confused with criteria and thresholds used for the Navy's SURTASS LFA sonar. SURTASS LFA features pings lasting many tens of seconds. The sonars of concern for use within the MIRC emit pings lasting a few seconds at most. SURTASS LFA risk functions were expressed in terms of the received "single ping equivalent" SPL. Physiological effect thresholds in this LOA request are expressed in terms of the total received EL. The

SURTASS LFA risk function parameters cannot be directly compared to the effect thresholds used in this LOA request and the MIRC EIS/OEIS. Comparisons must take into account the differences in ping duration, number of pings received, and method of accumulating effects over multiple pings (refer to Section 1.9.1.2).

#### 6.1.5.7 Previous Use of EL for Physiological Effects

Energy measures have been used as a part of dual criteria for cetacean auditory effects in shock trials, which only involve impulsive-type sounds (DoN 1997, 2001a). These actions used 192 dB re 1 µ$Pa^2$-s as a reference point to derive a TTS threshold in terms of EL. A second TTS threshold, based on peak pressure, was also used. If either threshold was exceeded, effect was assumed.

The 192 dB re 1 µ$Pa^2$-s reference point differs from the threshold of 195 dB re 1 µ$Pa^2$-s used in this MIRC LOA request and EIS/OEIS. The 192 dB re 1 µ$Pa^2$-s value was based on the minimum observed by Ridgway et al. (1997) and Schlundt et al. (2000) during TTS measurements with bottlenose dolphins exposed to 1-second tones. At the time, no impulsive test data for marine mammals were available and the 1-second tonal data were considered to be the best available. The minimum value of the observed range of 192 to 201 dB re 1 µ$Pa^2$-s was used to protect against misinterpretation of the sparse data set available. The 192 dB re 1 µ$Pa^2$-s value was reduced to 182 dB re 1 µ$Pa^2$-s to accommodate the potential effects of pressure peaks in impulsive waveforms.

The additional data now available for onset-TTS in small cetaceans confirm the original range of values and increase confidence in it (Finneran et al. 2001, 2003; Nachtigall et al. 2003a, 2003b). The MIRC EIS/OEIS, therefore, uses the more complete data available and the mean value of the entire Schlundt et al. (2000) data set (195 dB re 1 µ$Pa^2$-s), instead of the minimum of 192 dB re 1 µ$Pa^2$-s. From the standpoint of statistical sampling and prediction theory, the mean is the most appropriate predictor—the “best unbiased estimator”—of the EL at which onset-TTS should occur; predicting the number of exposures in future actions relies (in part) on using the EL at which onset-TTS will most likely occur. When that EL is applied over many pings in each of many sonar exercises, that value will provide the most accurate prediction of the actual number of exposures by onset-TTS over all of those exercises. Use of the minimum value would overestimate the number of exposures because many animals counted would not have experienced onset-TTS. Further, there is no logical limiting minimum value of the distribution that would be obtained from continued successive testing. Continued testing and use of the minimum would produce more and more erroneous estimates.

### 6.1.6 Criteria and Thresholds for Behavioral Effects

Section 6.1.3 categorized the potential effects of sound into physiological effects and behavioral effects. This Section presents the effect criterion and threshold for behavioral effects of sound leading to behavioral disturbance without accompanying physiological effects. Since TTS is used as the biological indicator for a physiological effect leading to behavioral disturbance, the behavioral effects discussed in this section may be thought of as behavioral disturbance occurring at exposure levels below those causing TTS.

A large body of research on terrestrial animal and human response to airborne sound exists, but results from those studies are not readily extendible to the development of effect criteria and thresholds for marine mammals. For example, “annoyance” is one of several criteria used to define impact to humans from exposure to industrial sound sources. Comparable criteria cannot be developed for marine mammals because there is no acceptable method for determining whether a non-verbal animal is annoyed. Further, differences in hearing thresholds, dynamic range of the ear, and the typical exposure patterns of interest (e.g., human data tend to focus on 8-hour-long exposures) make extrapolation of human sound exposure standards inappropriate.

Behavioral observations of marine mammals exposed to anthropogenic sound sources exist, however, there are few observations and no controlled measurements of behavioral disruption of cetaceans caused by sound sources with frequencies, waveforms, durations, and repetition rates comparable to those employed by the tactical sonars to be used in the MIRC. At the present time there is no consensus on how to account for behavioral effects on marine mammals exposed to continuous-type sounds (NRC, 2003). Response can range from avoidance of the sound source, changes in vocalizations rates, duration or intensity, changes in foraging behavior, swim speed or even investigation of the sound source (review by Richardson et al. 1995; Croll et al. 2001; Nowacek et al. 2007)

This application uses behavioral observations from three studies of trained or wild cetaceans exposed to underwater sound. The first study was conducted under controlled circumstances with odontocetes in the laboratory (Schlundt et al. 2000; Finneran and Schlundt 2004). The second study exposed mysticetes in the wild to known sound sources (Nowacek et al. 2004, 2007). The third study consisted of observations of the behavior of odonticetes in the wild near ships using mid frequency active sonar (NMFS 2005a; Navy 2004b; Fromm 2004a, 2004b).

## 6.2 Assessing MMPA Level B Behavioral Harassment Using Risk Function

### 6.2.1 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 substantially 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 sound. In other circumstances, the same individual or other individuals may avoid an acoustic source at much lower received levels (Richardson et al. 1995a; Wartzok et al. 2003; Southall et al. 2007). 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 training activities, 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, Portugal in 2000; the Canary Islands in 2002, and Spain in 2006 (Marine Mammal Commission 2006).

In these circumstances, exposure to acoustic energy has been considered a potential indirect cause of the death of marine mammals (Cox et al. 2006). A popular hypothesis regarding a potential cause of the strandings is that tissue damage results from a "gas and fat embolic syndrome" (Fernandez et al. 2005; Jepson et al. 2003, 2005). Models of nitrogen saturation in diving marine mammals have been used to suggest that altered dive behavior might result in the accumulation of nitrogen gas such that the potential for nitrogen bubble formation is increased (Houser et al. 2001; Zimmer and Tyack 2007). If so, this mechanism might explain the findings of gas and bubble emboli in stranded beaked whales. It is also possible 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 and not the direct result of exposure to sonar (Cox et al. 2006).

### 6.2.2 Risk Function Adapted from Feller (1968)

The particular acoustic risk function developed by the Navy and NMFS 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/HFA sonar. The mathematical function is derived from a solution in Feller (1968) for the probability as defined in the SURTASS LFA Sonar Final OEIS/EIS (DoN 2001c), and relied on in the Supplemental SURTASS LFA Sonar EIS (DoN 2007a) for the probability of MFA/HFA sonar risk for MMPA Level B behavioral harassment with input parameters modified by NMFS for MFA sonar for mysticetes, odontocetes, and pinnipeds.

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 Navy (2001c), the mathematical function below is adapted from a solution in Feller (1968).

$$R = \frac{1-\left(\frac{L-B}{K}\right)^{-A}}{1-\left(\frac{L-B}{K}\right)^{-2A}}$$

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 (A=10 odontocetes (except harbor porpoises)/pinnipeds; A=8 mysticetes) (explained in Section 6.2.2.3).

In order to use this function, the values of the three parameters (B, K, and A) need to be established. As further explained in Section 6.2.2.1, the values used in this analysis are based on three sources of data: TTS experiments conducted at SPAWAR Systems Center (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 NMFS, (2005a); Navy (2004b); 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.

#### 6.2.2.1 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 (Cox et al. 2006; Southall et al. 2007). The 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 sonar. These data sets represent the only known data that specifically relate altered behavioral responses to exposure to MFA sound sources. Until applicable data sets are evaluated to better qualify harassment from HFA sources, the risk function derived for MFA sources will apply to HFA.

***Data from SSC's Controlled Experiments***

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. 2002a). Bottlenose dolphins exposed to 1-second (sec) intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 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. 2002a). 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-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 sound in the bay, low-level broadband masking sound was used to keep hearing thresholds consistent despite fluctuations in the ambient sound. 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 sound level (below 50 dB re 1 µPa$^2$/hertz [Hz]), and no masking sound 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 SPL were randomly presented.

**Data from Studies of Baleen (Mysticetes) Whale Responses**

The only mysticete data available resulted from a field experiments in which baleen whales (mysticetes) were exposed to sounds ranging in frequency from 50 Hz (ship noise playback) to 4500 Hz (alert stimulus) (Nowacek et al. 2004). Behavioral reactions to an alert stimulus, consisting of a combination of tones and frequency and amplitude modulated signals ranging in frequency from 500 Hz to 4500 Hz, was the only portion of the study used to support the risk function input parameters.

2. Nowacek et al. (2004; 2007) 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 sound, 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/√Hz.

**Observations of Killer Whales in Haro Strait in the Wild**

In May 2003, killer whales (*Orcinus orca*) were observed exhibiting behavioral responses while USS SHOUP was engaged in MFA sonar use in the Haro Strait in the vicinity of Puget Sound, Washington. Although these observations were made in an uncontrolled environment, the sound field associated with the sonar use 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. The DOC (National Marine Fisheries 2005a); Navy (2004b); Fromm (2004a, 2004b) documented reconstruction of sound fields produced by USS SHOUP associated with the behavioral response of killer whales observed in Haro Strait. Observations from this reconstruction included an estimate of 169.3 dB SPL which represents the mean received level at a point of closest approach within a 1,640 ft. (500 m) wide area in which the animals were exposed. Within that area, the estimated received levels varied from approximately 150 to 180 dB SPL.

#### 6.2.2.2 Limitations of the Risk Function Data Sources

There are substantial 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.

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 the Haro Strait 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.

SSC San Diego Trained Bottlenose Dolphins and Beluga Data Set:

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 $\mu Pa^2$-s).

The animals were not exposed in the open ocean but in a shallow bay or pool.

The tones used in the tests were 1-second pure tones similar to MFA sonar.

North Atlantic Right Whales in the Wild Data Set:

The observations of behavioral response were from exposure to alert stimuli that contained mid-frequency components but was not similar to an 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.

Killer Whales in the Wild Data Set:

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 observed response as opposed to baseline conditions.

#### 6.2.2.3 Input Parameters for the Feller-Adapted Risk Function

The values of B, K, and A need to be specified in order to utilize the risk function defined in Section 6.2.2 previously. The risk continuum function approximates the dose-response function in a manner analogous to pharmacological risk assessment (DoN 2001c, Appendix A). 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 scientists, 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.

##### *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 Navy use A=10 as the value for odontocetes (except harbor porpoises), and pinnipeds, and A=8 for mysticetes, (Figures 6-7 and 6-8) (NMFS 2008).

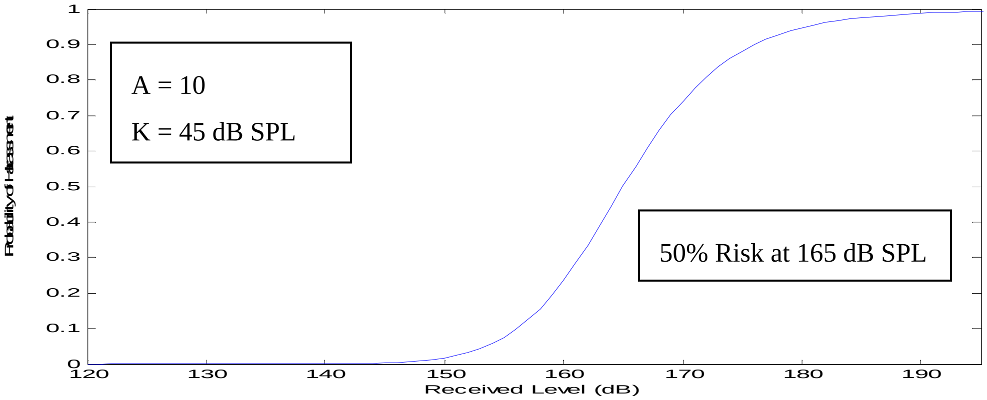


**Figure 6-7. Risk Function Curve for Odontocetes (except harbor porpoises) (Toothed Whales) and Pinnipeds**

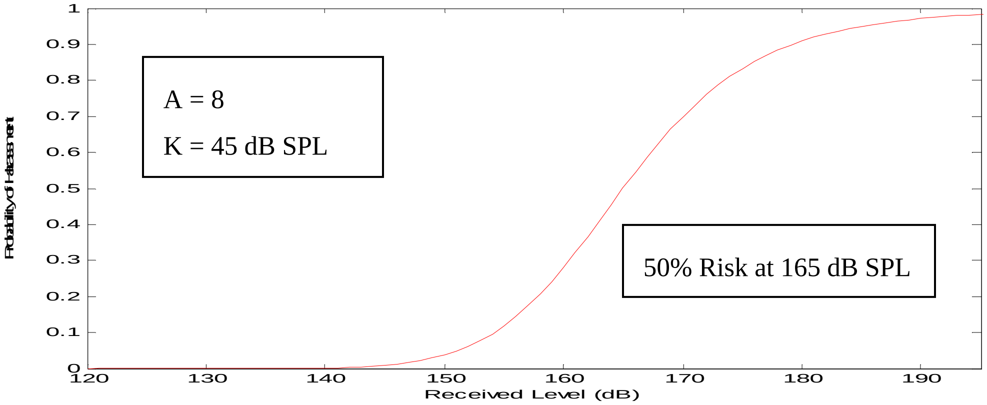


**Figure 6-8. Risk Function Curve for Mysticetes (Baleen Whales)**

Justification for the Steepness Parameter of A=10 for the Odontocete Curve

The NMFS independent review process described in Section 4.1.2.4.9 of Navy (2008) provided the impetus for the selection of the parameters for the risk function curves. One scientist recommended staying close to the risk continuum concept as used in the SURTASS LFA sonar EIS. This scientist opined that both the basement and slope values; B=120 dB and A=10 respectively, from the SURTASS LFA sonar risk continuum concept are logical solutions in the absence of compelling data to select alternate values supporting the Feller-adapted risk function for MFA sonar. Another scientist indicated a steepness parameter needed to be selected, but did not recommend a value. Four scientists did not specifically address selection of a slope value. After reviewing the six scientists' recommendations, the two NMFS scientists recommended selection of A=10. Direction was provided by NMFS to use the A=10 curve for odontocetes based on the scientific review of potential risk functions explained in Section 4.1.2.4.9.2 of DoN (2008).

As background, a sensitivity analysis of the A=10 parameter was undertaken and presented in Appendix D of the SURTASS/LFA FEIS (DoN 2001c). The analysis was performed to support the A=10 parameter for mysticete whales responding to a low-frequency sound source, a frequency range to which the mysticete whales are believed to be most sensitive to. The sensitivity analysis results confirmed the increased risk estimate for animals exposed to sound levels below 165 dB. Results from the Low Frequency Sound Scientific Research Program (LFS SRP) phase II research showed that whales (specifically gray whales in their case) did scale their responses with received level as supported by the A=10 parameter (Buck and Tyack 2000). In the second phase of the LFS SRP research, migrating gray whales showed responses similar to those observed in earlier research (Malme et al. 1983, 1984) when the low frequency source was moored in the migration corridor (2 km [1.1 nm] from shore). The study extended those results with confirmation that a louder SL elicited a larger scale avoidance response. However, when the source was placed offshore (4 km [2.2 nm] from shore) of the migration corridor, the avoidance response was not evident. This implies that the inshore avoidance model – in which 50 percent of the whales avoid exposure to levels of 141 ± 3 dB – may not be valid for whales in proximity to an offshore source (DoN 2001c). As concluded in the SURTASS LFA Sonar Final OEIS/EIS (DoN 2001c), 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; Buck and Tyack 2000; and SURTASS LFA Sonar EIS, Subchapters 1.43, 4.2.4.3 and Appendix D, and NMFS 2008).

Justification for the steepness parameter of A=8 for the Mysticete Curve

The Nowacek et al. (2004) study provides the only available data source for a mysticete species behaviorally responding to a sound source (i.e., alert stimuli) with frequencies in the range of tactical mid-frequency sonar (1-10 kHz), including empirical measurements of received levels (RLs). While there are fundamental differences in the stimulus used by Nowacek et al. (2004) and tactical mid-frequency sonar (*e.g.*, source level, waveform, duration, directionality, likely range from source to receiver), they are generally similar in frequency band and the presence of modulation patterns. Thus, while they must be considered with caution in interpreting behavioral responses of mysticetes to mid-frequency sonar, they seemingly cannot be excluded from this consideration given the overwhelming lack of other information. The Nowacek et al. (2004) data indicate that five out the six North Atlantic right whales exposed to an alert stimuli "significantly altered their regular behavior and did so in identical fashion" (i.e., ceasing feeding and swimming to just under the surface). For these five whales, maximum RLs associated with this response ranged from root- mean-square sound (rms) pressure levels of 133-148 dB (re: 1 µPa).

When six scientists (one of them being Nowacek) were asked to independently evaluate available data for constructing a dose response curve based on a solution adapted from Feller (1968), the majority of them (4 out of 6; one being Nowacek) indicated that the Nowacek et al. (2004) data were not only appropriate but also necessary to consider in the analysis. While other parameters associated with the solution adapted from Feller (1968) were provided by many of the scientists (i.e., basement parameter [B], increment above basement where there is 50% risk [K]), only one scientist provided a suggestion for the risk transition parameter, A.

A single curve may provide the simplest quantitative solution to estimating behavioral harassment. However, the policy decision, by NMFS-OPR, to adjust the risk transition parameter from A=10 to A=8 for mysticetes and create a separate curve was based on the fact the use of this shallower slope better reflected the increased risk of behavioral response at relatively low RLs suggested by the Nowacek et al. (2004) data. In other words, by reducing the risk transition parameter from 10 to 8, the slope of the curve for mysticetes is reduced. This results in an increase the proportion of the population being classified as behaviorally harassed at lower RLs. It also slightly reduces the estimate of behavioral response probability at quite high RLs, though this is expected to have quite little practical result owing to the very limited probability of exposures well above the mid-point of the function. This adjustment allows for a slightly more conservative approach in estimating behavioral harassment at relatively low RLs for mysticetes compared to the odontocete curve and is supported by the only dataset currently available. It should be noted that the current approach (with A=8) still yields an extremely low probability for behavioral responses at RLs between 133-148 dB, where the Nowacek data indicated significant responses in a majority of whales studied. (Note: Creating an entire curve based strictly on the Nowacek et al. [2004] data alone for mysticetes was advocated by several of the reviewers and considered inappropriate, by NMFS-OPR, since the sound source used in this study was not identical to tactical mid-frequency sonar, and there were only five data points available). The policy adjustment made by NMFS-OPR was also intended to capture some of the additional recommendations and considerations provided by the scientific panel (i.e., the curve should be more data driven and that a greater probability of risk at lower RLs be associated with direct application of the Nowacek et al. 2004 data).

### 6.2.3 Basic Application of the Risk Function and Relation 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/HFA 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.

NMFS and Navy made the decision to apply the MFA risk function curve to HFA sources due to lack of available and complete information regarding HFA sources. As more specific and applicable data become available for MFA/HFA sources, NMFS can use these data to modify the outputs generated by the risk function to make them more realistic. 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). In the Hawaii Range Complex example, animals exposed to received levels between 120 and 130 dB may be more than 65 nautical miles (131,651 yards) from a sound source; 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, the 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 on 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. Generally speaking, the 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.

**Table 6-2. Percent of Harassments at Each Received Level Band**

| Received Level | Distance at which Levels Occur in MIRC | Percent of Harassments Occurring at Given Levels |
|---|---|---|
| Below 140 dB SPL | 36 km–125 km | <1% |
| 140>Level>150 dB SPL | 15 km–36 km | 2% |
| 150>Level>160 dB SPL | 5 km–15 km | 20% |
| 160>Level>170 dB SPL | 2 km–5 km | 40% |
| 170>Level>180 dB SPL | 0.6–2 km | 24% |
| 180>Level>190 dB SPL | 180–560 meters | 9% |
| Above 190 dB SPL | 0–180 meters | 2% |
| TTS (195 dB EFDL) | 0–110 meters | 2% |
| PTS (215 dB EFDL) | 0–10 meters | <1% |

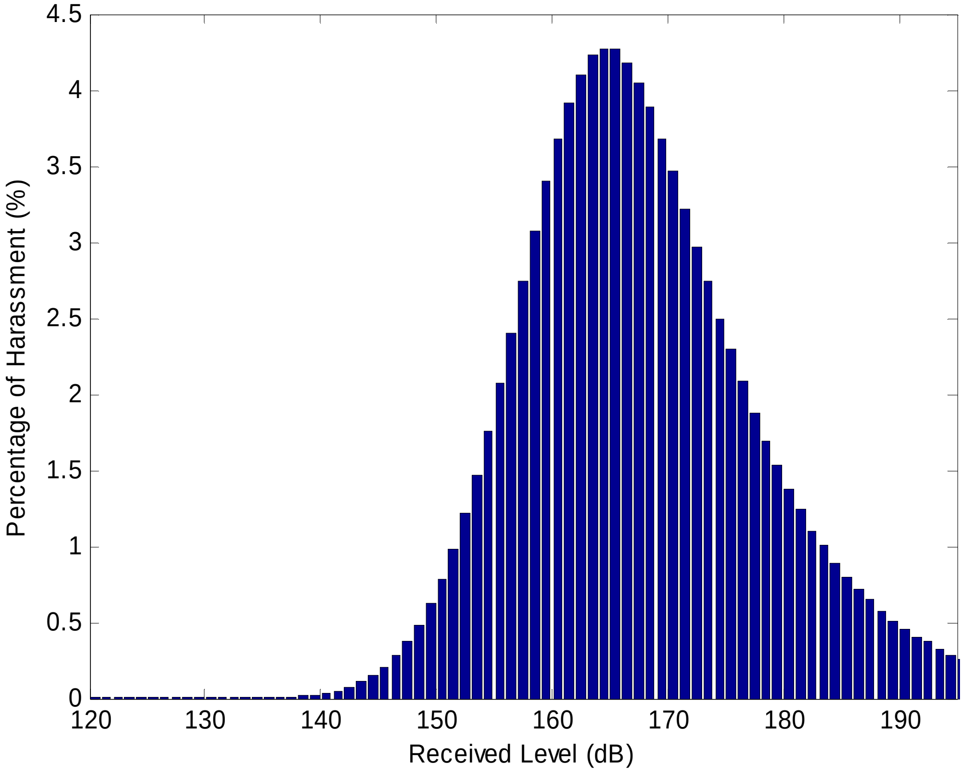


**Figure 6-9. The Percentage of Behavioral Harassments Resulting from the Risk Function for Every 5 dB of Received Level**

### 6.2.4 Navy Post Acoustic Modeling Analysis

The quantification of the acoustic modeling results includes additional analysis to increase the accuracy of the number of marine mammals affected. Table 6-3 provides a summary of the modeling protocols used in this analysis. Post modeling analysis includes reducing acoustic footprints where they encounter land masses, accounting for acoustic footprints for sonar sources that overlap to accurately sum the total area when multiple ships are operating together, and to better account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of one day or a discreet continuous sonar event.

**Table 6-3. Navy Protocols Providing for Accurate Modeling Quantification of Marine Mammal Exposures**

| | | |
|---|---|---|
| **Acoustic Parameters** | AN/SQS-53 and AN/SQS-56 | The AN/SQS-53 and the AN/SQS-56 active sonar sources were modeled separately to account for the differences in source level, frequency, and exposure effects. |
| | Submarine Sonar | Submarine active sonar use is included in effects analysis calculations. |
| **Post Modeling Analysis** | Land Shadow | For sound sources within the acoustic footprint of land, (approximately 65 nautical miles [nm] for the MIRC subtract the land area from the marine mammal exposure calculation). |
| | Multiple Ships | Correction factors are used to address the maximum potential of exposures to marine mammals resulting from multiple counting based on the acoustic footprint when there are occasions for more than one ship operating within approximately 130 nm of one another. |
| | Multiple Exposures | Accurate accounting for MIRC training events within the course of one day or a discreet continuous sonar event:<br>• Other MIRC ASW training – 12 hours<br>• Joint Multi-strike Group – 12 hours |

As described above and as required by NMFS as a Cooperating Agency, the analysis in this LOA application assumes that short-term, non-injurious sound exposure levels (SELs) predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment from TTS. Application of this criterion assumes an effect even though not every behavioral disruption or instances of TTS will result in the abandonment or significant alteration of behavioral patterns (Military readiness definition of "harassment"). Given the context of exposures at the lowest received levels (~120 dB) we would expect that there will be adjustments to the modeled exposures, or at least consideration of these factors in the preparation of an incidental take authorization. To date, there is no information indicating a correlation between MFA/HFA sonar use and marine mammals abandoning their habitat in other range complexes such as Hawaii and Southern California.

## 6.2.5 Other Effects Considered

### 6.2.5.1 Stress

A possible effect for marine mammals exposed to sound, including MFA/HFA sonar, is health and physiological stress (Review by Fair and Becker, 2000). A stimulus may cause a number of behavioral and physiological responses such as an increase in vigilance, elevated heart rate, increases in endocrine and neurological function, and decreased immune function, particularly if the animal perceives the stimulus as life threatening (Seyle 1950; Moberg 2000, Sapolsky et al. 2005). The primary response to the stressor is to move away to avoid continued exposure although other factors such as foraging or tending to an offspring may influence the animal to stay in the area of exposure. Next, the animal's physiological response to a stressor is to engage the autonomic nervous system with the classic "fight or flight" response. This includes changes in the cardiovascular system (increased heart rate), the gastrointestinal system (decrease digestion), the exocrine glands (increased hormone output), and the adrenal glands (increased nor-epinephrine). These physiological and hormonal responses are short lived and may not have significant long-term effects on an animal's health or fitness. Generally these short term responses are not detrimental to the animal except when the health of the animal is already compromised by disease, starvation or parasites; or the animal is chronically exposed to a stressor.

Exposure to chronic or high intensity sound sources can cause physiological stress. Acoustic exposures and physiological responses have been shown to cause stress responses (elevated respiration and increased heart rates) in humans (Jansen 1998). Jones (1998) reported on reductions in human performance when faced with acute, repetitive exposures to acoustic disturbance. Trimper et al. (1998) reported on the physiological stress responses of osprey to low-level aircraft sound. Krausman et al. (2004) reported on the auditory (TTS) and physiology stress responses of endangered Sonoran pronghorn to military overflights. Smith et al. (2004a, 2004b) recorded sound-induced physiological stress responses in a hearing-specialist fish that was associated with TTS and PTS. Welch and Welch (1970) reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Most of these responses to sound sources or other stimuli have been studied extensively in terrestrial animals but are much more difficult to determine in marine mammals. Increases in heart rate are common reaction to acoustic disturbance in marine mammals (Miksis et al. 2001) as are small increases in the hormones norepinephrine, epinephrine, and dopamine (Romano et al. 2002; 2004). Increases in cortical steroids are more difficult to determine because blood collection procedures will also cause stress (Romano et al. 2002; 2004). A recent study, Chase Encirclement Stress Studies (CHESS), was conducted by NMFS on chronic stress effects in small odontocetes affected by the eastern tropical Pacific (ETP) tuna fishery (Forney et al. 2002). Analysis was conducted on blood constituents, immune function, reproductive parameters, heart rate and body temperature of small odontocetes that had been pursued and encircled by tuna fishing boats. Some effects were noted, including lower pregnancy rates, increases in norepinephrine, dopamine, adrenocorticotropic hormone (ACTH) and cortisol levels, heart lesions and an increase in fin and surface temperature when chased for over 75 minutes but with no change in core body temperature (Forney et al. 2002). These stress effects in small cetaceans that were actively pursued (sometimes for over 75 minutes) were relatively small and difficult to discern. It is unlikely that marine mammals exposed to active sonar would be exposed at long as the cetaceans in the CHESS study and would not be pursued by the Navy ships, therefore stress effects would be minimal from the short term exposure to sonar. Ridgway et al. (2006) reported that increased vigilance in bottlenose dolphins exposed to sound over a five day period did not cause an sleep deprivation or stress effects such as changes in cortisol or epinephrine levels.

### 6.2.5.2 Acoustically Mediated Bubble Growth

One suggested cause of injury to marine mammals is by 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 a gas, such as nitrogen which makes up approximately 78 percent of air (remainder of air is about 21 percent oxygen with some carbon dioxide). 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 (for example, 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 deeper than approximately 162 ft for phocids (Kooyman et al. 1970). Collapse of the lungs would force air in to the non-air exchanging areas of the lungs (in to the bronchioles away from the alveoli) or nasal passages thus significantly decreasing nitrogen diffusion in to 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 super saturation 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 and exposed to a continuous sound source for bubbles to become of a problematic size.

#### 6.2.5.3 Decompression Sickness

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 that would cause decompression sickness (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 but requires further investigation. Conversely, Fahlman et al. (2006) suggested 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 Blaineville’s (*Mesoplodon densirostris*) beaked whales in Hawaii (Baird et al. 2006) and in the Ligurian Sea in Italy (Tyack et al. 2006) showed that while these species do dive deeply (regularly exceed depths of 2,624 ft) 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 in response to sonar should not cause decompression sickness. Currently it is not known if beaked whales do rapidly ascend in response to sonar or other disturbances. It may be that deep diving animals would be better protected diving to depth to avoid predators, such as killer whales, rather than ascending to the surface where they may be more susceptible to predators.

A recent publication by Zimmer et al. (2007) modeled a scenario that suggested that beaked whales may incur decompression sickness during shallow repetitive dives while trying to flee a predator or some sound source. There is no evidence to support this type of diving behavior as it has not been observed in beaked whales but the model was an attempt to explain the presence of tissue damage that may be caused by bubble formation from decompression. Conversely, as explained above these instances of tissue damage may only reflect injuries that occur during the stranding as they roll on the beach or rocks or could be post mortem changes.

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 2003). 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 and complicating factors associated with introduction of gas in to 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. Beaked whales are, however, assessed differently from other species to account for factors that may have contributed to prior beaked whale strandings as set out in the previous section.

#### 6.2.5.4 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—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 (for example, 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 Navy MFA sonar caused resonance effects in beaked whales that eventually led to their stranding (DOC and DoN 2001). The conclusions of that group were that resonance in air-filled structures the frequencies at which resonance were predicted to occur were below the frequencies utilized by the sonar systems employed. Furthermore, air cavity vibrations due to the resonance effect were not considered to be of sufficient amplitude to cause tissue damage.

#### 6.2.5.5 Likelihood of Prolonged Exposure

The proposed ASW activities within the MIRC would not result in prolonged exposure because the vessels are constantly moving, and the flow of the activity in the MIRC when ASW training occurs reduces the potential for prolonged exposure. The implementation of the mitigation measures described in Chapter 11 would further reduce the likelihood of any prolonged exposure.

#### 6.2.5.6 Likelihood of 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 manmade sources (for example, 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. A recent study by Nachtigall and Supin (2008) showed that false killer whales adjust their hearing to compensate for ambient sounds and the intensity of returning echolocation signals.

The proposed MIRC ASW areas are away from harbors but may include heavily traveled shipping lanes, although shipping lanes are a small portion of the overall range complex. The loudest mid-frequency underwater sounds in the Proposed Action area are those produced by hull-mounted MFA or HFA tactical sonar. 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, the total number of hours of training activities per year are small, and these hull-mounted MFA and HFA tactical sonars transmit within a narrow band of frequencies (typically less than one-third octave).

For the reasons outlined above, the chance of sonar training activities causing masking effects is considered negligible.

#### 6.2.5.7 Long-Term Effects

Navy activities are conducted in the same general areas throughout the MIRC, so marine mammal populations could be exposed to repeated activities over time. However, as described earlier, short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment. Application of this criterion assumes an effect even though it is highly unlikely that all behavioral disruptions or instances of TTS will result in long term significant impacts. In addition, sonar exercises have been conducted in the MIRC for 40 years without a sonar related stranding being observed. Most populations of marine mammals have been stable or increasing in the MIRC.

Monitoring programs for the MIRC are being developed by the Navy to assess population trends and responses of marine mammals to Navy activities. Short-term monitoring programs for major exercises (e.g., RIMPAC, Joint Task Force Exercises [JTFEX]) are being developed to assess mitigation measures and responses of marine mammals to Navy activities.

### 6.2.6 Application of Exposure Thresholds to Other Species

#### 6.2.6.1 Mysticetes

Information on auditory function in mysticetes is extremely lacking. Sensitivity to low-frequency sound by baleen whales has been inferred from observed vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system. Baleen whales are estimated to hear from 15 Hz to 20 kHz, with good sensitivity from 20 Hz to 2 kHz (Ketten 1998). Filter-bank models of the humpback whale’s ear have been developed from anatomical features of the humpback’s ear and optimization techniques (Houser et al. 2001a). The results of these studies suggest that humpbacks are sensitive to frequencies between 40 Hz and 16 kHz, but best sensitivity is likely to occur between 100 Hz and 8 kHz. However, absolute sensitivity has not been modeled for any baleen whale species. Furthermore, there is no indication of what sorts of sound exposure produce threshold shifts in these animals.

The criteria and thresholds for PTS and TTS developed for odontocetes for this activity are also used for mysticetes. This generalization is based on the assumption that the empirical data at hand are representative of both groups until data collection on mysticete species shows otherwise. For the frequencies of interest for this action, there is no evidence that the total amount of energy required to induce onset-TTS and onset-PTS in mysticetes is different than that required for odontocetes.

#### 6.2.6.2 Beaked Whales

Previous beaked whale strandings involving multiple animals have prompted inquiry into the relationship between high-amplitude sonar-type sound and the cause of those strandings. For example, in the stranding in the Bahamas in 2000, the Navy mid-frequency sonar was identified as the only contributory cause that could have lead to the stranding. The Bahamas exercise entailed multiple ships using mid-frequency sonar during transit of a long constricted channel. The Navy participated in an extensive investigation of the stranding with the NMFS. The “Joint Interim Report, Bahamas Marine Mammal Stranding Event of 15-16 March 2000” concluded that the variables to be considered in managing future risk from tactical mid-range sonar were “sound propagation characteristics (in this case a surface duct), unusual underwater bathymetry, intensive use of multiple sonar units, a constricted channel with limited egress avenues, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars.” (DoC and DoN 2001).

The Navy analyzed the known range of operational, biological, and environmental factors involved in the Bahamas stranding and focused on the interplay of these factors to reduce risks to beaked whales from ASW training activities. Mitigation measures based on the Bahamas investigation are presented in Chapter 11.1. The confluence of these factors do not occur in the MIRC.

Although beaked whales are visually and acoustically detected in areas where sonar use routinely takes place, there has not been a stranding of beaked whales in the MIRC associated with the 30-year use history of the present sonar systems.

This history would suggest that the simple exposure of beaked whales to sonar is not enough to cause beaked whales to strand. Brownell et al (2004) suggested that the high number of beaked whale strandings in Japan between 1980 and 2004 may be related to Navy sonar use in those waters given the presence of U.S. Naval Bases and exercises off Japan. The Center for Naval Analysis compiled the history of naval exercises taking place off Japan and found there to be no correlation in time for any of the stranding events presented in Brownell et al (2004). Like the situation in California, there are clearly beaked whales present in the waters off Japan (as evidenced by the strandings) however, there is no correlation in time to strandings and sonar use. Sonar did not causing the strandings provided by Brownell et al. (2004) and more importantly, this suggests sonar use in the presence of beaked whales over two decades has not resulted in strandings related to sonar use.

As suggested by the known presence of beaked whales in waters sonar use has historically taken place, it is likely that beaked whales have been occasionally exposed to sonar during the last 40 years of sonar use in Hawaii, Southern California and the Mariana Islands; and yet there is no indication of any adverse impact on beaked whales from exposure to sonar.

The Navy and NMFS are coordinating on the need for development of a stranding response plan specific to the Mariana Islands. If completed, appropriate information concerning the overall plan will be incorporated herein.

## 6.3 Non-Acoustic Effects

The MIRC Draft EIS/OEIS (2008) concluded that the non-acoustic activities associated with training activities would not have a significant impact on marine mammals, and that non-acoustic effects would not result in the take of MMPA-protected species.

Collisions with commercial or recreational ships and 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., sperm whale).

Accordingly, the Navy has adopted standard operating procedures to reduce the potential for collisions with surfaced marine mammals. These standard operating procedures include: (1) use of lookouts trained to detect all objects on the surface of the water, including marine mammals; (2) reasonable and prudent actions to avoid the close interaction of Navy assets and marine mammals; and (3) maneuvering to keep away from any observed marine mammal. Based on these standard operating procedures, collisions with marine mammals are not expected.

**Ship Collisions**

Collisions with commercial and Navy ships can cause major wounds and may occasionally cause fatalities to sea turtles and cetaceans. 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., sperm whale). In addition, some baleen whales, such as the northern right whale and fin whale swim, slowly and 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, bottlenose and pantropical spotted dolphins-move quickly throughout the water column and are often seen riding the bow wave of large ships. Marine mammal responses to vessels may include avoidance and changes in dive pattern (NRC 2003).

After reviewing historical records and computerized stranding databases for evidence of ship strikes involving baleen and sperm whales, Laist et al. (2001) found that accounts of large whale ship strikes involving motorized boats in the area date back to at least the late 1800s. Ship collisions remained infrequent until the 1950s, after which point they increased. Laist et al. (2001) report that both the number and speed of motorized vessels have increased over time for trans-Atlantic passenger services, which transit through the area. They concluded that most strikes occur over or near the continental shelf, that ship strikes likely have a negligible effect on the status of most whale populations, but that for small populations or segments of populations the impact of ship strikes may be significant.

Although ship strike mortalities may represent a small proportion of whale populations, Laist et al. (2001) also concluded that, when considered in combination with other human-related mortalities in the area (e.g., entanglement in fishing gear), these ship strikes may present a concern for whale populations.

Of 11 species known to be hit by ships, fin whales are struck most frequently; right whales, humpback whales, sperm whales, and gray whales are all hit commonly (Laist et al 2001). In some areas, one-third of all fin whale and right whale strandings appear to involve ship strikes.

Sperm whales spend long periods (typically up to 10 minutes; Jacquet et al. 1998) "rafting" at the surface between deep dives. This could make them exceptionally vulnerable to ship strikes. Berzin (1972) noted that there were "many" reports of sperm whales of different age classes being struck by vessels, including passenger ships and tug boats. There were also instances in which sperm whales approached vessels too closely and were cut by the propellers (NMFS 2006b).

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

- 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.

Navy shipboard lookouts are highly qualified and experienced observers of the marine environment. Their duties require that they report all objects sighted in the water to the Officer of the Deck (e.g., trash, a periscope, marine mammals, sea turtles) and all disturbances (e.g., surface disturbance, discoloration) that may be indicative of a threat to the vessel and its crew. There are personnel serving as lookouts on station at all times (day and night) when a ship or surfaced submarine is moving through the water. Navy lookouts undergo extensive training in order to qualify as a lookout. This training includes on-the-job instruction under the supervision of an experienced lookout, followed by completion of the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects).

The Navy includes marine species awareness training (MSAT) as part of its training for its bridge lookout personnel on ships and submarines. Lookouts are trained how to look for marine species, and report sightings to the Officer of the Deck so that action may be taken to avoid the marine species or adjust the exercise to minimize effects to the species. The MSAT was updated in 2006, and the additional training materials are now included as required training for Navy ship and submarine lookouts. Additionally, all Commanding Officers and Executive Officers of units involved in training exercises are required to undergo MSAT. This training addresses the lookout's role in environmental protection, laws governing the protection of marine species, Navy stewardship commitments, and general observation information to aid in avoiding interactions with marine species.

**Torpedo Guidance Wire**

The potential entanglement impact of Mk 48 torpedo control wires on sea turtles and marine mammals is very low because of the following:

The control wire is very thin (approximately 0.02 inch) and has a relatively low breaking strength. Even with the exception of a chance encounter with the control wire while it was sinking to the sea floor (at an estimated rate of 0.5 ft per second), a marine animal would not be vulnerable to entanglement given the low breaking strength.

The torpedo control wire is held stationary in the water column by drag forces as it is pulled from the torpedo in a relatively straight line until its length becomes sufficient for it to form a catenary droop (DoN 1996). When the wire is released or broken, it is relatively straight and the physical characteristics of the wire prevent it from tangling, unlike the monofilament fishing lines and polypropylene ropes identified in the entanglement literature (DoN 1996). The Navy therefore believes the potential for any harm or harassment to these species is extremely low.

ASW is a primary warfare area for Navy patrol ships (surface and submarines), aircraft, and ASW helicopters. ASW aircrews must practice using sensors, including electro-optical devices, radar, magnetic anomaly detectors, sonar (including helicopter dipping sonar and both active and passive sonobuoys) in both the deep and shallow water environment. The training events being analyzed are not new and have taken place in the MIRC over the past 40 years, and with no significant changes in the equipment being used in the last 30 years. Although there may be many hours of active ASW sonar events, the actual "pings" of the sonar signal may only occur several times a minute, as it is necessary for the ASW operators to listen for the return echo of the sonar ping. As a result of scientific advances in acoustic exposure effects analysis modeling on marine mammals, the extent of acoustic exposure on marine mammals can be estimated.

**Torpedo Flex Hoses**

Improved flex hoses or strong flex hoses will be expended during torpedo exercises. DoN (1996) analyzed the potential for the flex hoses to affect sea turtles. This analysis concluded that the potential entanglement effects to marine animals will be insignificant for reasons similar to those stated for the potential entanglement effects of control wires:

- Due to its weight, the flex hoses will rapidly sing to the bottom upon release. With the exception of a chance encounter with the flex hose while it was sinking to the sea floor, a marine animal would be vulnerable to entanglement only if its diving and feeding patterns placed it in contact with the bottom.
- Due to its stiffness, the 250-ft-long flex hose will not form loops that could entangle marine animals.

**Parachutes**

Aircraft-launched sonobuoys, torpedoes, and EMATTs deploy nylon parachutes of varying sizes. At water impact, the parachute assembly is expended, and it sinks away from the exercise sonobuoy or torpedo. The parachute assembly will potentially be at the surface for a short time before sinking to the sea floor. Entanglement and the eventual drowning of a sea turtle in a parachute assembly will be unlikely, since the parachute will have to land directly on an animal, or an animal will have to swim into it before it sinks. The potential for a sea turtle to encounter an expended parachute is extremely low, given the generally low probability of a sea turtle being in the immediate location of deployment, especially given the mitigation measures outlined in Chapter 11.

All of the material is negatively buoyant and will sink to the ocean floor. Many of the components are metallic and will sink rapidly. The expended material will accumulate on the ocean floor and will be covered by sediments over time, thereby remaining on the ocean floor, reducing the potential for entanglement. This accrual of material is not expected to cause an increased potential for sea turtle entanglement. If bottom currents are present, the canopy may billow (bulge) and pose an entanglement threat to marine animals with bottom-feeding habits; however, the probability of a sea turtle encountering a parachute assembly and the potential for accidental entanglement in the canopy or suspension lines is considered to be unlikely.

The overall possibility of marine mammals ingesting parachute fabric or becoming entangled in cable assemblies is very remote.

**Entanglement**

Marine mammals become entangled in abandoned fishing gear and cannot submerge to feed or surface to breathe; they may lose a limb or attract predators with their struggling. Debris, such as sonobuoy floats and parachutes, torpedo parachutes, and missile and target components that float may be encountered by marine mammals in the waters of the MIRC. Entanglement in military-related debris was not cited as a source of injury or mortality for any marine mammals recorded in a large marine mammal and sea turtle stranding database for Californian waters. That is most likely attributable to the relatively low density of military debris that remains on or near the sea surface where it might be encountered by a marine mammal. Parachute and cable assemblies used to facilitate target recovery are collected in conjunction with the target during normal training. Sonobuoys and flares sink along with the attached parachutes. Range scrap/debris and munition constituents will not likely adversely affect marine mammal species in the action area.

**Expendable Mobile Acoustic Training Target (EMATT)**

EMATTs are approximately 5 by 36 in (12 by 91 cm) and weigh approximately 10 kg (21 lb). EMATTs are much smaller than sonobuoys and ADCs. EMATTs, their batteries, parachutes, and other components will scuttle and sink to the ocean floor throughout the MIRC and will be covered by sediments over time. In addition, the small amount of expended material will be spread over a relatively large area. Due to the small size and low density of the materials, these components are not expected to float at the water surface or remain suspended within the water column. Over time, the amount of materials will accumulate on the ocean floor, but due to ocean currents, the materials will not likely settle in the same vicinity.

**Falling Debris**

Marine mammals are widely dispersed in the MIRC therefore, there is an extremely low probability of injury to a marine mammal from falling debris and shock waves from inert munitions and target impacts on the water surface.

## 6.4 Marine Mammal Mitigation Measures Related To Acoustic Effects

Effective training in the MIRC dictates that ship, submarine, and aircraft participants utilize their sensors and train with their weapons to their optimum capabilities as required by the mission. The Navy recognizes that such use has the potential to cause behavioral disruption of some marine mammal species in the vicinity of an exercise. As part of their standard operating procedures, the Navy has developed mitigation measures that would be implemented to protect marine mammals and ESA listed species during ASW training. These mitigation measures include the establishment of a safety zone and procedures to power down or shut off sonar if animals are detected within the safety zone and are a part of the No-Action Alternative. For a detailed list of mitigation measures, Chapter 11. During ASW events, Navy ships always have two, although usually more, personnel on watch serving as lookouts. In addition to the qualified lookouts, the bridge team, at a minimum, also includes an Officer of the Deck and one Junior Officer of the Deck whose responsibilities also include observing the waters in the vicinity of the ship. At night, personnel engaged in ASW events may also employ the use of night vision goggles and infrared detectors, as appropriate, which can also aid in the detection of marine mammals. Passive acoustic detection of vocalizing marine mammals is also used to alert bridge lookouts to the potential presence of marine mammals in the vicinity. Navy lookouts undergo extensive training. This training includes on-the-job instruction under the supervision of an experienced lookout, followed by completion of the Personal Qualification Standard program. The Navy includes Marine Species Awareness Training (MSAT) for its bridge lookout personnel on ships and submarines as required training for Navy lookouts. This training addresses the lookout's role in environmental protection, laws governing the protection of marine species, Navy stewardship commitments, and general observation information to aid in avoiding interactions with marine species.

Operating procedures are implemented to maximize the ability of personnel to recognize instances when marine mammals are close aboard and avoid adverse effects. These procedures include measures such as decreasing the source level and then shutting down active tactical sonar training when marine mammals are encountered in the vicinity of a training event. Although these mitigation measures are standard operating procedures, their use is also reinforced through promulgation of an Environmental Annex to the Operational Order for an exercise. Sonar operators on ships, submarines, and aircraft utilize both passive and active sonar detection indicators of marine mammals as a measure of estimating when marine mammals are close. When marine mammals are detected in close vicinity, all ships, submarines, and aircraft engaged in ASW would reduce MFA sonar power levels in accordance with specific guidelines developed for each type of training event.

## 6.5 Cetacean Stranding Events

The Navy is very concerned about and thoroughly investigates each stranding potentially associated with Navy sonar use to better understand these interactions. Strandings can be a single animal or several to hundreds. An event where animals are found out of their normal habitat is considered a stranding even though animals do not necessarily end up beaching (such as the July 2004 Hanalei Mass Stranding Event; Southall et al. 2006). Several hypotheses have been given for the mass strandings which include the impact of shallow beach slopes on odontocete sonar, disease or parasites, geomagnetic anomalies that affect navigation, following a food source in close to shore, avoiding predators, social interactions that cause other cetaceans to come to the aid of stranded animals, and human actions. Generally, inshore species do not strand in large numbers but generally just as a single animal. This may be due to their familiarity with the coastal area whereas pelagic species that are unfamiliar with obstructions or sea bottom tend to strand more often in larger numbers (Woodings 1995). The Navy has studied several stranding events in detail that may have occurred in association with Navy sonar activities. To better understand the causal factors in stranding events that may be associated with Navy sonar activities, the main factors, including bathymetry (i.e. steep drop offs), narrow channels (less than 35 nm), environmental conditions (e.g., surface ducting), and multiple sonar ships (Section on Stranding Events Associated with Navy Sonar) were compared between the different stranding events.

In a review of 70 reports of mass stranding events between 1960 and 2006, 48 (68 percent) involved beaked whales, three (4 percent) involved dolphins, and 14 (20 percent) involved whale species. Cuvier's beaked whales were involved in the greatest number of these events (48 or 68 percent), followed by sperm whales (7 or 10 percent), and Blainville's and Gervais' beaked whales (4 each or 6 percent). Naval training activities that might have involved tactical sonars are reported to have coincided with 9 (13 percent) or 10 (14 percent) of those stranding events. Between the mid-1980s and 2003 (the period reported by the IWC 2007), the Navy identified reports of 44 mass cetacean stranding events of which at least seven have been correlated with naval training activities that were using MFA sonar.

### 6.5.1 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 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 the 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).

#### 6.5.1.1 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 amended the MMPA to establish the Marine Mammal Health and Stranding Response Program (MMHSRP) under authority of the DOC, NMFS. 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 the NMFS, the National Marine Mammal Stranding Network (NMMSN) 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 141 organizations are authorized by NMFS to respond to marine mammal strandings (NMFS 2007). Through a National Coordinator and six regional coordinators, NMFS authorizes and oversees stranding response activities and provides specialized training for the network.

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).

#### 6.5.1.2 Stranding Data

Stranding events, though unfortunate, can be useful to scientists and resource managers because they can provide information that is not accessible at sea or through any other means. Necropsies are useful in attempting to assess a reason for the stranding, and are performed on stranded animals when the situation allows. Stranded animals have provided us with the opportunity to gain insight into the lives of marine mammals such as their natural history, seasonal distribution, population health, reproductive biology, environmental contaminant levels, types of interactions with humans, and the prevalence of disease and parasites. The only existing information on some cetacean species has been discovered from stranding events (NMFS 2007c).

Currently the government agency that is responsible for responding to strandings is the MMHSRP within NMFS. The NMMSN, which is one part of the more comprehensive MMHSRP, is made up of smaller organizations partnered with NMFS to investigate marine mammal strandings. These stranding networks are established in all coastal states and consist of professionals and volunteers from nonprofit organizations, aquaria, universities, and state and local governments who are trained in stranding response. NMFS authorizes, coordinates, and participates in response activities and personnel training (NMFS 2007c). NMFS oversees stranding response via a National Coordinator and a regional coordinator in each of the NMFS regions. Stranding reporting and response efforts over time have been inconsistent and have been increasing over the past three decades, making any trends hard to interpret (NMFS 2007d). Over the past decade (1990–2000), approximately 40,000 stranded marine mammals have been reported by the regional stranding networks, averaging 3,600 strandings reported per year (NMFS 2007f). The highest number of strandings was reported between the years 1992–1993 and 1997–1998, with a peak in the number of reported strandings in 1998 totaling 5,708 (NMFS 2007f; 2007f). These have since been determined to have been El Niño years, which for a variety of reasons can have a drastic effect on marine mammals (see below). Reporting effort has been more consistent since 1994. Between 1994 and 1998 a total of 19,130 strandings were reported, with an average of 3,826 per year (NMFS 2007d). The composition of animals involved in strandings varied by region.

Peak years for cetacean strandings were in 1994 and 1999, and can be attributed to two UMEs. In 1994, 220 bottlenose dolphins stranded off Texas, which represented almost double the annual average (NMFS 2007f). It has been determined that the probable cause for these strandings was a morbillivirus outbreak. Then in 1999, 223 harbor porpoises stranded from Maine to North Carolina, representing a four-fold increase over the annual average (NMFS 2007f). The most likely cause for these strandings is interspecific aggression due to sea surface temperatures and a shift in prey species in the Mid-Atlantic (NMFS 2007f).

Table 6.4 presents the numbers and composition of reported strandings during the five year period 2001-2005.

**Table 6-4. Summary of the Number of Cetacean and Pinniped Strandings by Region from 2001-2005**

| Region | Number of Cetaceans | Number of Pinnipeds |
|---|---|---|
| Pacific | 421 | 357 |
| Southeast | 3,549 | 55 |
| Northeast | 2,144 | 4,744 |
| Southwest | 49 | 230 |
| Northwest | 321 | 1,984 |
| Alaska | 152 | 119 |
| **Five-Year Totals** | **6,636** | **7,489** |

Source: National Marine Fisheries Service, 2007d, 2008

### 6.5.2 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

#### 6.5.2.1 Causes of Natural Stranding

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 2007a). 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 although exposure can also occur through inhalation and skin contact (Van Dolah 2005).

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 (microscopic marine plants) 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; Bejarano et al. 2007; Bargu et al. 2008; Goldstein et al. 2008). Other algal toxins associated with marine mammal strandings include saxitoxins and ciguatoxins and are summarized by Van Dolah (2005). These diatoms are widespread and can be found on the east and west coasts of the United States as well as in the Gulf of Mexico (NMFS 2007n). Domoic acid has also been known to have serious effects on public health and a variety of marine species (NMFS 2007n). Since 1998, domoic acid has been identified as the cause of mass mortalities of seabirds and marine mammals off the coast of California, and whale deaths off Georges Bank and it was suspected in mass mortalities as early as 1992 otherwise listed as “unknown neurologic disorder” (NMFS 2007n). Other algal toxins associated with marine mammal strandings include saxitoxins and ciguatoxins and are summarized by Van Dolah (2005).

In 2004, between March 10 and April 13, 107 bottlenose dolphins were found dead and stranded on the Florida Panhandle, along with hundreds of dead fish and marine invertebrates (NMFS 2007o). This event was declared a UME. Analyses of the dolphins found brevetoxins at high levels within the dolphin stomach contents, and at variable levels within their tissues (NMFS 2007o). Low levels of domoic acid were also detected in some of the dolphins, and a diatom that produces domoic acid (*Pseudo-nitzschia* *delicatissima*) was present in low to moderate levels in water samples (NMFS 2007o). In the Gulf of Mexico, two other UMEs associated with red tide involving bottlenose dolphins occurred previously in 1996, and between 1999 and 2000 (NMFS 2005h).

Insufficient information is available to determine how, or at what levels and in what combinations, environmental contaminants may affect cetaceans (Marine Mammal Commission 2003). There is growing evidence that high contaminant burdens are associated with several physiological abnormalities, including skeletal deformations, developmental effects, reproductive and immunological disorders, and hormonal alterations (Reijnders and Aguilar 2002). It is possible that anthropogenic chemical contaminants initially cause immunosuppression, rendering whales susceptible to opportunistic bacterial, viral, and parasitic infection (De Swart et al. 1995).

### Weather Events and Climate Influences on Stranding

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).

**Predation**

Many species of marine mammal serve as prey to other animals and forms of marine life, including sharks and even other marine mammals. Predation from sharks is considered to be a contributing factor in the decline of the Hawaiian monk seal (Geraci et al. 1999). A stranded marine mammal will sometimes show signs of interactions with predators such as bites, teeth marks, and other injuries, which occasionally are severe enough to have been the primary cause of injury, death, and stranding.

#### 6.5.2.2 Human Influenced (Anthropogenic) Causes

Over the past few decades there has been an increase in marine mammal mortalities believed to be caused by a variety of human activities (Geraci et al. 1999; NMFS 2007p), such as gunshots, ship strikes (NOAA 2006e; Nelson et al. 2007), and other trauma and mutilations.

- Gunshot injuries are the most common man-made cause of strandings in sea lions and seals on the U.S. West Coast (NMFS 2007d).
- Every year a few northern right whales are killed within shipping lanes along the U.S. Atlantic coast, which may be enough to jeopardize stock recovery (Geraci et al. 1999).
- In 1998, two bottlenose dolphins and a calf were killed by vessel strikes in the Gulf of Mexico (NMFS 2005h).

- In 1999 there was one report of a stranded false killer whale on the Alabama coast that was classified as likely caused by fishery interactions or other human interaction due to limb mutilation (the fins and flukes of the animal had been amputated) (NMFS 2005e).
- 1,377 bottlenose dolphins were found stranded in the Gulf of Mexico from 1999 through 2003; 73 animals (11 percent) showed evidence of human interactions as the cause of death (e.g., gear entanglement, mutilations, gunshot wounds) (NMFS 2005h).

Data from strandings in which there was evidence of human interaction is available for the years 1999–2000. Table 6-5 provides the number of stranded marine mammals (cetaceans and pinnipeds) during this period that displayed evidence of human interactions (taken from NMFS 2007f). (Stranding data for the California region for the year 1999 is unavailable; therefore numbers are for stranded animals in 2000 only. Similarly, data is unavailable for the year 2000 in the Alaska region; numbers provided represent strandings for 1999 only.)

**Table 6-5. Summary of Marine Mammal Strandings by Cause for Each Region from 1999-2000**

| Interaction | Southeast | Northeast | Northwest | California | Alaska |
|---|---|---|---|---|---|
| Fisheries | 89 | 75 | 10 | 30 | 16 |
| Vessel Strike | 9 | 6 | 1 | 8 | 2 |
| Gun Shot | 6 | 6 | 12 | 41 | 4 |
| Blunt Trauma | - | 1 | - | - | - |
| Mutilation | 4 | 17 | - | - | - |
| Plastic Ingestion | 1 | 3 | - | - | - |
| Power Plant Entrapment | 1 | 11 | - | 23 | - |
| Harassment | - | 9 | - | - | - |
| Arrow Wound | - | - | 1 | - | - |
| Harpoon Wound | - | - | 2 | - | - |
| Hit by Car | - | - | 1 | 1 | - |
| Hit by Train | - | - | 1 | - | - |
| Marine Debris Entanglement | - | - | 1 | 3 | - |
| **Total** | **110** | **128** | **27** | **106** | **22** |

Source: National Marine Fisheries Service, 2007f

### Fisheries Interaction: By-Catch, Directed Catch, and Entanglement

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 procedures 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). Eighty-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 fishing gear is a major cause of death or severe injury among the 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). 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, 927 harbor porpoises were reported stranded from Maine to North Carolina, many of which had cuts and body damage suggestive of net entanglement (NMFS 2005e). 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 2005e). In 2000, one stranded porpoise was found with monofilament line wrapped around its body (NMFS 2005e). In addition, in 2003, nine stranded harbor porpoises were attributed to fishery interactions, with an additional three mutilated animals (NMFS 2005e). An estimated 78 baleen whales were killed annually in the offshore southern California/Oregon drift gillnet fishery during the 1980s (Heyning and Lewis 1990). From 1998-2005, based on observer records, five fin whales (CA/OR/WA stock), 19 humpback whales (ENP stock), and six sperm whales (CA/OR/WA stock) were either seriously injured or killed in fisheries off the mainland west coast of the U.S. (California Marine Mammal Stranding Network Database 2006).

### Ship Strike

Ship 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). In assessing records in which vessel speed was known, Laist et al. (2001) found a direct relationship between the occurrence of a whale strike and the speed of the vessel involved in the collision. The authors concluded that most deaths occurred when a vessel was traveling in excess of 13 knots.

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.

Navy ship traffic is a small fraction of the overall U.S. commercial and fishing vessel traffic. While U.S. Navy vessel movements may contribute to the ship strike threat, given the lookout and mitigation measures adopted by the Navy, probability of vessel strikes is greatly reduced. Furthermore, actions to avoid close interaction of Navy 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 lookouts 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.

### 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 2007g). 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 2005d). In 1987 a pair of latex examination gloves was retrieved from the stomach of a stranded dwarf sperm whale (NMFS 2005d). 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 et al. 2003; 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 (dichloro diphyenyl trichloroethane), are both considered persistent organic pollutants that are currently banned in the United States for their harmful effects in wildlife and humans (NMFS, 2007c). Despite having been banned for decades, the levels of these compounds are still high in marine mammal tissue samples taken along U.S. coasts (Hickie et al. 2007; Krahn et al. 2007; NMFS 2007c). 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 2007c).

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). However, 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).

Navy ship transit between ports and exercise locations has the potential for release of small amounts of pollutant discharges into the water column. Navy ships 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

Anthropogenic sound that could affect ambient sound arises from the following general types of activities in and near the sea, any combination of which, can contribute to the total sound at any one place and time. These sounds include: transportation; dredging; construction; oil, gas, and mineral exploration in offshore areas; geophysical seismic and/or mapping surveys; commercial and military sonar; explosions; and ocean research activities (Richardson et al. 1995a).

Mechanical noise from commercial fishing vessels, cruise ships, cargo transports, recreational boats, and aircraft, all contribute sound into the ocean (NRC 2003, 2006). Mechanical noise from Navy ships, especially those engaged in ASW, is very quiet in comparison to civilian vessels of similar or larger size. This general feature is also enhanced by the use of additional quieting technologies as a means of limiting passive detection by opposing submarines.

Several investigators have argued that anthropogenic sources of noise have increased ambient sound levels in the ocean over the last 50 years (NRC 1994, 2000, 2003, 2005; Richardson et al. 1995a; 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 (National Research Council, 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 sound spectrum expected in the deep ocean. Shipping, seismic activity, and weather are the primary causes of deep-water ambient sound. The ambient sound 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 sound 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 sound 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 sound include distant shipping and industrial activities, wind and waves, marine animals (Urick 1983). At any given time and place, the ambient sound is a mixture of all of these sound 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 than 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 to affect their ability to communicate. Acoustic devices have also been used in fisheries nets to prevent marine mammal entanglement 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, International Council for the Exploration of the Sea [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 (DonN 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 sound 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. 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, or swim away from low flying aircraft. Due to the transient nature of sounds from aircraft involved in at-sea training, such sounds would not likely cause physical effects.

Sound emitted from large vessels, particularly in the course of transit, is the principal source of sound 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 sound emitted by a large vessel depending on its travel speed. Military vessels underway or involved in naval training activities or exercises, also introduce anthropogenic sound 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 to 337 meters 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. As noted previously, Navy ships in general and in particular those engaged in ASW, are designed to be very quiet as a means of limiting passive detection by opposing submarines.

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 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 PTS 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.

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 km away (Ross 1976 in Polefka 2004). Navy 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 Navy 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 Navy 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.

### *Commercial and Research Sonar*

Almost all vessels at sea are equipped with active sonar for use in measuring the depth of the water: a fathometer. In addition, many vessels engaged in commercial or recreational fishing also use active sonar commonly referred to as "fish-finders." Both types of sonar tend to be higher in frequency and lower in power as compared to the hull mounted MFA or HFA sonar used during Navy training; however, there are many more of these sonars, and they are in use much more often and in more locations than Navy sonars.

Seismic sound sources employed include powerful multibeam and sidescan sonars that are generally used for mapping the ocean floor and include both mid-frequency and high-frequency systems. During mapping surveys, these sonars are run continuously, sweeping the large areas of ocean to accurately chart the complex bathymetry present on the ocean floor.

### *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 Navy: 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 MFA/HFA 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 Navy MFA 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.

In the Caribbean, sperm whales were observed to interrupt their activities by stopping echolocation and leaving the area in the presence of underwater sounds surmised (since they did not observe any vessels) to have originated from submarines using sonar (Watkins and Schevill 1975; Watkins et al. 1985). The authors did not report receive levels from these exposures, and also got a similar reaction from artificial noise they generated by banging on their boat hull. It was unclear if the sperm whales were reacting to the sonar signal itself or to a potentially new unknown sound in general.

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.

#### 6.5.2.3 Beaked Whale Stranding Events

Recent beaked whale strandings have prompted inquiry into the relationship between high-amplitude continuous-type sound and the cause of those strandings. For example, in the stranding in the Bahamas in 2000, the Navy MFA sonar was identified as the only contributory cause that could have lead to the stranding. The Bahamas exercise entailed multiple ships using MFA sonar during transit of a long constricted channel. The Navy participated in an extensive investigation of the stranding with the NMFS. The "Joint Interim Report, Bahamas Marine Mammal Stranding Event of 15-16 March 2000" concluded that the variables to be considered in managing future risk from tactical mid-range sonar were "sound propagation characteristics (in this case a surface duct), unusual underwater bathymetry, intensive use of multiple sonar units, a constricted channel with limited egress avenues, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars." (DOC and DoN 2001).

The Navy analyzed the known range of operational, biological, and environmental factors involved in the Bahamas stranding and focused on the interplay of these factors to reduce risks to beaked whales from ASW training. The confluence of these factors do not occur in the Mariana Islands although surface ducts may be present, there are rapid changes in bathymetry over relatively short distances, and beaked whales are present where MFA sonar is used. Although beaked whales are visually and acoustically detected in areas where sonar use routinely takes place, there has not been a stranding of beaked whales in the Mariana Islands associated with the approximately 30 year use history of the present sonar systems.

This history would suggest that the simple exposure of beaked whales to sonar is not enough to cause beaked whales to strand. Brownell et al. (2004) have suggested that the high number of beaked whale strandings in Japan between 1980 and 2004 may be related to Navy sonar use in those waters given the presence of U.S. Naval Bases and exercises off Japan. The Center for Naval Analysis compiled the history of naval exercises taking place off Japan and found there to be no correlation in time for any of the stranding events presented in Brownell et al. (2004). Like the situation in Hawaii, there are clearly beaked whales present in the waters off Japan (as evidenced by the strandings); however, there is no correlation in time to strandings and sonar use. Sonar did not cause the strandings identified by Brownell et al. (2004), and more importantly, this suggests sonar use in the presence of beaked whales over two decades has not resulted in strandings related to sonar use.

In the MIRC, there have been no detected beaked whales strandings associated with the use of MFA/HFA sonar. While the absence of evidence does not prove there have been no affects on beaked whales, approximately 30 years of history with no evidence of any impacts or strandings would seem to indicate that problems encountered in locations far from MIRC involving beaked whales are location and context specific and do not apply in Marianas waters.

It has been suggested that there is an absence of strandings and floating dead marine mammals related to sonar use because (it is argued) dead marine mammals will not float, are eaten by sharks, are carried out to sea, or end up on remote shorelines and are never discovered. Typically, dead marine mammals will initially sink, then refloat, and finally sink again after substantial deterioration (Spitz 1993). The timeline of this process will vary depending primarily upon water temperature and water depth, as well as other factors such as gut content, amount of body fat, etc., that affect bacterial and other decomposition processes. Generally, refloating occurs within a few days while final sinking may require, for a large whale, several weeks.

### 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 training activities 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 misquoted.

The discussion below centers on those worldwide stranding events that may have some association with naval training activities, and global strandings that the Navy feels are either inconclusive or can not be associated with naval training.

**Naval Association to Strandings**

In the following sections, specific stranding events that have been putatively linked to potential sonar training activities 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 North Atlantic Treaty Organization (NATO) exercises or events where Navy presence was limited (Greece, Portugal, Spain). One of the five events involved only Navy ships (Bahamas).

Beaked whale stranding events associated with potential naval training.

| | | |
|---|---|---|
| 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) |

The following sections provide details and analysis concerning the five events noted above in addition to other events where MFA sonar use has been alleged to be potentially causal and/or a factor contributing to the stranding event.

<u>Greece Beaked Whale Mass Stranding (May 12 – 13, 1996)</u>

*Description*

Twelve Cuvier's beaked whales (*Ziphius cavirostris*) were stranded along a 38.2-kilometer strand 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 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*

Necropsies of eight of the animals were performed, but were limited to basic external examinations and the sampling of stomach contents. No ears or organs were collected, and no histological samples were preserved because of problems related to permits, lack of trained specialists, and lack of facilities and means (ICES 2005a).

- At least 12 of the 14 animals stranded alive in an atypical way (ICES 2005a). The spread of strandings were also atypical in location and time, as mass-strandings usually occur at the same place and at the same time (Frantzis 1998).
- No apparent abnormalities or wounds were found (Frantzis 2004).
- Examination of photos of the animals revealed that the eyes of at least four of the individuals were bleeding. Photos were taken soon after their death (Frantzis 2004).
- Stomach contents contained the flesh of cephalopods, indicating that feeding had recently taken place (Frantzis 1998).

- No unusual environmental events occurred before or during the stranding (Frantzis, 2004).

*Conclusions*

All available information regarding the conditions associated with this stranding were compiled, and many potential causes were examined including major pollution events, important tectonic activity, unusual physical or meteorological events, magnetic anomalies, epizootics, and conventional military activities (ICES 2005a). However, none of these potential causes coincided in time with the mass stranding, or could explain its characteristics (ICES 2005a). The robust condition of the animals, plus the recent stomach contents, is not consistent with pathogenic causes (Frantzis 2004). In addition, environmental causes can be ruled out as there were no unusual environmental circumstances or events before or during this time period (Frantzis 2004).

It was determined that because of the rarity of this mass stranding of Cuvier's beaked whales in the Kyparissiakos Gulf (first one in history), the probability for the two events (the military exercises and the strandings) to coincide in time and location, while being independent of each other, was extremely low (Frantzis 1998).

Because full necropsies had not been conducted, and no abnormalities were noted, the cause of the strandings cannot be precisely determined (Cox et al. 2006). The analysis of this stranding event provided support for, but no clear evidence for, the cause-and-effect relationship of sonar training activities and beaked whale strandings (Cox et al. 2006).

<u>2000 Bahamas Marine Mammal Mass Stranding (March 15-16, 2000)</u>

*Description*

On March 15-16, 2000, seventeen marine mammals comprised of four different species (Cuvier's beaked whales, Blainville's beaked whales, Minke whales, and one spotted dolphin) stranded along the Northeast and Northwest Providence Channels of the Bahamas Islands (NMFS 2001b; DoN and DoC 2001). The strandings occurred over a 36-hour period and coincided with Navy use of MFAsonar 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-53 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-53) to 223 dB SPL (AN/SQS-56). The center frequency of pings was 3.3 kHz and 6.8 to 8.2 kHz, respectively.

Because of the unusual nature and situation surrounding these strandings, a comprehensive investigation into every possible cause was quickly launched (DoN and DOC, 2001).

Strandings were first reported at the southern end of the channels, and proceeded northwest throughout March 15, 2000. It is probable that all of the strandings occurred on March 15, even though some of the animals were not found or reported until March 16. Seven of the animals died, while ten animals were returned to the water alive; however, it is unknown if these animals survived or died at sea at a later time. (DoN and DoC 2001)

The animals that are known to have died include five Cuvier's beaked whales, one Blainville's beaked whale, and the single spotted dolphin (DoN and DoC 2001). Six necropsies were performed and three of the six necropsied whales (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. Results from the spotted dolphin necropsy revealed that the animal died with systemic debilitation disease, and is considered unrelated to the rest of the mass stranding (DoN and DoC 2001).

Based on necropsies performed on the other five beaked whales, it was preliminarily determined that they had experienced some sort of acoustic or impulse trauma which led to their stranding and ultimate demise

(DoN and DoC 2001). Detailed microscopic tissue studies followed in order to determine the source of the acoustic trauma and the mechanism by which trauma was caused.

- All five necropsied beaked whales were in good body condition, showing no signs of infection, disease, ship strike, blunt trauma, or fishery related injuries, and three still had food remains in their stomachs (DoN and DoC 2001).
- Auditory structural damage was discovered in four of the whales, specifically bloody effusions or hemorrhaging around the ears (DoN and DoC 2001).
- Bilateral intracochlear and unilateral temporal region subarachnoid hemorrhage with blood clots in the lateral ventricles were found in two of the whales (DoN and DoC 2001).
- Three of the whales had small hemorrhages in their acoustic fats (located along the jaw and in the melon) (DoN and DoC 2001).
- Passive acoustic monitor recordings within the area during the time of the stranding showed no signs of an explosion or other geological event such as an earthquake (DoN and DoC 2001).
- The beaked whales showed signs of overheating, physiological shock, and cardiovascular collapse, all of which commonly result in death following a stranding (DoN and DoC 2001).

*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 2005b, 2005c).

### 2000 Madeira Island, Portugal Beaked Whale Strandings (May 10 – 14, 2000)

*Description*

From May 10–14, 2000, three Cuvier’s beaked whales were found stranded on two islands in the Madeira archipelago, Portugal (Cox et al. 2006)—two on Porto Santo Island, and one on the northeast coast of Madeira Island (Freitas 2004). A fourth animal was reported floating in the Madeiran waters by fisherman, but did not come ashore (Woods Hole Oceanographic Institution 2005).

Joint NATO amphibious training peacekeeping exercises involving participants from 17 countries took place in Portugal during May 2–15, 2000. The NATO exercises were conducted across an area that stretched from the Island of Madeira to the Gulf of Gascony, and was named “Linked Seas 2000.” It involved Greek, British, Spanish, Portuguese, French, Romanian, and U.S. forces, and included 80 warships and several thousand men landing on the beaches (U.S. Army Corps of Engineers 2001). The NATO exercises occurred concurrently with this atypical mass stranding of beaked whales (Freitas 2004).

The bodies of the three stranded whales were examined post mortem (Woods Hole Oceanographic Institution 2005). Two heads were taken to be examined, one intact and the other partially seared from a fire started by locals during an attempt to dispose of the corpse (Woods Hole Oceanographic Institution

2005). Only one of the stranded whales was fresh enough (24 hours after stranding) to be necropsied (Cox et al. 2006).

- Results from the necropsy revealed evidence of hemorrhage and congestion in the right lung and both kidneys (Cox et al. 2006).
- There was also evidence of intercochlear and intracranial hemorrhage similar to that which was observed in the whales that stranded in the Bahamas event (Cox et al. 2006).
- There were no signs of blunt trauma, and no major fractures (Woods Hole Oceanographic Institution, 2005).
- The cranial sinuses and airways were found to be quite clear with little or no fluid deposition, which may indicate good preservation of tissues (Woods Hole Oceanographic Institution 2005).

*Conclusions*

Several observations on the Madeira stranded beaked whales, such as the pattern of injury to the auditory system, are the same as those observed in the Bahamas strandings. Blood in and around the eyes, kidney lesions, pleural hemorrhages, and congestion in the lungs are particularly consistent with the pathologies from the whales stranded in the Bahamas, and are consistent with stress and pressure related trauma. The similarities in pathology and stranding patterns between these two events suggest that a similar pressure event may have precipitated or contributed to the strandings at both sites (Woods Hole Oceanographic Institution 2005)

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).

- Exercises were conducted in areas of at least 547 fathoms depth near a shoreline where there is a rapid change in bathymetry on the order of 547 to 3,281 fathoms occurring a cross a relatively short horizontal distance (Freitas 2004).
- Multiple ships were operating around Madeira. It is not known if MFA sonar was used, and the specifics of the sound sources used the Linked Seas 2000 exercises, and their propagation characteristics, are unknown (Cox et al. 2006, Freitas 2004).
- Exercises took place in an area surrounded by landmasses separated by less than 35 nm and at least 10 nm in length, or in an embayment. Exercises involving multiple ships employing MFA near land may produce sound directed towards a channel or embayment that may cut off the lines of egress for marine mammals (Freitas 2004).

2002 Canary Islands Beaked Whale Mass Stranding (24 September 2002)

*Description*

The southeastern area within the Canary Islands is well known for aggregations of beaked whales due to its ocean depths of greater than 547 fathoms within a few hundred meters of the coastline (Fernandez et al. 2005). On September 24, 2002, 14 beaked whales were found stranded on Fuerteventura and Lanzaote Islands in the Canary Islands (ICES 2005a). Seven whales died, while the remaining seven live whales were returned to deeper waters (Fernandez et al. 2005). Four beaked whales were found stranded dead over the next 3 days either on the coast or floating offshore.

These strandings occurred within close proximity of an international naval exercise named Neo-Tapon 2002 that involved numerous surface warships and several submarines. Spanish naval sources indicated that tactical mid-range frequency sonar was utilized during the exercises, but no explosions occurred

(Fernandez et al. 2005). Strandings began about 4 hours after the onset of MFA sonar activity (International Council For Exploration of the Sea 2005a; Fernandez et al. 2005).

*Findings*

Eight Cuvier’s beaked whales, one Blainville’s beaked whale, and one Gervais’ beaked whale were necropsied, six of them within 12 hours of stranding (Fernández et al. 2005).

- No pathogenic bacteria were isolated from the carcasses (Jepson et al. 2003)
- The animals displayed severe vascular congestion and hemorrhage especially around the tissues in the jaw, ears, brain, and kidneys, displaying marked disseminated microvascular hemorrhages associated with widespread fat emboli (Jepson et al. 2003; ICES 2005a).
- Several organs contained intravascular bubbles, although definitive evidence of gas embolism *in vivo* is difficult to determine after death (Jepson et al. 2003).
- The livers of the necropsied animals were the most consistently affected organ, which contained macroscopic gas-filled cavities and had variable degrees of fibrotic encapsulation. In some animals, cavitary lesions had extensively replaced the normal tissue (Jepson et al., 2003).
- Stomachs contained a large amount of fresh and undigested contents, which suggests a rapid onset of disease and death (Fernandez et al. 2005).
- Head and neck lymph nodes were enlarged and congested, and parasites were found in the kidneys of all animals (Fernandez et al. 2005).

*Conclusions*

The association of NATO MFA 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 the 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. Tyack et al. (2006) showed that beaked whales often make rapid ascents from deep dives suggesting that it is unlikely that beaked whales would suffer from decompression sickness. Zimmer and Tyack (2007) speculated that if repetitive shallow dives are used by beaked whales to avoid a predator or a sound source, they could accumulate high levels of nitrogen because they would be above the depth of lung collapse (above about 210 ft) and could lead to decompression sickness. There is no evidence that beaked whales dive in this manner in response to predators or sound sources and other marine mammals such as Antarctic and Galapagos fur seals, and pantropical spotted dolphins make repetitive shallow dives with no apparent decompression sickness (Kooyman and Trillmich 1984; Kooyman et al. 1984; Baird et al. 2001). Preliminary data from Houser (2007) showed no increase in circulating blood nitrogen levels in trained bottlenose dolphins making repetitive dives to 100 m. 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).

### <u>2006 Spain, Gulf of Vera Beaked Whale Mass Stranding (26-27 January 2006)</u>

#### *Description*

The Spanish Cetacean Society reported an atypical mass stranding of four beaked whales that occurred January 26, 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, Standing NATO Response Force Maritime Group Two (five of seven ships including one U.S. ship under NATO Operational Control) had conducted active sonar training against a Spanish submarine within 50 nm of the stranding site.

#### *Findings*

Veterinary pathologists necropsied the two male and two female beaked whales (*Ziphius cavirostris*, family *Ziphiidae*).

*Conclusions*

According to the pathologists, the most likely primary cause of this type of beaked whale mass stranding event is anthropogenic acoustic activities, most probably anti-submarine MFA sonar used during the military naval exercises. However, 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).

- Exercises were conducted in areas of at least 547 fathoms depth near a shoreline where there is a rapid change in bathymetry on the order of 547 to 3,281 fathoms occurring across a relatively short horizontal distance (Freitas 2004).
- Multiple ships (in this instance, five) were operating (in this case, MFA sonar) in the same area over extended periods of time (in this case, 20 hours) in close proximity.
- Exercises took place in an area surrounded by landmasses, or in an embayment. Exercises involving multiple ships employing MFA 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 Navy activity in popular press are presented. As detailed in the individual case study conclusions, the Navy 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.

<u>2003 Washington State USS SHOUP (May 5 2003)</u>

On May 5, 2003 at 8:55 a.m., USS SHOUP got underway from the pier at Naval Station Everett, Washington. USS SHOUP then transited from Everett through Admiralty Inlet to the west side of Whidbey Island, where at 10:30 a.m. it began a training exercise. Use of USS SHOUP’s MFA tactical sonar began at 10:40 a.m. At 2:20 p.m., USS SHOUP entered the Haro Strait at a speed of 18 knots. USS SHOUP terminated active sonar use at 2:38 p.m.

Between May 2 and June 2, 2003, approximately 16 strandings involving 15 harbor porpoise and one Dall’s porpoise 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 Navy (2004b). 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 had been putatively linked to these sonar training activities (NMFS 2005a), the NMFS undertook an analysis of whether sonar caused the strandings of the harbor porpoises.

As a result of the allegations regarding USS SHOUP, NMFS initiated a necropsy study involving 11 of the stranded animals discovered between May 2 and June 2, 2003. Gross examination, histopathology, age determination, blubber analysis, and various other analyses were conducted on each of the carcasses (Norman et al. 2004). The necropsies took place at the National Marine Mammal Laboratory in Seattle.

*Findings*

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 were considered to have moderate to advanced decomposition.

- None of the 11 necropsied harbor porpoise showed signs of acoustic trauma (NMFS 2003).
- One of the animals had fibrinous peritonitis, one had salmonellosis, and another had profound necrotizing pneumonia (Norman et al., 2004).
- Two of the five had perimortem blunt trauma injury with associated broken bones in their heads (NMFS 2003)
- No cause of death could be determined for the remaining six animals, which is consistent with the expected percentage in most marine mammal necropsies from the region (NMFS 2003). 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.

*Conclusions*

The 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 phenomena 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 2003a). 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 23 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 USS 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 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 1 to 3 weeks after USS SHOUP’s May 5 transit of the Haro Strait, making it difficult to causally link the sonar activities of 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 MFA 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 MFA sonar was used by USS SHOUP, the distribution of harbor porpoise strandings by location and with respect to time surrounding the event do not support the suggestion that MFA 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 on Dall's porpoise, orca, and a minke whale also arose in association with this event (see DoN 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, and 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 USS SHOUP's use of sonar. The behavior of the minke whale was the only unusual behavior clearly present on May 5, 2003, however, given the existing information, there was not way to determine 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.

### July 3, 2004, Hanalei Bay, Kauai Stranding Event

The majority of the following information is taken from the NMFS report on the stranding event (Southall et al. 2006) but is inclusive of additional and new information not presented in the NMFS report. 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). The whales were moving fast, but not at maximum speed.

At 6:45 a.m. on July 3, 2004, approximately 25 nm from Hanalei Bay, active sonar was tested briefly prior to the start of an ASW event; this was about 15 minutes before the whales were observed in Hanalei Bay. At the nominal swim speed for melon-headed whales (5 to 6 knots), the whales had to be minimally within 1.5 to 2 nm of Hanalei Bay before the sonar at Pacific Missile Range Facility (PMRF) was activated. 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).

The whales stopped in the southwest portion of the bay grouping tightly with lots of spy hopping and tail slapping. As people went in the water among the whales, spy hopping increased and the pod separated into two groups with individual animals moving between the two clusters (Braun 2005). This continued through most of the day, with the animals slowly moving south and then southeast within the bay (Braun 2005). By about 3:00 p.m. police arrived and kept people from interacting with the animals. The Navy believes that the abnormal behavior by the whales during this time is likely the result of people and boats in the water with the whales rather than the result of sonar activities taking place 25 or more miles off the coast.

At 4:45 p.m. on July 3, 2004, the RIMPAC Battle Watch Captain received a call from an NMFS representative in Honolulu, Hawaii, reporting the sighting of as many as 200 melon-headed whales in Hanalei Bay. At 4:47 p.m., out of caution, the Battle Watch Captain directed all ships in the area to cease all active sonar transmissions.

An NMFS representative arrived at Hanalei Bay at 7:20 p.m. on July 3, 2004, and observed a tight single pod 75 yards from the southeast side of the bay (Braun 2005). The pod was circling in a tight group and there was frequent tail slapping and minimal spy hopping. No predators were observed in the bay and no animals were reported as having fresh injuries. Occasionally one or two sub-adult sized animals broke from the tight pod and came nearer the shore to apparently chase fish and be in the shore break (Braun 2005). The pod stayed in the bay through the night of July 3, 2004.

On July 4, 2004, a 700–800-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, by about 11:30 a.m. on July 4, 2004, the pod was coaxed out of the bay (Braun, 2005).

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 9:00 a.m. and 10:00 a.m. near the Hanalei pier. NMFS collected the carcass and had it shipped to California for necropsy, tissue collection, and diagnostic imaging. Preliminary findings indicated the cause of death was starvation (Farris 2004) and this was later confirmed upon completion of the NMFS stranding report (Southall et al. 2006).

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 MFA 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 to reach Hanalei Bay, the animals would have had to swim around the island of Kauai at a speed of 1.4-4.0 m/s for between 6.5 to 17.5 hours after having possibly heard sonar off the west coast of Oahu and/or the channel between Kauai and Oahu on July 2, to reach Hanalei Bay by 7:00 a.m. on July 3. Sonar transmissions began on July 3, 25 nm to the north of Hanalei Bay as part of an ASW event that started at 6:45 a.m. and lasted until 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 for intervals during the day when the vessels were generally pointed toward Kauai.

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 (Mobley et al. 2007). One of the first observations of the whales entering the bay reported the pod came into the bay in a line “as if chasing fish” (Braun 2005). 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 by the Navy is based on a number of factors:

1. The speculation that the whales may have been exposed to sonar the day before and then fled to 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. 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/s for some time, it is improbable that a neonate could achieve the same for a period of many hours.

2. 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 MFA 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 training activities 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.

3. At the nominal swim speed for melon-headed whales, the whales had to be within 1.5 to 2 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).

4. 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 (Mobley et al. 2007). Thus, it is possible that the melon-headed whales were capitalizing on a lunar event that provided an opportunity for relatively easy prey capture.

   Both the Rota and Hanalei Bay incidents occurred on the same day, which followed a full moon (the date was different given the international date line). Analysis of 18 live and near strandings involving melon-headed whales for which specific dates were provided (Brownell et al. 2006), plus three additional live strandings not listed in that report, revealed a non-random pattern with respect to lunar phase. The majority of stranding events tended to occur during the full and third quarter phases, with fewer during the new moon and one during the first quarter. Squid and other species of the deep scattering layer show vertical migrations responsive to lunar cycles. Lunar influences have been shown with other squid-eating species, including the foraging behavior of Galapagos fur seals and stranding patterns of north Atlantic sperm whales (Mobley et al. 2007) In addition, 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.

5. 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. Received levels, however, 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 the 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 Navy believes the Hanalei stranding does not appear as anomalous as initially indicated in the NMFS report, and the speculation that sonar was a likely contributing 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 Navy vessels using MFA 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 U.S. Navy 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 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 Navy vessels did not lead to any of the strandings documented by Brownell et al. (2004).

#### 2004 Alaska Beaked Whale Strandings (June 7-16, 2004)

##### *Description*

In the timeframe between June 17 and July 19, 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 MFA 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.

#### North Carolina Marine Mammal Mass Stranding Event, January 15-16, 2005

##### *Description*

On January 15 and 16, 2005, 36 marine mammals comprised of three separate species (33 short-finned pilot whales, one minke whale, and two dwarf sperm whales) stranded alive on the beaches of North Carolina (NMFS 2007i; Hohn et al. 2006) distributed over a 69-mile area between the northern part of the state down to Cape Hatteras (NMFS 2007j). Thirty-one different species of marine mammals have been known to strand along the North Carolina coast since 1992; all three of the species involved in this stranding occasionally strand in this area (NMFS 2007j). This stranding event was determined to be a UME because live strandings of three different species in one weekend in North Carolina are extremely rare; in fact, it is the only stranding of offshore species to occur within a two to three day period in the region on record (NMFS 2007i; Hohn et al. 2006).

The Navy indicated that from January 12-14 some unit-level training with MFA sonar was conducted by vessels that were 93 to 185 km 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 away (NMFS 2007i). The unit-level training activities were not unusual for the area or time of year and the vessels were not involved in ASW exercises (NMFS 2007j). Marine mammal observers located on the Navy vessels reported that they did not detect any marine mammals (NMFS 2007i). 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. 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 (1 to 4 days) winter storms are common for this region.

*Findings*

On January 16 and 17, 2005, 2 dwarf sperm whales, 27 pilot whales, and the single minke whale were necropsied and sampled. Because of the uniqueness of the stranding, nine locations of interest within 25 of the stranded cetacean heads were examined closely. The only common finding in all of the heads was a form of sinusitis (NMFS 2007i).

- The pilot whales and the dwarf sperm whale were not considered to be emaciated, even though none of them had recently-eaten food in their stomachs (NMFS 2007i).
- The minke whale was emaciated, and it is believed that this was a dependent calf that had become separated from its mother, and was not a part of the other strandings (NMFS 2007i).
- Most biochemistry abnormalities indicated deteriorating conditions from being on land for an extended amount of time, and are believed to be a result of the stranding itself (NMFS 2007i).
- Three pilot whales showed signs of pre-existing systemic inflammation (NMFS 2007i).
- Lesions involving all organ systems were seen, but consistent lesions were not observed across species (NOAA 2006e; Hohn et al. 2006).
- Cardiovascular disease was present in one pilot whale and one dwarf sperm whale, while musculoskeletal disease was present in two pilot whales (NMFS 2007i).
- Parasites were found and collected from 26 pilot whales and 2 dwarf sperm whales; parasite loads were considered to be within normal limits for free-ranging cetaceans (NMFS 2007i).
- There were no harmful algal blooms present along the coastline during the months prior to the strandings (NMFS 2007i; Hohn et al. 2006).
- Sonar transmissions prior to the strandings were limited in nature and did not share the concentration identified in previous events associated with MFA 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).
- 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.
- Environmental conditions that are consistent with conditions under which other mass strandings have occurred were present (a gently sloping shore, strong winds, and changes in up-welling to down-welling conditions) (NMFS 2007i).

*Conclusions*

Several whales had pre-existing conditions that may have contributed to the stranding, but were not determined to be the cause of the stranding event (NOAA 2006e; NMFS 2007j). The actual cause of death for many of the whales was determined to be a result of the stranding itself (NMFS 2007j). NMFS concluded that this mass stranding event occurred simultaneously in time and space with MFA sonar naval activities, and has several features in common with other possible sonar-related stranding events (NMFS 2007i). For this reason, along with the rarity of the event, NMFS believes that it is possible that there exists a causal rather than a coincidental association between naval sonar activity and the stranding event (NMFS 2007i). However, they also acknowledge that there are differences in operational and environmental characteristics between this event and other possible sonar-related stranding events (NMFS 2007i), such as constricted channels (NMFS 2007j).

Even though the stranding occurred while active military sonar was being utilized off the North Carolina coast, the investigation team was unable to determine what role, if any, military activities played in the stranding events (Hohn et al. 2006). If MFA sonar played a part in the strandings, sound propagation models indicated that received acoustic levels would depend heavily on the position of the whales relative to the source; however, because the exact location of the cetaceans is unknown it is impossible to estimate the level of their exposure to active sonar transmissions (NMFS 2007i). Evidence to support a definitive association is lacking, and consistent lesions across species and individuals that could indicate a single cause of the stranding were not found (NMFS 2007i).

Based on the physical evidence, it cannot be definitively determined if there is a causal link between the strandings and anthropogenic sonar activity and/or environmental conditions, or a combination of both (NMFS 2007i).

### 6.5.3 Stranding Section Conclusions

Marine mammal strandings have been a historic and ongoing occurrence attributed to a variety of causes. Over the last 50 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 vs. 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 major threat, or significant portion of the overall ocean noise budget.

Several stranding events have been associated with Navy sonar activities but relatively few of the total stranding events that have been recorded occurred spatially or temporally with Navy sonar activities. While sonar may be a contributing factor under certain rare conditions, the presence of sonar it is not a necessary condition for stranding events to occur.

A review of past stranding events associated with sonar suggests that the potential factors that may contribute to a stranding event are steep bathymetry changes, narrow channels, multiple sonar ships, surface ducting and the presence of beaked whales that may be more susceptible to sonar exposures. The most important factors appear to be the presence of a narrow channel (e.g., Bahamas and Madeira Island, Portugal) that may prevent animals from avoiding sonar exposure and multiple sonar ships within that channel. There are no narrow channels (less than 35 nm wide and 10 nm in length) in the MIRC and the ships would be spread out over a wider area allowing animals to move away from sonar activities if they choose. In addition, beaked whales may not be more susceptible to sonar but may favor habitats that are more conducive to sonar effects.

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. 2005; ICES 2005b; Barlow and Gisiner 2006; Cox et al. 2006).

## 6.6 Estimated Effects Modeling

Modeling of the effects of mid-frequency sonar and underwater detonations was conducted using methods described in brief below. A detailed description of the representative modeling areas, sound sources, model assumptions, acoustic and oceanographic parameters, underwater sound propagation and transmission models, and diving behavior of species modeled are presented in Appendix B.

### 6.6.1.1 Acoustic Source Modeling

The approach for estimating potential acoustic effects from MIRC ASW training activities on cetacean species makes use of the methodology that was developed in cooperation with NOAA for the Navy's Undersea Warfare Exercise (USWEX) Environmental Assessment/Overseas Environmental assessment (EA/OEA) (DoN 2007c), RIMPAC EA/OEA (2006) and Composite Training Unit Exercise/Joint Task Force Exercise (COMPTUEX/JTFEX) EA/OEA (2007), as well as additional cooperative work with NMFS for analyzing behavioral effects to marine mammals using the risk-function methodology (DoN 2008). The methodology is provided here to determine the number and species of marine mammals for which incidental take authorization is requested.

In order to estimate acoustic effects from the MIRC ASW training activities, acoustic sources to be used were examined with regard to their operational characteristics. Sources were examined using simple spreadsheet calculations to ensure that they did not need to be considered further. For example, if a sonobuoy's typical use yielded an exposure area that produced no marine mammal exposures based on the maximum marine mammal density that sonobuoy as a source was designated non-problematic and was not modeled in the sense of running its parameters through the environmental model (CASS), generating an acoustic footprint, etc.

In addition, systems with an operating frequency greater than 100 kHz were not analyzed in the detailed modeling as these signals attenuate rapidly (due to the frequency) resulting in very short propagation distances for a received level exceeding the acoustic thresholds of concern. There are no ASW sonars transmitting sound underwater in excess of 50 kHz in use by the Navy in the MIRC Study Area.

Based on the information above, only hull-mounted MFA tactical sonar, DICASS sonobuoy, MK 48 torpedo (HFA sonar), and AN/AQS 22 (dipping sonar) were determined to have the potential to affect marine mammals protected under the MMPA and ESA during MIRC ASW training events.

For modeling purposes, sonar parameters (source levels, ping length, the interval between pings, output frequencies, etc.) were based on records from training events, previous exercises, and preferred ASW tactical doctrine to reflect the sonar use expected to occur during events in the MIRC. The actual sonar parameters such as output settings, distance between ASW surface, subsurface, and aerial units, their deployment patterns, and the coordinated ASW movement (speed and maneuvers) across the exercise area are classified, however, modeling used to calculate exposures to marine mammals employed actual and preferred parameters to which the participants are trained and have in the past, used during ASW events in the MIRC.

For discussion purposes surface ship sonars can be considered as having the nominal source level of 235 dB re 1 $\mu Pa^2$-s @ 1 m, transmitting a 1 second omnidirectional ping at center frequencies of 2.6 kHz and 3.3 kHz, with 30 seconds between pings.

Every active sonar training activity includes the potential to harass marine animals in the vicinity of the source. The number of animals exposed to potential harassment 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).

#### 6.6.1.2 Modeling Physiological Effects

For the MIRC, the relevant measure of potential physiological effects to marine mammals due to sonar training is the accumulated (summed over all source emissions) energy flux density level received by the animal over the duration of the activity.

The modeling for estimating received energy flux density level from surface ship active tactical sonar occurred in five broad steps, listed below. Results were calculated based on the typical ASW activities planned for the MIRC.

- **Step 1**. Environmental Seasons. The MIRC study area is divided into two seasons, dry season and wet season and each has a unique combination of environmental conditions.
- **Step 2**. Transmission Loss. Since sound propagates differently in these nine environments, separate transmission loss calculations must be made for each, in both seasons. The transmission loss is predicted using Comprehensive Acoustic System Simulation 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. Repeating this calculation for each environment in each season gives the hourly ensonified volume, by depth, for each environment and season.
- **Step 4**. Marine Mammal Densities. The marine mammal densities were given in two dimensions, but using sources such as the North Pacific Acoustic Laboratory EIS, the depth regimes of these marine mammals are used to project the two dimensional densities into three dimensions.
- **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 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. Calculated exposures above 0.5 were counted as one exposure.

The movement of various units during an ASW event is largely unconstrained and dependent on the developing tactical situation presented to the commander of the forces.

Only when all exposures for all training are summed for the year does the model indicate the potential for exposure in excess of 215 dB re 1 $\mu Pa^2$-s. This summation for the year results in 0.66 of an exposure (rounded up to one (1)) counting as one incident of exposure for humpback whale and 0.53 of an exposure counted as one exposure for striped dolphin. However, the likelihood of exposures above the thresholds for Level A harassment is considered highly improbable. In addition, mitigation measures that will be implemented during the proposed activities would reduce the potential for these two Level A exposures to occur.

#### 6.6.1.3 Modeling Behavioral Effects

For the MIRC, the relevant measure of potential behavioral disturbance effects to marine mammals due to sonar training is the maximum sound pressure level (SPL) received by the animal over the duration of the activity (or over each day).

The modeling for estimating received energy flux density from surface ship active tactical sonar is analogous to the modeling for energy flux density level, discussed above. However, the SPL metric yields the maximum SPL (and not the sum of energies).

Results were calculated based on the typical ASW activities planned for the MIRC. Acoustic propagation and mammal population data are analyzed for both the dry season (December to June) and wet season (July to November; See Appendix A for modeling protocol).

#### 6.6.1.3.1 Explosive Source Criteria

The criterion for mortality for marine mammals used in the *CHURCHILL FEIS* (DoN 2001) is "onset of severe lung injury." This 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-ms.'" 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-ms index is a complicated calculation. Again, to be conservative, *CHURCHILL* used the mass of a calf dolphin (at 12.2 kg), so that the threshold index is 30.5 psi-ms (Table 6.1).

The dual criteria are used for injury: onset of slight lung hemorrhage and 50 percent eardrum rupture (tympanic membrane [TM] rupture). These criteria are considered indicative of the onset of injury (Table 6-7).

- The threshold for onset of slight lung injury is calculated for a small animal (a dolphin calf weighing 27 lb), and is given in terms of the "Goertner modified positive impulse," indexed to 13 psi-ms in the (DoN, 2001a). This threshold is conservative since the positive impulse needed to cause injury is proportional to animal mass, and therefore, larger animals require a higher impulse to cause 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 rupture); this is stated in terms of an EL value of 205 dB re 1 $\mu Pa^2$-s. The criterion reflects the fact 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 dual criteria is considered for non-injurious harassment (TTS), which is a temporary, recoverable, loss of hearing sensitivity (NMFS 2001; DoN 2001a).

- The first criterion for TTS is 182 dB re 1 $\mu Pa^2$-s maximum EL level in any 1/3-octave band at frequencies >100 hertz (Hz) for odontocetes and > 10 Hz for mysticetes.

- A second criterion for estimating TTS threshold has also been developed. A threshold of 12 pounds per square inch (psi) peak pressure was developed for 10,000 pound charges as part of the *CHURCHILL Final EIS* (DoN, 2001a, [FR70/160, 19 Aug 05; FR 71/226, 24 Nov 06]). It was introduced to provide a more conservative safety zone for TTS when the explosive or the animal approaches the sea surface (for which case the explosive energy is reduced but the peak pressure is not). Navy policy is to use a 23 psi criterion for explosive charges less than 2,000 lb and the 12 psi criterion for explosive charges larger than 2,000 lb. This is below the level of onset of TTS for an odontocete (Finneran et al. 2002). All explosives modeled for the MIRC EIS are less than 1,500 lbs.

The third criterion is used for estimation of behavioral disturbance before TTS (sub-TTS) for cases with multiple successive explosions (having less than 2 seconds separation between explosions). The threshold is 177 dB re 1 $\mu Pa^2$-s (EL) to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. Since there may be rare occasions when multiple explosions in succession (separated by less than 2 seconds) occur during BOMBEX, GUNEX, and NSFS using other than inert rounds, the Churchill approach was extended to cover multiple exposure events at the same location. For multiple exposures, accumulated energy over the entire training time is the natural extension for energy thresholds since energy accumulates with each subsequent shot; this is consistent with the treatment of multiple arrivals in Churchill. For analysis in the MIRC EIS/OEIS, therefore, given that multiple successive explosions are rare, in consideration of range clearance procedures designed to preclude the presence of marine species within the target area, and because previous modeling efforts have not resulted in expected exposures at the sub-TTS threshold level, modeling for these rare live fire events (BOMBEX, GUNEX, and NSFS) was not undertaken.

#### 6.6.1.3.2 Explosive Source and Live Fire Procedures

As part of the official Navy clearance procedure before an underwater detonation or live fire exercise, the target area must be inspected visually (from vessels and available aircraft) and determined to be clear. The required clearance zone at the target areas, and training activities within controlled ranges, minimizes the risk to marine mammals. Open ocean clearance procedures are the same for live or inert ordnance. Whenever ships and aircraft use the ranges for missile and gunnery practice, the weapons are used under controlled circumstances involving clearance procedures to ensure cetaceans, pinnipeds, or sea turtles are not present in the target area. These involve, at a minimum, a detailed visual search of the target area by aircraft reconnaissance, range safety boats, and range controllers and passive acoustic monitoring.

Ordnance cannot be released until the target area is determined clear. Training activities are immediately halted if cetaceans, pinnipeds, or sea turtles are observed within the target area. Training activities are delayed until the animal clears the target area. All observers are in continuous communication in order to have the capability to immediately stop the training activities. The procedures can be modified as necessary to obtain a clear target area. If the area cannot be cleared, the event is canceled. All of these factors serve to avoid the risk of harming cetaceans, pinnipeds, or sea turtles. Post event monitoring of underwater detonations have not observed any injured marine mammals.

The weapons used in most missile and live fire exercises pose little risk to marine mammals unless they were to be near the surface at the point of impact. Machine guns (0.50 caliber), 5-in guns, 76mm guns, and close-in weapons systems (anti missile systems) exclusively fire non-explosive ammunition. The same applies to larger weapons firing inert ordnance for training activities. The rounds pose an extremely low risk of a direct hit and potential to directly affect a marine species. Target area clearance procedures would again reduce this risk.

A SINKEX uses a variety of live fire weapons; many of these are guided “smart” weapons. The intention is for the ordnance to hit the target vessel and not the water. Target area clearance procedures would again reduce this risk. Modeling results of the potential exposures of marine mammals to underwater sound from a SINKEX is included in the summary presented in Table 6-7.

The Navy has developed a mitigation plan to maximize the probability of sighting any ships or protected species in the vicinity of a training activity. In order to minimize the likelihood of taking any threatened or endangered species that may be in the area, the following monitoring plan would be adhered to:

- All weapons firing would be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.
- Extensive range clearance procedures would be conducted in the hours prior to commencement of the training, ensuring that no shipping is located within the hazard range of the longest-range weapon being fired for that event.
- An exclusion zone with a radius of 1 nm would be established around each target. This exclusion zone is based on calculations using a 990 lb net explosive weight high explosive source detonated 5 feet below the surface of the water, which yields a distance of 0.85 nm (cold season) and 0.89 nm (warm season) beyond which the received level is below the 182 dB re: 1 $\mu Pa^2$-s threshold established for the *WINSTON S. CHURCHILL* (DDG 81) shock trials. An additional buffer of 0.5

nm would be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which extends from the exclusion zone at 1 nm out an additional 0.5 nm, would be surveyed. Together, the zones extend out 2 nm from the target.

A series of surveillance over-flights would be conducted within the exclusion and the safety zones, prior to and during the training, when feasible. Survey protocol would be as follows:

- All visual surveillance training activities would be conducted by Navy personnel trained in visual surveillance. In addition to the over flights, the exclusion zone would be monitored by passive acoustic means, when assets are available.
- If a protected species observed within the exclusion zone is diving, firing would be delayed until the animal is re-sighted outside the exclusion zone, or 30 minutes has elapsed. After 30 minutes, if the animal has not been re-sighted it would be assumed to have left the exclusion zone. This is based on a typical dive time of 30 minutes for traveling listed species of concern. The officer-in-charge of the exercise (OCE) would determine if the ESA listed species is in danger of being adversely affected by commencement of the training activity.

## 6.7 Estimated Effects on Marine Mammals

### 6.7.1 Model Results Explanation

Acoustic exposures are evaluated based on their potential direct effects on marine mammals, and these effects are then assessed in the context of the species biology and ecology to determine if there is a mode of action that may result in the acoustic exposure warranting consideration as a harassment level effect.

**Table 6-6. Summary of predicted annual usage for the different sonar sources including the 53, 56, submarine BQQ-10, AN/AWS-22 dipping sonar, SSQ-62 Sonobuoys, and MK-48 torpedo sonar.**

| Exercise | 53 Sonar Hours | 53 King Fisher Sonar Hours | 56 Sonar Hours | BQQ-10 Sub Hours | Total Sonar Hours | Number of Dips for AQS-22 & 13 | Number of DICASS/AEER Sonobuoys Deployments[1] | MK-48 Torpedo Events |
|---|---|---|---|---|---|---|---|---|
| Major Exercise | 866 | 0 | 77 | 0 | 943 | 288 | 254 | 1 |
| Other ASW | 134 | 30 | 13 | 12 | 189 | 128 | 46 | 9 |
| **Total Hours or Number of Events** | **1,000** | **30** | **90** | **12** | **1,132** | **416** | **300** | **10** |

Note: [1] The majority of deployments are associated with DICASS Sonobuoys. DICASS Sonobuoy modeling parameters were used to model exposures associated with AEER use. Once AEER parameters are defined, additional modeling will be conducted and results will be provided in an addendum to this LOA.

The risk function methodology estimates 36,841 annual exposures to MFA and HFA sonar that could result in a behavioral change (Level B harassment from non-TTS) and 595 that could result in TTS (Level B Harassment from TTS). There will be one annual exposure that could result in injury such as PTS to a pantropical spotted dolphin and none would result in fatalities. The modeled sonar exposure numbers by species are presented in Table 6-7. These exposure modeling results are estimates of marine mammal sonar exposures without consideration of standard mitigation and monitoring procedures. The implementation of the mitigation and monitoring procedures, as addressed in Chapter 11, will minimize the potential for marine mammal exposures to MFA and HFA sonar.

A large body of research on terrestrial animal and human response to airborne sound exists, but results from those studies are not readily applicable to the development of behavioral criteria and thresholds for marine mammals. Differences in hearing thresholds, dynamic range of the ear, and the typical exposure patterns of interest (e.g., human data tend to focus on 8-hour-long exposures), and the difference between acoustics in air and in water make extrapolation of human sound exposure standards inappropriate.

Behavioral observations of marine mammals exposed to anthropogenic sound sources exists, however, there are few observations and no controlled measurements of behavioral disruption of cetaceans caused by sound sources with frequencies, waveforms, durations, and repetition rates comparable to those employed by the tactical sonars described in this EIS/OEIS (Deecke 2006) or for multiple explosives. Controlled studies in the laboratory have been conducted to determine physical changes (TTS) in hearing of marine mammals associated with sound exposure (Finneran et al. 2001, 2003, 2005). Research on behavioral effects has been difficult because of the difficulty and complexity of implementing controlled conditions.

At the present time there is no general scientifically accepted consensus on how to account for behavioral effects on marine mammals exposed to anthropogenic sounds including military sonar and explosions (National Research Council [NRC] 2003, 2005). While the first elements in Figure 6-10 can be easily defined (source, propagation, receiver) the remaining elements (perception, behavior, and life functions) are not well understood given the difficulties in studying marine mammals at sea (NRC 2005). The NRC (2005) acknowledges “there is not one case in which data can be integrated into models to demonstrate that noise is causing adverse affects on a marine mammal population.”

For purposes of predicting the number of marine mammals that will be behaviorally harassed or sustain either TTS or PTS, the Navy uses an acoustic impact model process with numeric criteria agreed upon with the NMFS.

There are some caveats necessary to understand in order to put these exposures in context. For instance, (1) significant scientific uncertainties are implied and carried forward in any analysis using marine mammal density data as a predictor for animal occurrence within a given geographic area; (2) there are limitations to the actual model process based on information available (animal densities, animal depth distributions, animal motion data, impact thresholds, type of sound source and intensity, behavior (involved in reproduction or foraging), previous experience and supporting statistical model); and determination of what constitutes a significant behavioral effect in a marine mammal is still unresolved (National Research Council 2005). The sources of marine mammal densities used in this LOA are derived from NMFS surveys (Barlow 2003, 2006; Mobley et al. 2001; Ferguson and Barlow 2001; 2003; DoN 2007b). These ship board surveys cover significant distance around the Hawaiian Islands, Eastern Tropical Pacific and the Mariana Islands. Although survey design includes statistical placement of survey tracks, the survey itself can only cover so much ocean area. Post-survey statistics are used to calculate animal abundances and densities (Barlow and Forney 2007). There is often significant statistical variation inherent within the calculation of the final density values depending on how many sightings were available during a survey. Occurrence of marine mammals within any geographic area including the Mariana Islands is highly variable and strongly correlated to oceanographic conditions, bathymetry, and ecosystem level patterns (prey abundance and distribution) (Benson et al. 2002; Moore et al. 2002; Tynan 2005; Redfern 2006).

For some species, distribution may be even more highly influenced by relative small scale biological or oceanographic features over both short and long-term time scales (Ballance et al. 2006; Etnoyer et al. 2006; Ferguson et al. 2006; Skov et al. 2007). Unfortunately, the scientific understanding of some large scale and most small scale processes thought to influence marine mammal distribution is incomplete.

Given the uncertainties in marine mammal density estimation and localized distributions, the Navy's acoustic impact models can not currently take into account locational data for any marine mammals within specific areas of the MIRC. To resolve this issue and allow modeling to precede, animals are "artificially and uniformly distributed" within the modeling provinces described in Appendix B.

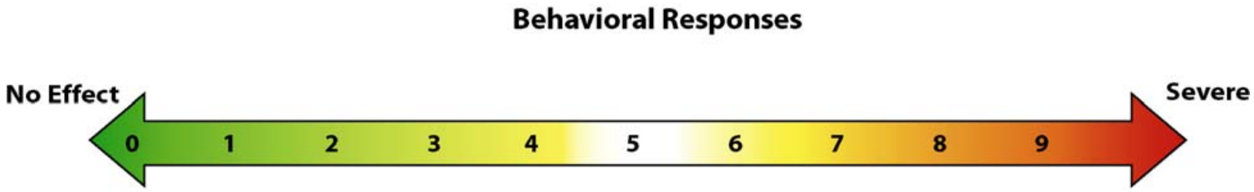
**Behavioral Responses**

The intensity of the behavioral responses exhibited by marine mammals depends on a number of conditions including the age, reproductive condition, experience, behavior (foraging or reproductive), species, received sound level, type of sound (impulse or continuous) and duration (including whether exposure occurs once or multiple times) of sound (Reviews by Richardson et al. 1995a; Wartzok et al. 2003; Cox et al. 2006, Nowacek et al. 2007; Southall et al. 2007) (Figure 6-10). Many behavioral responses may be short term (seconds to minutes orienting to the sound source or over several hours if they move away from the sound source) and of little immediate consequence for the animal. However, certain responses may lead to a stranding or mother-offspring separation (Baraff and Weinrich 1994; Gabriele et al. 2001). Active sonar exposure is brief as the ship is constantly moving and the animal will likely be moving as well. Generally the louder the sound source the more intense the response although duration is also very important (Southall et al. 2007).

According to the severity scale response spectrum (Figure 6-10) proposed by Southall et al. (2007), responses classified as from 0-3 are brief and minor, those from 4-6 have a higher potential to affect foraging, reproduction, or survival and those from 7-9 are likely to affect foraging, reproduction and survival. Sonar and explosive mitigation measures (sonar power-down or shut-down zones and explosive exclusion zones) would likely prevent animals from being exposed to the loudest sonar sounds or explosive effects that could potentially result in TTS or PTS and more intense behavioral reactions (i.e. 7-9) on the response spectrum.

There are little data on the consequences of sound exposure on vital rates of marine mammals. Several studies have shown the effects of chronic noise (either continuous or multiple pulses) on marine mammal presence in an area exposed to seismic survey airguns or ship noise (e.g., Malme et al. 1984; McCauley et al. 1998; Nowacek et al. 2004). MFA/HFA sonar use in the MIRC is not new given the current hull-mounted sonar employs the same basic sonar equipment and having the same output for over approximately 30 years. Given this history, the Navy believes that risk to marine mammals from sonar training is low.

Even for more cryptic species such as beaked whales, the main determinant of causing a stranding appears to be exposure in a limited egress areas (a long narrow channel) with multiple ships. The result is that animals may be exposed for a prolonged period rather than several sonar pings over several minutes and the animals having no means to avoid the exposure. Under these specific circumstances and conditions, MFA sonar is believed to have contributed to the stranding resulting in indirectly caused mortality of a small number of beaked whales in locations other than the MIRC. There are no limited egress areas (long narrow channels) in the MIRC, therefore, it is unlikely that the proposed sonar use would result in any strandings. Although the Navy has substantially changed operating procedures to avoid the aggregate of circumstances that may have contributed to previous strandings, it is important that future unusual stranding events be reviewed and investigated so that any human cause of the stranding can be understood and avoided.



0 - No observable response
1- Brief orientation response (investigation / visual orientation)
2 - Moderate or multiple orientation behaviors
  - Brief or minor cessation / modification of vocal behavior
  - Brief or minor change in respiration rates
3 - Prolonged orientation behavior
  - Individual alert behavior
  - Minor changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source
  - Moderate change in respiration rate
  - Minor cessation or modification of vocal behavior (duration < duration of source activity), including the Lombard Effect
4 - Moderate changes in locomotion speed, direction, and/or dive profile, but not avoidance of sound source
  - Brief, minor shift in group distribution
  - Moderate cessation or modification of vocal behavior (approximate duration of source activity)
5 - Extensive or prolonged changes in locomotion speed, direction, and / or dive profile, but not avoidance in sound source
  - Moderate shift in group distribution
  - Change in inter-animal distance and / or group size (aggregation or separation)
  - Prolonged cessation or modification of vocal behavior (duration > duration of source activity)
6 - Minor or moderate individual and / or group avoidance of sound source
  - Brief or minor separation of females and dependent offspring
  - Aggressive behavior related to noise exposure (e.g., tail / flipper slapping, fluke display, jaw clapping / gnashing teeth, abrupt directed movement, bubble clouds)
  - Extended cessation or modification of vocal behavior
  - Visible startle response
  - Brief cessation of reproductive behavior
7 - Excessive or prolonged aggressive behavior
  - Moderate separation of females and dependent offspring
  - Clear antipredator response
  - Severe and / or sustained avoidance of sound source
  - Moderate cessation of reproductive behavior
8 - Obvious aversion and / or progressive sensitization
  - Prolonged or significant separation of females and dependent offspring with disruption of acoustic reunion mechanism
  - Long-term avoidance of area (> source activity)
  - Prolonged cessation of reproductive behavior
9 - Outright panic, fight, stampede, attack of conspecifics, or stranding event
  - Avoidance behavior related to predator detection

Source: Southall et al., 2007

**Figure 6-10. Proposed Marine Mammal Response Severity Scale Spectrum to Anthropogenic Sounds In Free Ranging Marine Mammals**

There have been no beaked whales strandings in the MIRC associated with the use of MFA/HFA sonar. This is a critically important contextual difference between the MIRC and areas of the world where strandings have occurred (Southall et al. 2007). While the absence of evidence does not prove there have been no impacts on beaked whales, decades of history with no evidence cannot be lightly dismissed.

#### TTS

A TTS is a temporary recoverable, loss of hearing sensitivity over a small range of frequencies related to the sound source to which it was exposed. The animal may not even be aware of the TTS and does not become deaf, but requires a louder sound stimulus (relative to the amount of TTS) to detect that sound within the affected frequencies. TTS may last several minutes to several days and the duration is related to the intensity of the sound source and the duration of the sound (including multiple exposures). Sonar exposures are generally short in duration and intermittent (several sonar pings per minute from a moving ship), and with mitigation measures in place, TTS in marine mammals exposed to MFA or HFA sonar and underwater detonations are unlikely to occur. There is currently no information to suggest that if an animal has TTS, that it will decrease the survival rate or reproductive fitness of that animal. TTS range from a MFA sonar's 235 dB source level one second ping is approximately 361 ft. (110 m) from the bow of the ship under nominal oceanographic conditions.

#### PTS

A PTS is non-recoverable, results from the destruction of tissues within the auditory system, and occurs over a small range of frequencies related to the sound exposure. The animal does not become deaf but requires a louder sound stimulus (relative to the amount of PTS) to detect that sound within the affected frequencies. Sonar exposures are generally short in duration and intermittent (several sonar pings per minute from a moving ship) and with mitigation measures in place, PTS in marine mammals exposed to MFA or HFA sonar is unlikely to occur. There is currently no information to suggest that if an animal has PTS, it decreases the survival rate or reproductive fitness of that animal. The distance to PTS from a MFA sonar's 235 dB source level one second ping is approximately 33 ft. (10 m) from the bow of the ship under nominal oceanographic conditions.

#### Population Level Effects

Some MIRC training activities will be conducted in the same general areas, so marine mammal populations could be exposed to repeated activities over time. This does not mean, however, that there will be a repetition of any effects given the vast number of variables involved. The acoustic analyses assume that short-term non-injurious sound levels predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment from TTS. However, it is unlikely that most behavioral disruptions or instances of TTS will result in long-term significant effects. Mitigation measures reduce the likelihood of exposures to sound levels that would cause significant behavioral disruption (the higher levels of 7-9 in Figure 6-10), TTS or PTS. Based on modeling the Navy has estimated that 37,447 marine mammals per year might be exposed to activities that NMFS would consider Level B harassment under MMPA (risk function [or non-TTS] and TTS from active sonar) as a result of the Proposed Actions. The Navy does not anticipate any indirectly caused mortality to result from the Proposed Actions. It is unlikely that the short term behavioral disruption would adversely affect the species or stock through effects on annual rates of recruitment or survival.

### 6.7.2 Exposures Summary

This Section includes summary tables for sonar and underwater detonation exposures. Table 6-7 and 6-8 represent the total number of Level A and Level B harassment without mitigation measures. Note that Table 6-7 sums the Level B harassment authorization requested based on the risk function, and the 195 dB onset TTS and 205 dB onset PTS thresholds are based on energy flux density level. Only species expected to be present in the MIRC were evaluated for this LOA request.

## Table 6-7. Summary of Estimated Level A and B Annual Exposures from All ASW Sonar

| Species | Level B Sonar Exposures | | Level A Sonar Exposures |
|---|---|---|---|
| | Risk Function | TTS | PTS |
| **ESA Species** | | | |
| Blue whale | 60 | 1 | 0 |
| Fin whale | 86 | 1 | 0 |
| Humpback whale | 0 | 0 | 0 |
| Sei whale | 150 | 2 | 0 |
| Sperm whale | 383 | 5 | 0 |
| Sei/Bryde's whale | 29 | 0 | 0 |
| Unidentified Balaenopterid | 34 | 0 | 0 |
| **Mysticetes** | | | |
| Bryde's whale | 212 | 4 | 0 |
| Minke whale | 207 | 4 | 0 |
| **Odontocetes** | | | |
| Blainville's beaked whale | 358 | 6 | 0 |
| Bottlenose dolphin | 80 | 1 | 0 |
| Bottlenose/Rough-toothed | 34 | 1 | 0 |
| Cuvier's beaked whale | 1,694 | 22 | 0 |
| Dwarf/Pygmy sperm whale | 3,114 | 50 | 0 |
| False killer whale | 608 | 12 | 0 |
| Fraser's dolphin | 2,150 | 36 | 0 |
| Ginkgo-toothed beaked whale | 199 | 3 | 0 |
| Killer whale | 108 | 2 | 0 |
| Longman's beaked whale | 96 | 1 | 0 |
| Melon-headed whale | 1,334 | 22 | 0 |
| Pantropical spotted dolphin | 15,215 | 245 | 0 |
| Pygmy killer whale | 75 | 1 | 0 |
| Risso's dolphin | 3,150 | 53 | 0 |
| Rough-toothed dolphin | 111 | 2 | 0 |
| Short-beaked common dolphin | 434 | 8 | 0 |
| Short-finned pilot whale | 1,064 | 17 | 0 |
| Spinner dolphin | 998 | 17 | 0 |
| Striped dolphin | 4,148 | 67 | 0 |
| Unidentified delphinid | 721 | 12 | 0 |
| **Total** | **36,852** | **595** | **0** |

MFA and HFA Sonar Risk Function Curve 120-195 dB SPL
195 dB – TTS 195-215 dB re 1 µPa$^2$-s
215 dB- PTS >215 dB re 1 µPa$^2$-s
TTS = temporary threshold shift
PTS = permanent threshold shift

**Table 6-8. Summary of Estimated Level A and Level B Annual Exposures from Underwater Detonations**

| **Species** | **Level B Exposures** | | **Level A Exposures** | **Onset Massive Lung Injury or Mortality 31 psi-ms** |
|---|---|---|---|---|
| | **Sub TTS 177 dB** | **TTS 182 dB/23 psi** | **50% TM Rupture 205 dB or Slight Lung Injury 13 psi-ms** | |
| **ESA Species** | | | | |
| Blue whale | 0 | 0 | 0 | 0 |
| Fin whale | 0 | 0 | 0 | 0 |
| Humpback whale | 0 | 0 | 0 | 0 |
| Sei whale | 0 | 0 | 0 | 0 |
| Sei/Bryde’s whale | 0 | 0 | 0 | 0 |
| Sperm whale | 0 | 0 | 0 | 0 |
| **Mysticetes** | | | | |
| Bryde’s whale | 0 | 0 | 0 | 0 |
| Minke whale | 0 | 0 | 0 | 0 |
| Unidentified Balenoptera | 0 | 0 | 0 | 0 |
| **Odontocetes** | | | | |
| Blainevillе’s beaked whale | 0 | 0 | 0 | 0 |
| Bottlenose dolphin | 0 | 0 | 0 | 0 |
| Cuvier’s beaked whale | 6 | 2 | 0 | 0 |
| Dwarf/Pygmy sperm whale | 6 | 2 | 0 | 0 |
| False killer whale | 0 | 0 | 0 | 0 |
| Fraser’s dolphin | 6 | 2 | 0 | 0 |
| Ginkgo-toothed beaked whale | 0 | 0 | 0 | 0 |
| Killer whale | 0 | 0 | 0 | 0 |
| Longman’s beaked whale | 0 | 0 | 0 | 0 |
| Melon-headed whale | 6 | 2 | 0 | 0 |
| Pantropical spotted dolphin | 6 | 2 | 0 | 0 |
| Pygmy killer whale | 0 | 0 | 0 | 0 |
| Risso’s dolphin | 12 | 4 | 0 | 0 |
| Rough-toothed dolphin | 0 | 0 | 0 | 0 |
| Short-beaked common | 0 | 0 | 0 | 0 |
| Short-finned pilot whale | 0 | 0 | 0 | 0 |
| Spinner dolphin | 0 | 0 | 0 | 0 |
| Striped dolphin | 0 | 0 | 0 | 0 |
| Unidentified Delphinid | 0 | 0 | 0 | 0 |
| **Total** | **42** | **14** | **0** | **0** |

dB – decibel
psi = pounds per square inch
ms = milli second
TM = Tympanic Membrane

When analyzing the results of the acoustic exposure modeling to provide an estimate of effects, it is important to understand that there are limitations to the ecological data used in the model, and that the model results must be interpreted within the context of a given species' ecology. When reviewing the acoustic effects modeling results, it is also important to understand that the estimates of marine mammal sound exposures are presented without consideration of standard mitigation operating procedures or the fact that there have been no confirmed acoustic effects on any marine species in previous MIRC exercises or from any other MFA/HFA sonar training events within the MIRC.

All Level B harassment would be short term and temporary in nature. In addition, the short-term non-injurious exposures predicted to cause TTS or temporary behavioral disruptions are considered Level B harassment in this LOA even though it is highly unlikely that the disturbance would be to a point where behavioral patterns are abandoned or significantly altered. The modeling for MIRC analyzed the potential interaction of MFA/HFA tactical sonar and underwater detonations with marine mammals that occur in the MIRC.

The annual estimated number of exposures for MFA/HFA sonar and underwater detonations (mine neutralization, MISSILEX, BOMBEX, and GUNEX) are given for each species. The modeled exposure is the probability of a response that NMFS would classify as harassment under the MMPA. These exposures are calculated for all activities modeled and represent the total exposures per year and are not based on a per day basis.

Due to wind and swell conditions in the MIRC and the cryptic nature of some marine mammal species, detection of marine mammals during training events can be challenging. A detailed description of the mitigation measures for mid-frequency sonar and underwater detonation activities are presented in Sections 11.1 and 11.2.

### 6.7.3 Sonar Exposure Summary

The modeling for MFA/HFA sonar using the risk function methodology predicts 36,852 annual acoustic exposures that result in Level B harassment along with 595 annual exposures that exceed the TTS threshold (Level B Harassment). The model predicts no annual exposures that exceed the PTS threshold (Level A Harassment). The summary of modeled sonar exposure harassment numbers by species are presented in Table 6-7 and represent potential harassment without implementation of mitigation measures.

For each of the types of exercises, marine mammals are exposed to mid -frequency sonar from several sources. Table 6-7 provides the number of exposures modeled based on risk function (120-195 dB SPL), the TTS threshold (195 dB), and the PTS threshold (215 dB). The values given for risk function and TTS are further subdivided based on the type of sonar (Table 6-9). For PTS, the numbers are so small that only the total values are given. Each source is modeled separately and then the exposures are summed to get the number of exposures requested in this LOA. This is a conservative approach in that if the more powerful 53 sonar overlaps one of the other sonars then the lesser sonar would not actually produce an exposure. However, for modeling purposes all sonar exposures were counted.

**Table 6-9. Sonar Exposures by Sonar Source Type**

| Source | Risk Function | TTS | PTS |
|---|---|---|---|
| AN-SQS-53 (Search mode) | 36,445 | 595 | 0 |
| AN-SQS-53 (Kingfisher mode) | 0 | 0 | 0 |
| AN-SQS-56 | 156 | 0 | 0 |
| BQQ-10 Submarine sonar | 47 | 0 | 0 |
| ASQ-22 Dipping Sonar | 153 | 0 | 0 |
| SSQ-62 DICASS Sonobuoy | 22 | 0 | 0 |
| SSQ-125 AEER Sonobuoy[1] | 11 | 0 | 0 |
| MK-48 Torpedo Sonar | 18 | 0 | 0 |
| **Total** | **36,852** | **595** | **0** |

Note: [1]DICASS Sonobuoy modeling parameters were used to model exposures associated with AEER use. Once AEER parameters are defined, additional modeling will be conducted and results will be provided in an addendum to this LOA.

### 6.7.4 Explosive Exposure Summary

The modeled exposure harassment numbers for all training activities involving explosives are presented by species in Table 6-8. The modeling indicates 42 annual exposures to pressure from underwater detonations that could result in TTS (Level B Harassment). The modeling indicates 14 exposures from pressure from underwater detonations that could cause slight injury (Level A Harassment). The modeling indicates that no marine mammals would be exposed to pressure from underwater detonations that could cause severe injury or mortality.

Training activities involving explosives include Mine Neutralization, A-S MISSILEX, S-S MISSILEX, BOMBEX, SINKEX, S-S GUNEX, and NSFS. In a SINKEX, weapons are typically fired in order of decreasing range from the source with weapons fired until the target is sunk. Since the target may sink at any time during the exercise, the actual number of weapons used can vary widely. In the representative case, however, all of the ordnances are assumed expended; this represents the worst case of maximum exposure. The sequence of weapons firing for the representative SINKEX is described in Appendix A. Guided weapons are nearly 100 percent accurate and are modeled as hitting the target (that is, no underwater acoustic effect) in all but two cases: (1) the Maverick is modeled as a miss to represent the occasional miss, and (2) the MK-48 torpedo intentionally detonates in the water column immediately below the hull of the target. Unguided weapons are more frequently off-target and are modeled according to the statistical hit/miss ratios. Note that these hit/miss ratios are artificially low in order to demonstrate a worst-case scenario; they should not be taken as indicative of weapon or platform reliability.

**Table 6-10. Underwater Detonation Exposures by Source Type**

| Source | Level B Exposures | | Level A Exposures | Onset Massive Lung Injury or Mortality 31 psi-ms |
|---|---|---|---|---|
| | Sub TTS 177 dB | TTS 182 dB/23 psi | 50% TM Rupture 205 dB or Slight Lung Injury 13 psi-ms | |
| 5 in | 0 | 0 | 0 | 0 |
| 76 mm | 0 | 0 | 0 | 0 |
| HARPOON | 0 | 0 | 0 | 0 |
| Maverick | 0 | 0 | 0 | 0 |
| MK 48 | 0 | 0 | 0 | 0 |
| MK 82 | 0 | 0 | 0 | 0 |
| MK 83 | 0 | 0 | 0 | 0 |
| MK 84 | 0 | 0 | 0 | 0 |
| SINKEX | 42 | 14 | 0 | 0 |
| IEER | 0 | 0 | 0 | 0 |
| **Total** | **42** | **14** | **0** | **0** |

All exposures are added up in this table but exposures of less than 0.5 are not considered in the Level A and Mortality exposures for each species.

It is highly unlikely that a marine mammal would experience any long-term effects because the large MIRC training areas makes individual mammals' repeated and/or prolonged exposures to high-level sonar signals unlikely. Specifically, MFA/HFA sonars have limited marine mammal exposure ranges and relatively high platform speeds. Therefore, long term effects on individuals, populations or stocks are unlikely.

When analyzing the results of the acoustic exposure modeling to provide an estimate of effects, it is important to understand that there are limitations to the ecological data (diving behavior, migration or movement patterns and population dynamics) used in the model, and that the model results must be interpreted within the context of a given species' ecology.

When reviewing the acoustic exposure modeling results, it is also important to understand that the estimates of marine mammal sound exposures are presented without consideration of standard protective measure operating procedures. Section 11.1 presents details of the mitigation measures currently used for ASW activities including detection of marine mammals and power down procedures if marine mammals are detected within one of the safety zones. The Navy will work through the MMPA incidental harassment regulatory process to discuss the mitigation measures and their potential to reduce the likelihood for incidental harassment of marine mammals.

As described previously, this LOA request assumes that short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment. This approach is overestimating because there is no established scientific correlation between MFA/HFA sonar use and long term abandonment or significant alteration of behavioral patterns in marine mammals.

Because of the time delay between pings, and platform speed, an animal encountering the sonar will accumulate energy for only a few sonar pings over the course of a few minutes. Therefore, exposure to sonar would be a short-term event, minimizing any single animal's exposure to sound levels approaching the harassment thresholds.

## 6.8 Assessment of Marine Mammal Response to Acoustic Exposures

Section 6.2.1 presented the concept that potential effects of sound include both physiological effects and behavioral effects. Sections 6.1.4 and 6.1.5 provide information on how physiological effects and behavioral responses are considered in development of acoustic modeling.

Acoustic exposures are evaluated based on their potential direct effects on marine mammals, and these effects are then assessed in the context of the species biology and ecology to determine if there is a mode of action that may result in the acoustic exposure warranting consideration as a harassment level effect. A large body of research on terrestrial animal and human response to airborne sound exists, but results from those studies are not readily extendible to the development of effect criteria and thresholds for marine mammals. For example, "annoyance" is one of several criteria used to define impact to humans from exposure to industrial sound sources. Comparable criteria cannot be developed for marine mammals because there is no acceptable method for determining whether a non-verbal animal is annoyed. Further, differences in hearing thresholds, dynamic range of the ear, and the typical exposure patterns of interest (e.g., human data tend to focus on 8-hour-long exposures) make extrapolation of human sound exposure standards inappropriate. Behavioral observations of marine mammals exposed to anthropogenic sound sources exist, however; there are few observations and no controlled measurements of behavioral disruption of cetaceans caused by sound sources with frequencies, waveforms, durations, and repetition rates comparable to those employed by the tactical sonars to be used in the MIRC. At the present time there is no consensus on how to account for behavioral effects on marine mammals exposed to continuous-type sounds (NRC 2003).

This application uses behavioral observations of trained cetaceans exposed to intense underwater sound under controlled circumstances to develop a criterion and threshold for behavioral effects of sound. These data are described in detail in Schlundt et al. (2000) and Finneran and Schlundt (2004). These data, because they are based on controlled, tonal sound exposures within the tactical sonar frequency range, are the most applicable.

When analyzing the results of the acoustic effect modeling to provide an estimate of harassment, it is important to understand that there are limitations to the ecological data used in the model, and to interpret the model results within the context of a given species' ecology.

Limitations in the model include:

- Density estimates (May be limited in duration and time of year and are modeled to derive density estimates).
- The estimates of marine mammal sound exposures are presented without consideration of mitigation which may reduce the potential for estimated sound exposures to occur.
- Overlap of TTS and risk function.

#### 6.8.1.1 Potential Injury

As described previously, with respect to the acoustic model, the model inputs included the lowest sound level at which a response might occur. For example, the model considered the potential of onset of PTS in estimating exposures that might result in permanent tissue damage. Other effects postulated as permanent damage to marine mammal tissues also are considered in evaluating the potential for the estimated acoustic exposures to actually result in tissue damage. Resonance, rectified diffusion and decompression sickness were describe above the arguments for and against were presented with the conclusion that these effects are unlikely to occur.

#### 6.8.1.2 Behavioral Disturbance

TTS used as an onset of physiological response but not at the level of injury. This response is easily measured in a laboratory situation but is difficult to predict in free ranging animals expose to sound. Because it is an involuntary response, it is easier to predict than behavioral responses. The risk function methodology considers other exposures which may include a variety of modes of action that could result in behavioral responses.

Limited information from literature on the proximal responses specific to MFA/HFA sonar and marine mammals require the use of information from other species and from other types of acoustic sources to build a conceptual model for considering issues such as allostatic loading, spatial disorientation, impaired navigation and disrupted life history events, disrupted communication, or increased energy costs. The risk function methodology assumes a range of responses from very low levels of exposure for certain individuals (with some individuals being more reactive then others depending on the situation – i.e., foraging, breeding, migrating), with increasing probability of response as the received sound level increases. The result is estimate of probability that the range of physiological and behavioral responses that might occur are accounted for in determining the number of harassment incidents. The predicted responses using the risk function and TTS methodology are conservatively estimated to result in the disruption of natural behavioral patterns although it is assumed that such behavioral patterns are not abandoned or significantly altered.

#### 6.8.1.3 No Harassment

Although a marine mammal may be exposed to MFA/HFA sonar, it may not respond or may only show a mild response, which may not rise to the level of harassment. In using the risk function it is assumed that the response of animals is variable, depending on their activity, gender or age, and that higher sound levels would elicit a greater response. Each exposure, using the Risk Function methodology, represents the probability of a response that NMFS would classify as harassment under the MMPA. The ESA listed species that may be exposed to MFA/HFA sonar in the MIRC include the blue whale, fin whale, humpback whale, sei whale, and sperm whale. The exposure modeling was completed using the same methodology as that for non-ESA listed species.

##### 6.8.1.3.1 Marine Mammals

The best scientific information on the status, abundance and distribution, behavior and ecology, diving behavior and acoustic abilities are provided for each species expected to be found within the MIRC (Sections 4.1 and 4.2). Information was reviewed on the response of marine mammals to other sound sources such as seismic air guns or ships but these sources tend to be longer in the period of exposure or continuous in nature. The response of marine mammals to those sounds, and MFA sonar, are variable with some animals showing no response or moving toward the sound source while others may move away (Review by Richardson et al. 1995; Andre et al. 1997; Nowacek et al. 2004; Southall et al. 2007). The analytical framework shows the range of physiological and behavioral responses that can occur when an animal is exposed to an acoustic source. Physiological effects include auditory trauma (TTS, PTS, and tympanic membrane rupture), stress or changes in health and bubble formation or decompression sickness. Behavioral responses may occur due to stress in response to the sound exposure. Behavioral responses may include flight response, changes in diving, foraging or reproductive behavior, changes in vocalizations (may cease or increase intensity), changes in migration or movement patterns or the use of certain habitats. Whether an animal responds, the types of behavioral changes, and the magnitude of those changes may depend on the intensity level of the exposure and the individual animal's prior status or behavior. Little information is available to determine the response of animals to MFA/HFA sonar and its effects on ultimate and proximate life functions or at the population or species level.

## 6.8.2 Estimated Effects on ESA Species

The endangered species that may be affected as a result of implementation of the MIRC activities include the blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), and sperm whale (*Physeter macrocephalus*). The modeling estimated that no humpback whales (*Megaptera novaeangliae*) would be exposed to sound or pressure that would reach the threshold of a behavioral response. The north Pacific right whale (*Eubalaena japonica*), Hawaiian monk seal (*Monachus schauinslandi*) and dugong (*Dugong dugon*) were not considered in the modeling because they are extralimital in the area and are not expected to occur in the MIRC.

### 6.8.2.1 Blue Whale

The risk function and Navy post-modeling analysis estimates 60 blue whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No blue whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold, and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the large size (up to 98 ft [30 m]) of individual blue whales (Leatherwood et al. 1982), pronounced vertical blow, and aggregation of approximately two to three animals in a group (probability of track line detection = 0.90 in Beaufort Sea States of 6 or less; Barlow 2003), it is likely that lookouts would detect a group of blue whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

Based on the model results, behavioral patterns, acoustic abilities of blue whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11.1 for sonar and Section 11.2 for underwater detonations, the Navy finds that the MIRC training events may affect but are not likely to adversely affect blue whales. It is unlikely that training activities would result in any death or injury to blue whales. Modeling does indicate the potential for Level B harassment, indicating the proposed ASW exercises may affect blue whales but are not likely to cause long-term effects on their behavior or physiology or abandonment of areas that are regularly used by blue whales.

An ESA consultation will be initiated, and will include the finding that the proposed ASW exercises may affect blue whales. Should consultation under the ESA conclude that the estimated exposures of humpback whales can be avoided using mitigation measures or that the received sound is not likely to adversely affect blue whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 61 blue whales by Level B harassment (61 from MFA/HFA sonar and none from underwater detonations) and no blue whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation.

### 6.8.2.2 Fin Whale

The risk function and Navy post-modeling analysis estimates 86 fin whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No fin whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold, and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the large size (up to 78 ft [24m]) of individual fin whales (Leatherwood et al. 1982), pronounced vertical blow, mean aggregation of three animals in a group (probability of trackline detection = 0.90 in Beaufort Sea States of 6 or less; Barlow 2003) it is likely that lookouts would detect a group of fin whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound; and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS or PTS.

In the St. Lawrence estuary area, fin whales avoided vessels with small changes in travel direction, speed and dive duration, and slow approaches by boats usually caused little response (MacFarlane 1981). Fin whales continued to vocalize in the presence of boat sound (Edds and Macfarlane 1987). Even though any undetected fin whales transiting the MIRC may exhibit a reaction when initially exposed to active acoustic energy, field observations indicate the effects would not cause disruption of natural behavioral patterns to a point where such behavioral patterns would be abandoned or significantly altered.

Based on the model results, behavioral patterns, acoustic abilities of fin whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11.1 for sonar and Section 11.2 for underwater detonations, the Navy finds that the MIRC training events may affect but are not likely to adversely affect fin whales. It is unlikely that MIRC training activities would result in any death or injury to fin whales. Modeling does indicate the potential for Level B harassment, indicating the proposed ASW exercises may affect fin whales but are not likely to cause long-term effects on their behavior or physiology or abandonment of areas that are regularly used by fin whales.

An ESA consultation will be initiated, and will include the finding that the proposed ASW exercises may affect fin whales. Should consultation under the ESA conclude that the estimated exposures of fin whales can be avoided using mitigation measures or that the received sound is not likely to adversely affect fin whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 87 fin whales by Level B harassment (87 from MFA/HFA sonar and none from underwater detonations) and no fin whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation.

#### 6.8.2.3 Humpback Whale

Although humpback whales are known to occur in the MIRC (DoN 2007b), their seasonal migration does not coincide with major exercises, therefore, the risk function and Navy post-modeling analysis estimates that no humpback whales will be exposed to sound levels that exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No humpback whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold, and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the large size (up to 53 ft [16m] of individual humpback whales (Leatherwood et al. 1982), and pronounced vertical blow, it is likely that lookouts would detect humpback whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound; and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

There are no audiograms of baleen whales, but they tend to react to anthropogenic sound below 1 kHz, suggesting that they are more sensitive to low frequency sounds (Richardson et al. 1995). Based on this information, if they do not hear these sounds, they are not likely to respond physiologically or behaviorally to those received levels, such that effects would be insignificant. A single study suggested that humpback whales responded to mid-frequency sonar (3.1-3.6 kHz re 1 µPa$^2$-s) sound (Maybaum 1989). The hand held sonar system had a sound artifact below 1,000 Hz which caused a response to the control playback (a blank tape) and may have affected the response to sonar (i.e. the humpback whale responded to the low frequency artifact rather than the MFA sonar sound). Humpback whales responded to small vessels (often whale watching boats) by changing swim speed, respiratory rates and social interactions depending on proximity to the vessel and vessel speed, with responses varying by social status and gender (Watkins et al. 1981; Bauer 1986; Bauer and Herman 1986). Animals may even move out of the area in response to vessel noise (Salden 1988). Frankel and Clark (2000; 2002) reported that there was only a minor response by humpback whales to the Acoustic Thermometry of Ocean Climate (ATOC) sound source and that response was variable with some animals being found closer to the sound source during use.

Based on the model results, behavioral patterns, acoustic abilities of humpback whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11.1 for sonar and Section 11.2 for underwater detonations, the Navy finds that the MIRC training events may affect but are not likely to adversely affect humpback whales. It is unlikely that MIRC training would result in any death or injury to humpback whales. Modeling does not indicate the potential for Level B harassment, indicating the proposed ASW exercises will not affect humpback whales.

At this time, this application does not request authorization for the annual harassment of humpback whales by Level B or by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation.

#### 6.8.2.4 Sei Whale

The risk function and Navy post-modeling analysis estimates 150 sei whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be two exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No sei whales would be exposed to sound levels that could cause PTS.

Bryde’s whales and sei whales are often difficult to differentiate at sea and the Navy’s 2007 MISTCS survey had three sightings which were classified as Bryde’s/sei whales (DoN 2007b). Therefore, estimates were also made using the density for this group. The risk function and Navy post-modeling analysis estimates 35 Bryde’s/sei whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold; and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the large size (up to 53 ft [16m}) of individual sei whales (Leatherwood et al. 1982), pronounced vertical blow, aggregation of approximately three animals (probability of trackline detection = 0.90 in Beaufort Sea States of 6 or less; Barlow 2003), it is likely that lookouts would detect a group of sei whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound; and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

There is little information on the acoustic abilities of sei whales or their response to human activities. The only recorded sounds of sei whales are frequency modulated sweeps in the range of 1.5 to 3.5 kHz (Thompson et al. 1979) but it is likely that they also vocalized at frequencies below 1 kHz as do fin whales. Sei whales were more difficult to approach than were fin whales and moved away from boats but were less responsive when feeding (Gunther1949).

Based on the model results, behavioral patterns, acoustic abilities of sei whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11.1 for sonar and Section 11.2 for underwater detonations, the Navy finds that the MIRC training events may affect but are not likely to adversely affect sei whales. It is unlikely that MIRC training would result in any death or injury to sei whales. Modeling does indicate the potential for Level B harassment, indicating the proposed ASW exercises may affect sei whales but are not likely to cause long-term effects on their behavior or physiology or abandonment of areas that are regularly used by sei whales.

An ESA consultation will be initiated, and will include the finding that the proposed ASW exercises may affect sei whales. Should consultation under the ESA conclude that the estimated exposures of sei whales can be avoided using mitigation measures or that the received sound is not likely to adversely affect sei whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 152 sei whales by Level B harassment (152 from MFA/HFA sonar and none from underwater detonations) and no sei whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation.

#### 6.8.2.5 Sperm Whale

The risk function and Navy post-modeling analysis estimates 383 sperm whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be five exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No sperm whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the large size (up to 56 ft [17m]) of individual sperm whales (Leatherwood et al. 1982), pronounced blow (large and angled), mean group size of approximately seven animals (probability of trackline detection = 0.87 in Beaufort Sea States of 6 or less; Barlow 2003; 2006), it is likely that lookouts would detect a group of sperm whales at the surface. Sperm whales can make prolonged dives of up to two hours making detection more difficult but passive acoustic monitoring can detect and localize sperm whales from their calls (Watwood et al. 2006). The implementation of mitigation measures to reduce exposure to high levels of sonar sound; and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

In the unlikely event that sperm whales are exposed to mid-frequency sonar, the information available on sperm whales exposed to received levels of active mid-frequency sonar suggests that the response to mid-frequency (1 kHz to 10 kHz) sounds is variable (Richardson et al. 1995). While Watkins et al. (1985) observed that sperm whales exposed to 3.25 kHz to 8.4 kHz pulses interrupted their activities and left the area, other studies indicate that, after an initial disturbance, the animals return to their previous activity. During playback experiments off the Canary Islands, André et al. (1997) reported that foraging sperm whales exposed to a 10 kHz pulsed signal did not exhibit any general avoidance reactions. When resting at the surface in a compact group, sperm whales initially reacted strongly but then ignored the signal completely (André et al. 1997).

Based on the model results, behavioral patterns, acoustic abilities of sperm whales, results of past training, and the implementation of procedure mitigation measures presented in Section 11.1 for sonar and Section 11.2 for underwater detonations, the Navy finds that the MIRC training events may affect but are not likely to adversely affect sperm whales. It is unlikely that MIRC training activities would result in any death or injury to sperm whales. Modeling does indicate the potential for Level B harassment, indicating the proposed ASW exercises may affect sperm whales but are not likely to cause long-term effects on their behavior or physiology or abandonment of areas that are regularly used by sperm whales.

An ESA consultation will be initiated, and will include the finding that the proposed ASW exercises may affect sperm whales. Should consultation under the ESA conclude that the estimated exposures of sperm whales can be avoided using mitigation measures or that the received sound is not likely to adversely affect sperm whales, authorization for the predicted exposures would not be requested under MMPA. At this time, this application requests authorization for the annual harassment of 388 sperm whales by Level B harassment (388 from MFA/HFA sonar and none from underwater detonations) and no sperm whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation.

### 6.8.3 Estimated Exposures for Non-ESA Species

#### 6.8.3.1 Bryde's Whale

The risk function and Navy post-modeling analysis estimates 212 Bryde's whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be four exposures to accumulated acoustic energy above 195 dB re 1 μPa$^2$-s, which is the threshold established indicative of onset TTS. No Bryde's whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the large size (up to 46 ft. [14 m]) of individual Bryde's whales, pronounced blow, and mean group size of approximately 1.5 animals and (probability of trackline detection = 0.87 in Beaufort Sea States of 6 or less; Barlow 2003; 2006), it is likely that lookouts would detect a group of Bryde's whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 216 Bryde's whale by Level B harassment (216 from MFA/HFA sonar and none from underwater detonations) and no Bryde's by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of bottlenose dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to Bryde's whales.

#### 6.8.3.2 Minke Whale

The risk function and Navy post-modeling analysis estimates 207 minke whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be four exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No minke whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Minke whales are difficult to spot visually but can be detected using passive acoustic monitoring. The implementation of mitigation measures to reduce exposure to high levels of sonar sound; and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 211 minke whales by Level B harassment (211 from MFA/HFA sonar and none from underwater detonations) and no minke by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of minke whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to minke whales.

#### 6.8.3.3 Unidentified Balaenopterid Whale

Unidentified Balaenopterid whales (*Balaenoptera* spp.) would include those species, blue, fin, sei, Bryde's, and minke whales that could not be distinguished due to distance from the survey ship and sea conditions. The risk function and Navy post-modeling analysis estimates 34 unidentified Balaenopterid whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be no exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No minke whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 34 unidentified Balaenopterid whales by Level B harassment (34 from MFA/HFA sonar and none from underwater detonations) and no unidentified Balaenopterid whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's

MFA/HFA sonar, behavioral patterns and acoustic abilities of unidentified Balaenopterid whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to unidentified Balaenopterid whales.

#### 6.8.3.4 Blainville's Beaked Whale

The risk function and Navy post-modeling analysis estimates 358 Blainville's beaked whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be six exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No Blainville's beaked whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the size (up to 15.5 ft. [4.7 m]) of individual Blainville's beaked whales, aggregation of 2.3 animals, it is likely that lookouts may detect a group of Blainville's beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 364 Blainville's beaked whales by Level B harassment (364 from MFA/HFA sonar and none from underwater detonations) and no Blainville's beaked whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to Blainville's beaked whales.

#### 6.8.3.5 Bottlenose Dolphin

The risk function and Navy post-modeling analysis estimates 80 bottlenose dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No bottlenose dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the frequent surfacing, aggregation of approximately nine animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2003), it is likely that lookouts would detect a group of bottlenose dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 81 bottlenose dolphins by Level B harassment (81 from MFA/HFA sonar and none from underwater detonations) and no bottlenose dolphins by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of bottlenose dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to bottlenose dolphin.

#### 6.8.3.6 Cuvier's Beaked Whale

The risk function and Navy post-modeling analysis estimates 1,694 Cuvier's beaked whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 22 exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No Cuvier's beaked whale would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be six exposures from impulsive sound or pressures from underwater detonations that would exceed the sub-TTS threshold, two exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold, and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the medium size (up to 23 ft. [7.0 m]) of individual Cuvier's beaked whales, aggregation of approximately two animals (Barlow 2006), lookouts may detect a group of Cuvier's beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 1,724 Cuvier's beaked whales by Level B harassment (1,716 from MFA/HFA sonar and eight from underwater detonations) and no Cuvier's beaked whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of Cuvier's beaked whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to Cuvier's beaked whales.

#### 6.8.3.7 Dwarf/Pygmy Sperm Whale

Dwarf and pygmy sperm whales are difficult to distinguish from each other at sea, and sightings are usually grouped by genus as *Kogia spp*., therefore the two species were combined for acoustic exposure modeling. The risk function and Navy post-modeling analysis estimates 3,114 dwarf/pygmy sperm whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 50 exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No dwarf/pygmy sperm whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be six exposures from impulsive sound or pressures from underwater detonations that would exceed the sub-TTS threshold, two exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold, and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8). The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 3,172 dwarf/pygmy sperm whales by Level B harassment (3,164 from MFA/HFA sonar and eight from underwater detonations) and no dwarf/pygmy sperm whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of dwarf/pygmy sperm whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to dwarf sperm whales.

#### 6.8.3.8 False Killer Whale

The risk function and Navy post-modeling analysis estimates 608 false killer whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 12 exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No false killer whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their size (up to 19.7 ft) and large mean group size of 10.3 animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2003), it is very likely that lookouts would detect a group of false killer whales at the surface. Additionally, mitigation measures call for continuous visual observation during training with active sonar; therefore, false killer whales that are present in the vicinity of ASW training events would be detected by visual observers. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 620 false killer whales by Level B harassment (620 from MFA/HFA sonar and none from underwater detonations) and no false killer whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of false killer whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to false killer whales.

#### 6.8.3.9 Fraser's Dolphin

The risk function and Navy post-modeling analysis estimates 2,150 Fraser's dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 36 exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No Fraser's dolphins would be exposed to sound levels that could cause PTS.

Modeling indicates there would be six exposures from impulsive sound or pressures from underwater detonations that would exceed the sub-TTS threshold, two exposures to impulsive noise or pressures from underwater detonations of 182 dB or 23 psi, which is the threshold indicative of onset TTS, and no exposures to impulsive noise or pressures from underwater detonations that would cause slight physical injury or onset of massive lung injury (Table 6-8).

Given their large aggregations, mean group size of 286.3 animals (probability of trackline detection = 1.00 in Beaufort Sea States of 6 or less; Barlow 2006), it is very likely that lookouts would detect a group of Fraser's dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound; and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 2,194 Fraser's dolphins by Level B harassment (2,186 from MFA/HFA sonar and eight from underwater detonations) and no Fraser's by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of Fraser's dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to Fraser's dolphins.

#### 6.8.3.10 Ginkgo-toothed Beaked Whale

The risk function and Navy post-modeling analysis estimates 199 ginkgo-toothed beaked whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be three exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No ginkgo-toothed beaked whale would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the size (up to 15.5 ft. [4.7 m]) of individual ginkgo-toothed beaked whales, aggregation of 2.3 animals, lookouts may detect a group of ginkgo-toothed beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 202 ginkgo-toothed beaked whales by Level B harassment (202 from MFA/HFA sonar and none from underwater detonations) and no ginkgo-toothed beaked whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of ginkgo-toothed beaked whale, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to ginkgo-toothed beaked whales.

#### 6.8.3.11 Killer Whale

The risk function and Navy post-modeling analysis estimates 108 killer whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be two exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No killer whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their size (up to 23 ft [7.0 m]), conspicuous coloring, pronounce dorsal fin and large mean group size of 6.5 animals (probability of trackline detection = 0.90 in Beaufort Sea States of 6 or less; Barlow, 2003) it is very likely that lookouts would detect a group of killer whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 110 killer whales by Level B harassment (110 from MFA/HFA sonar and none from underwater detonations) and no killer whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of killer whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to killer whale.

#### 6.8.3.12 Longman's Beaked Whale

The risk function and Navy post-modeling analysis estimates 96 Longman's beaked whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No Longman's beaked whale would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the size (up to 15.5 ft. [4.7 m]) of individual Longman's beaked whales, aggregation of 2.3 animals, lookouts may detect a group of Longman's beaked whales at the surface although beaked whales make prolonged dives that can last up to an hour (Baird et al. 2004). The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 97 Longman's beaked whales by Level B harassment (97 from MFA/HFA sonar and none from underwater detonations) and no ginkgo-toothed beaked whales by Level A harassment from potential exposure to MFA/HFA sonar or underwater detonation. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of Longman's beaked whale, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to Longman's beaked whales.

#### 6.8.3.13 Melon-headed Whale

The risk function and Navy post-modeling analysis estimates 1,334 melon-headed whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 22 exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No melon-headed whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be would be six exposures from impulsive sound or pressures from underwater detonations that would exceed the sub-TTS threshold, two exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, exposures that would exceed the onset of slight injury threshold, and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Mitigation measures call for continuous visual observation during training with active sonar. Given their size (up to 8.2 ft) and large group size (mean of 89.2 whales) or more animals (probability of trackline detection = 1.00 in Beaufort Sea States of 6 or less; Barlow, 2003), it is very likely that lookouts would very likely detect a group of melon-headed whales at the surface during ASW training events. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 1,364 melon-headed whales by Level B harassment (1,356 from MFA/HFA sonar and eight from underwater detonations) and no melon-headed whales by Level A harassment from potential exposure to underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of melon-headed whales, observations made during past training events, and the planned implementation of mitigation (11.1 for sonar and 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to melon-headed whales.

#### 6.8.3.14 Pantropical Spotted Dolphin

The risk function and Navy post-modeling analysis estimates 15,215 pantropical spotted dolphin will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 245 exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No pantropical spotted dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be six exposures from impulsive sound or pressures from underwater detonations that would exceed the sub-TTS threshold, two exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, no exposures that would exceed the onset of slight injury threshold and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Mitigation measures call for continuous visual observation during training with active sonar and underwater detonations. Given their frequent surfacing and large group size hundreds of animals (Leatherwood et al. 1982), mean group size of 60.0 animals in Hawaii and probability of trackline detection of 1.00 in Beaufort Sea States of 6 or less (Barlow 2006), it is very likely that lookouts would detect a group of pantropical spotted dolphins at the surface during ASW training events. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 15,468 pantropical spotted dolphins by Level B harassment (15,460 from MFA/HFA sonar and eight from underwater detonations) and no pantropical spotted dolphins by Level A harassment from potential exposure to active sonar or underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of pantropical spotted dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to pantropical spotted dolphins.

#### 6.8.3.15 Pygmy Killer Whale

The risk function and Navy post-modeling analysis estimates 75 pygmy killer whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be one exposure to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No pygmy killer whales would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, one that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Mitigation measures call for continuous visual observation during training with active sonar. Given their size (up to 8.5 ft) and mean group size of 14.4 animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2003), it is likely that lookouts would detect a group of pygmy killer whales at the surface during ASW training events. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 76 pygmy killer whales by Level B harassment (76 from MFA/HFA sonar and none from underwater detonations) and no pygmy killer whales by Level A harassment from potential exposure to underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of pygmy killer whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to pygmy killer whales.

#### 6.8.3.16 Risso's Dolphin

The risk function and Navy post-modeling analysis estimates 3,150 Risso's dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 53 exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No Risso's dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be would be 12 exposures from impulsive sound or pressures from underwater detonations that would exceed the sub-TTS threshold, four exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, no exposures that would exceed the onset of slight injury threshold and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their frequent surfacing, light coloration and large group size of up to several hundred animals (Leatherwood et al. 1982), mean group size of 15.4 Risso's dolphins and probability of trackline detection of 0.76 in Beaufort Sea States of 6 or less (Barlow 2006), it is likely that lookouts would detect a group of Risso's dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 3,219 Risso's dolphins by Level B harassment (3,203 from MFA/HFA sonar and 16 from underwater detonations) and no Risso's dolphins by Level A harassment from potential exposure to underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of Risso's dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to Risso's dolphins.

#### 6.8.3.17 Rough-toothed Dolphin

The risk function and Navy post-modeling analysis estimates 111 rough-toothed dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be two exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No rough-toothed dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Mitigation measures call for continuous visual observation during training with active sonar and underwater detonations. Given their frequent surfacing and mean group size of 14.8 animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2006), it is likely that lookouts would detect a group of rough-toothed dolphins at the surface during ASW training events. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 113 rough-toothed dolphins by Level B harassment (113 from MFA/HFA sonar and none from underwater detonations), no rough-toothed dolphins by Level A harassment or that could cause severe lung injury or mortality. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of rough-toothed dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to rough-toothed dolphins.

#### 6.8.3.18 Short-Beaked Common Dolphin

The risk function and Navy post-modeling analysis estimates 434 short-beaked common dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be eight exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No short-beaked common dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposures that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given the frequent surfacing and their large group size of up to 1,000 animals (Leatherwood et al. 1982), it is very likely, that lookouts would detect a group of short-beaked common dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 442 short-beaked common dolphins by Level B harassment (442 from MFA/HFA sonar and none from underwater detonations), xx short-beaked common dolphins by Level A harassment (five from MFA/HFA sonar and xx from underwater detonations), no exposures to underwater detonations that could cause severe lung injury or mortality. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of short-beaked common dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to short-beaked common dolphins.

#### 6.8.3.19 Short-finned Pilot Whale

The risk function and Navy post-modeling analysis estimates 1,064 short-finned pilot whales will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 17 exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No short-finned pilot whale would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their size (up to 20 ft [6.1 m]), and large mean group size of 22.5 animals (probability of trackline detection = 0.76 in Beaufort Sea States of 6 or less; Barlow 2006), it is likely that lookouts would detect a group of short-finned pilot whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 1,081 short-finned pilot whales by Level B harassment (1,081 from MFA/HFA sonar and none from underwater detonations) and no short-finned pilot whales by Level A harassment from potential exposure to from MFA/HFA sonar or underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of short-finned pilot whales, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to short-finned pilot whales.

#### 6.8.3.20 Spinner Dolphin

The risk function and Navy post-modeling analysis estimates 998 spinner dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 17 exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No spinner dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their frequent surfacing, aerobatics and large mean group size of 31.7 animals (probability of trackline detection = 1.00 in Beaufort Sea States of 6 or less; Barlow 2006), it is likely that lookouts would detect a group of spinner dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 1,015 spinner dolphins by Level B harassment (1,015 from MFA/HFA sonar and none from underwater detonations) and no spinner dolphins by Level A harassment from potential exposures from MFA/HFA sonar or underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of spinner dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to spinner dolphins.

#### 6.8.3.21 Striped Dolphin

The risk function and Navy post-modeling analysis estimates 4,148 striped dolphins will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 67 exposures to accumulated acoustic energy above 195 dB re 1 µPa$^2$-s, which is the threshold established indicative of onset TTS. No striped dolphins would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their frequent surfacing, aerobatics and large mean group size of 37.3 animals (probability of trackline detection = 1.00 in Beaufort Sea States of 6 or less; Barlow 2006), it is likely that lookouts would detect a group of striped dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 4,215 striped dolphins by Level B harassment (4,215 from MFA/HFA sonar and none from underwater detonations) and no striped dolphins by Level A harassment from potential exposure to from MFA/HFA sonar or underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of striped dolphins, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to striped dolphins.

#### 6.8.3.22 Unidentified Delphinids

The risk function and Navy post-modeling analysis estimates 721 unidentified dephinids will exhibit behavioral responses NMFS will classify as harassment under the MMPA (Table 6-7). Modeling also indicates there would be 12 exposures to accumulated acoustic energy above 195 dB re 1 $\mu Pa^2$-s, which is the threshold established indicative of onset TTS. No unidentified dephinids would be exposed to sound levels that could cause PTS.

Without consideration of clearance procedures, there would be no exposures from impulsive sound or pressures from underwater detonations that would exceed the TTS threshold, none that would exceed the onset of slight injury threshold and no exposure that would exceed the onset of massive lung injury or mortality threshold (Table 6-8).

Given their frequent surfacing and generally large groups of delphinids species, it is likely that lookouts would detect a group of striped dolphins at the surface. The implementation of mitigation measures to reduce exposure to high levels of sonar sound, and the short duration and intermittent exposure to sonar, reduces the likelihood that exposure to MFA/HFA sonar sound would cause a behavioral response that may affect vital functions (reproduction or survival), TTS, or PTS.

At this time, this application requests authorization for the annual harassment of 733 unidentified dephinids by Level B harassment (733 from MFA/HFA sonar and none from underwater detonations) and no unidentified dephinids by Level A harassment from potential exposure to from MFA/HFA sonar or underwater detonations. Based on the model results, the nature of the Navy's MFA/HFA sonar, behavioral patterns and acoustic abilities of unidentified dephinids, observations made during past training events, and the planned implementation of mitigation (Section 11.1 for sonar and Section 11.2 for underwater detonations) measures, the Navy finds that the MIRC training events would not result in any population level effects, death or injury to unidentified dephinids.

# 7 IMPACTS TO MARINE MAMMAL SPECIES OR STOCKS

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

- All of the acoustic harassments are within the non-injurious TTS or behavioral effects zones (Level B harassment). There are no estimated exposures to sound levels that could cause PTS/injury (Level A harassment).
- Although the numbers presented in Tables 6-7 and 6-8 represent estimated harassment under the 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 mitigation measures, and is not indicative of a likelihood of either injury or harm.
- Additionally, the mitigation 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 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). Based on each species’ life history information, the expected behavioral patterns in the MIRC training and exercise locations, and an analysis of the behavioral disturbance levels in comparison to the overall population, an analysis of the potential impacts of the Proposed Action on species recruitment or survival is presented in Section 6.8 for each species. These species-specific analyses support the conclusion that proposed MIRC training events would have a negligible impact on marine mammals.

This authorization request assumes that short-term non-injurious sound exposure levels predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment. As discussed, this will overestimate reactions qualifying as harassment under MMPA because there is no established scientific correlation between MFA/HFA sonar use and long term abandonment or significant alteration of behavioral patterns in marine mammals. As detailed in Table 6-7 and Table 6-8, the total Level B takes is 37,503 (includes both MFA/HFA sonar and underwater detonations) and the total Level A takes are zero in this authorization request.

Neither NMFS nor the Navy anticipates that marine mammal strandings or indirectly caused mortality will result from the use of mid-frequency sonar during Navy exercises within the MIRC. However, to allow for scientific uncertainty regarding the strandings of beaked whales and the exact mechanisms of the physical effects, the Navy will request authorization for take, by indirectly caused mortality, of the beaked whale species present in the MIRC despite the decades long history of these same training activities with the same basic equipment having had no known effect on beaked whales or any other marine mammals. This request will include take by mortality of three Cuvier’s beaked whales, two Blainville’s beaked whales, two Longman’s beaked whale, one Ginkgo-tooth beaked whale, one Hubbs beaked whale, and one pantropical spotted dolphin for a total of 10 mortality takes. These numbers are based on worldwide historical stranding data and species occurance in the area.

# 8 IMPACT ON SUBSISTENCE USE

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

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

The primary source of effects to marine mammal habitat is exposures resulting from Pacific Fleet training activities. Sources that may affect marine mammal habitat include changes in water quality, introduction of sound into the water column, transiting vessels, and expendable material. Each of these components was considered in the MIRC Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) and was determined to have no effect on marine mammal habitat. A summary of the conclusions are included in subsequent sections.

There are no marine mammal critical habitats or known breeding areas within the MIRC. Most of the offshore area within the MIRC could potentially be utilized for active sonar activities or underwater detonations. Much is unknown about the specifics of dolphin mating, but it is presumed that these species mate throughout their habitat and possibly throughout the year. Even less is known about the mating habits of beaked whales. The Navy assumes that active sonar activities could take place within potential mating areas of these toothed whale species within the MIRC, although current state of knowledge is very limited and there may be seasonal components to distribution that could account for breeding activities outside of the MIRC. Baleen whales and sperm whales breed seasonally within the MIRC and some calves were seen with sperm, Bryde’s and sei whales (DoN 2007b) although it is not known where breeding and calving areas occur.

## 9.1 Water Quality

The MIRC EIS/OEIS analyzed the potential effects to water quality from sonobuoy, ADCs, and Expendable Mobile Acoustic Training Target (EMATT) batteries; explosive packages associated with the explosive source sonobuoy (AN/SSQ-110A), and Otto Fuel (OF) II combustion byproducts associated with torpedoes. Expendable bathythermographs do not have batteries and were not included in the analysis. In addition, sonobuoys were not analyzed since, once scuttled, their electrodes are largely exhausted during use and residual constituent dissolution occurs more slowly than the releases from activated seawater batteries. As such, only the potential effects of batteries and explosions on marine water quality in and surrounding the sonobuoy training area were completed. It was determined that there would be no significant effect to water quality from seawater batteries, lithium batteries, and thermal batteries associated with scuttled sonobuoys.

ADCs and EMATTs use lithium sulfur dioxide batteries. The constituents in the battery react to form soluble hydrogen gas and lithium dithionite. The hydrogen gas eventually enters the atmosphere and the lithium hydroxide dissociates, forming lithium ions and hydroxide ions. The hydroxide is neutralized by the hydronium formed from hydrolysis of the acidic sulfur dioxide, ultimately forming water. Sulfur dioxide, a gas that is highly soluble in water, is the major reactive component in the battery. The sulfur ioxide ionizes in the water, forming bisulfite (HSO3) that is easily oxidized to sulfate in the slightly alkaline environment of the ocean. Sulfur is present as sulfate in large quantities (i.e., 885 milligrams per liter [mg/L]) in the ocean. Thus, it was determined that there would be no significant effect to water quality from lithium sulfur batteries associated with scuttled ADCs and EMATTs.

Only a very small percentage of the available hydrogen fluoride explosive product in the explosive source sonobuoy (AN/SSQ-110A) is expected to become solubilized prior to reaching the surface and the rapid dilution would occur upon mixing with the ambient water. As such, it was determined that there would be no significant effect to water quality from the explosive product associated with the explosive source sonobuoy (AN/SSQ-110A).

OF II is combusted in the torpedo engine and the combustion byproducts are exhausted into the torpedo wake, which is extremely turbulent and causes rapid mixing and diffusion. Combustion byproducts include carbon dioxide, carbon monoxide, water, hydrogen gas, nitrogen gas, ammonia, hydrogen cyanide, and nitrogen oxides. All of the byproducts, with the exception of hydrogen cyanide, are below the EPA water quality criteria. Hydrogen cyanide is highly soluble in seawater and dilutes below the EPA criterion within 6.3 m (20.7 ft) of the torpedo. Therefore, it was determined there would be no significant effect to water quality as a result of OF II.

## 9.2 Sound

### 9.2.1 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 (Advisory Committee On Acoustic Impacts to Marine Mammals 2006). 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 Pacific Ocean;
- Operational parameters of the sonar operating during MIRC 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.

Sources of oceanic ambient noise, including physical, biological, and anthropogenic, are presented in the MIRC EIS/OEIS. 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 Gulf of Mexico, generally range from approximately 40 dB to about 110 dB (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 Hz, and 200 to 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 use. 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, 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 to 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 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 2007a).

The 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 seconds. 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 in3). 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 activities because the hull of the ship is a good transmitter of all the ship's internal noises. In addition, 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). These oil and gas industry activities occur year-round (not individual surveys, but collectively) and are usually operational 24 hours per day and 7 days per week.

There are both military and commercial sonars: military sonars are used for target detection, localization, and classification; 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. 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 the fact that both the vessel and animal are moving provide a very 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.

## 9.2.2 Sound Effects of Food Resources

### 9.2.2.1 Fish resources

The data obtained to date on effects of sound on fish are very limited both in terms of number of well controlled studies and in number of species tested. Moreover, there are significant limits in the range of data available for any particular type of sound source. Finally, most of the data currently available has little to do with actual behavior of fish in response to sound in their normal environment. As discussed, the extent of data, and particularly scientifically peer-reviewed data, on the effects of high intensity sounds on fish is exceedingly limited (Popper et al. 2007; Popper 2008). Some of these limitations include:

Types of sources tested; Effects of individual sources as they vary by such things as intensity, repetition rate, spectrum, distance to the animal, etc.; Number of species tested with any particular source; The ability to extrapolate between species that are anatomically, physiologically, and/or taxonomically, different; Potential differences, even within a species as related to fish size (and mass) and/or developmental history; Differences in the sound field at the fish, even when studies have used the same type of sound source (e.g., seismic airgun); Poor quality experimental design and controls in many of the studies to date; Lack of behavioral studies that examine the effects on, and responses of, fish in their natural habitat to high intensity signals; Lack of studies on how sound may impact stress, and the short- and long-term effects of acoustic stress on fish; and Lack of studies on eggs and larvae that specifically use sounds of interest to the Navy.

At the same time, in considering potential sources that are in the mid- and high-frequency range, a number of potential effects are clearly eliminated. Most significantly, since the vast majority of fish species studied to date are hearing generalists and cannot hear sounds above 500 to 1,500 Hz (0.5 to 1.5 kHz) (depending upon the species), there are not likely to be behavioral effects on these species from higher frequency sounds such as MFA/HFA sonar.

Moreover, even those marine species that may hear above 1.5 kHz, such as a few sciaenids and the clupeids (and relatives), have relatively poor hearing above 1.5 kHz as compared to their hearing sensitivity at lower frequencies. Thus, it is reasonable to suggest that even among the species that have hearing ranges that overlap with some mid- and high-frequency sounds, it is likely that the fish will only actually hear the sounds if the fish and source are very close to one another. And, finally, since the vast majority of sounds that are of biological relevance to fish are below 1 kHz (e.g., Zelick et al. 1999; Ladich and Popper 2004), even if a fish detects a mid- or high-frequency sound, these sounds will not mask detection of lower frequency biologically relevant sounds. Thus, a reasonable conclusion, even without more data, is that there will be few, and more likely no, impacts on the behavior of fish. At the same time, it is possible that very intense mid- and high-frequency signals, and particularly explosives, could have a physical impact on fish, resulting in damage to the swim bladder and other organ systems. However, even these kinds of effects have only been shown in a few cases in response to explosives, and only when the fish has been very close to the source. Such effects have never been shown to any Navy sonar. Moreover, at greater distances (the distance clearly would depend on the intensity of the signal from the source) there appears to be little or no impact on fish, and particularly no impact on fish that do not have a swim bladder or other air bubble that would be affected by rapid pressure changes.

#### 9.2.2.2 Invertebrates Food Resources

Very little is known about sound detection and use of sound by invertebrates (see Budelmann 1992a, b, Popper et al. 2001 for reviews). The limited data shows that some crabs are able to detect sound, and there has been the suggestion that some other groups of invertebrates are also able to detect sounds. In addition, cephalopods (octopus and squid) and decapods (lobster, shrimp, and crab) are thought to sense low-frequency sound (Budelmann 1992b). Packard et al. (1990) reported sensitivity to sound vibrations between 1-100 Hz for three species of cephalopods. McCauley et al. (2000) found evidence that squid exposed to seismic airguns show a behavioral response including inking. However, these were caged animals, and it is not clear how unconfined animals may have responded to the same signal and at the same distances used. In another study, Wilson et al. (2007) played back echolocation clicks of killer whales to two groups of squid (*Loligo pealeii*) in a tank. The investigators observed no apparent behavioral effects or any acoustic debilitation from playback of signals up to 199 to 226 dB re 1 µPa. It should be noted, however, that the lack of behavioral response by the squid may have been because the animals were in a tank rather than being in the wild. In another report on squid, Guerra et al. (2004) claimed that dead giant squid turned up around the time of seismic airgun operations off of Spain. The authors suggested, based on analysis of carcasses, that the damage to the squid was unusual when compared to other dead squid found at other times. However, the report presents conclusions based on a correlation to the time of finding of the carcasses and seismic testing, but the evidence in support of an effect of airgun activity was totally circumstantial. Moreover, the data presented showing damage to tissue is highly questionable since there was no way to differentiate between damage due to some external cause (e.g., the seismic airgun) and normal tissue degradation that takes place after death, or due to poor fixation and preparation of tissue. To date, this work has not been published in peer reviewed literature, and detailed images of the reportedly damaged tissue are also not available.

In summary, baleen whales feed on the aggregations of krill and small schooling fish, while toothed whales feed on epipelagic, mesopelagic, and bathypelagic fish and squid. As summarized above and in the MIRC EIS/OEIS in more detail, potential impacts to marine mammal food resources within the MIRC is negligible given both lack of hearing sensitivity to mid-frequency sonar, the very geographic and spatially limited scope of most Navy at sea activities including underwater detonations, and the high biological productivity of these resources. No short or long term effects to marine mammal food resources from Navy activities are anticipated within the MIRC.

## 9.3 Vessel Movement

Collisions with commercial and Navy ships can cause major wounds and may occasionally cause fatalities to cetaceans. 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., sperm whale). In addition, some baleen whales, such as the northern right whale and fin whale swim slowly and seem generally unresponsive to ship sound, making them more susceptible to ship strikes (Nowacek et al. 2004). Smaller marine mammals, for example, the delphinids move quickly throughout the water column and are often seen riding the bow wave of large ships. Marine mammal responses to vessels may include avoidance and changes in dive pattern (NRC 2003).

Unlike many commercial and recreational ships and boats, Navy ships usually maintain as low a speed as practical in terms of the tactical and transit considerations for a particular event in order to economize on fuel and associated fuel costs. In addition, each Navy vessel has at least three lookouts maintaining a visual search of the surrounding water during non-ASW events, and five lookouts during ASW-events. Not included in this count are additional observers involved with safe navigation (Officer of the Deck, Conning Officer, and other personnel on the bridge watch).

The Navy has adopted mitigation measures that reduce the potential for collisions with surfaced marine mammals and sea turtles (See Section 11). These standard operating procedures include: (1) use of lookouts trained to detect all objects on the surface of the water, including marine mammals; (2) reasonable and prudent actions to avoid the close interaction of Navy assets and marine mammals; and (3) maneuvering to keep away from any observed marine mammal. Based on these standard operating procedures, collisions with marine mammals are not expected.

## 9.4 Torpedoes

There is a negligible risk that a marine mammal could be struck by a torpedo during ASW training activities. This conclusion is based on (1) review of torpedo design features, and (2) review of a large number of previous naval exercise ASW torpedo activities. The acoustic homing programs of torpedoes are designed to detect either the mechanical sound signature of the submarine or active sonar returns from its metal hull with large internal air volume interface. The torpedoes are specifically designed to ignore false targets. As a result, their homing logic does not detect or recognize the relatively small air volume associated with the lungs of marine mammals. They do not detect or home to marine mammals. The Navy has conducted exercise torpedo activities since 1968. At least 14,322 exercise torpedo runs have been conducted since 1968. There have been no recorded or reported instances of a marine species strike by an exercise torpedo. Every exercise torpedo activity is monitored acoustically by on-scene range personnel listening to range hydrophones positioned on the ocean floor in the immediate vicinity of the torpedo activity. After each torpedo run, the recovered exercise torpedo is thoroughly inspected for any damage. The torpedoes then go through an extensive production line refurbishment process for re-use. This production line has stringent quality control procedures to ensure that the torpedo will safely and effectively operate during its next run. Since these exercise torpedoes are frequently used against manned

Navy submarines, this post activity inspection process is thorough and accurate. Inspection records and quality control documents are prepared for each torpedo run. This post exercise inspection is the basis that supports the conclusion of negligible risk of marine mammal strike. Therefore, there will be no significant impact and no significant harm to marine mammals resulting from interactions with torpedoes during MIRC activities. The probability of direct strike of torpedoes associated with MIRC training is negligible and therefore will have no effect on marine mammal species.

## 9.5 Military Expendable Material

Marine mammals are subject to entanglement in expended materials, particularly anything incorporating loops or rings, hooks and lines, or sharp objects. Most documented cases of entanglements occur when whales encounter the vertical lines of fixed fishing gear. This section summarizes the potential effects of expended materials on marine mammals. Detailed discussion of military expendable material is contained within the MIRC EIS/OEIS.

The Navy endeavors to recover expended training materials. Notwithstanding, it is not possible to recover all training debris, and some may be encountered by marine mammals in the waters of the MIRC. Debris related to military activities that is not recovered generally sinks; the amount that might remain on or near the sea surface is low, and the density of such debris in the MIRC would be very low. Types of training debris that might be encountered include: parachutes of various types (e.g., those employed by personnel or on targets, flares, or sonobuoys); torpedo guidance wires, torpedo “flex hoses;” cable assemblies used to facilitate target recovery; sonobuoys; and Expendable Mobile Acoustic Training Targets (EMATT).

Entanglement in military expendable material was not cited as a source of injury or mortality for any marine mammals recorded in a large marine mammal and sea turtle stranding database for California waters, an area with much higher density of marine mammals. Therefore as discussed in the MIRC EIS/OEIS, expendable material is highly unlikely to directly affect marine mammal species or potential habitat within the MIRC.

## 9.6 Summary

Based on detailed review within the MIRC EIS/OEIS and summarized within this section, there will be no effects to marine mammals resulting from loss or modification of marine mammal habitat including water quality, food resources, vessel movement, and expendable material. Marine mammal habitat would not be affected.

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

Based on the discussions in Chapter 9, there will be no impacts to marine mammals resulting from loss or modification of marine mammal habitat.

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

Effective training in the MIRC dictates that ship, submarine, and aircraft participants utilize their sensors and exercise weapons to their optimum capabilities as required by the mission. The Navy recognizes that such use has the potential to cause behavioral disruption of some marine mammal species in the vicinity of an exercise (as outlined in Chapter 6). Although any disruption of natural behavioral patterns is not likely to be to a point where such behavioral patterns are abandoned or significantly altered, this Chapter presents the Navy's mitigation measures, outlining steps that would be implemented to protect marine mammals and Federally-ESA listed species during training activities. It should be noted that these mitigation measures have been standard operating procedures for unit level ASW training since 2004. In addition, the Navy coordinated with the NMFS to further develop measures for protection of marine mammals during the period of the National Defense Exemption (NDE), and those mitigations for MFA sonar are detailed in this Section. This Chapter also presents a discussion of other measures that have been considered and rejected because they are either: (1) not feasible, (2) present a safety concern, (3) provide no known or ambiguous mitigation benefit, or (4) impact the effectiveness of the required ASW training military readiness activity.

A Letter of Instruction, Mitigation Measures Message or Environmental Annex to the Operational Order will be issued prior to each exercise to further disseminate the personnel training requirement and general marine mammal mitigation measures including monitoring and reporting. The Navy will continue to fund marine mammal research as outlined in Chapter 14.

This section includes mitigation measures that are followed for all types of exercises; those that are associated with a particular type of training event; and those that apply generally to all Navy training at sea. For major exercises, the applicable mitigation measures are incorporated into a naval message which is disseminated to all of the units participating in the exercise or training event and applicable responsible commands. Non-US participants in exercises taking place within the territorial seas of the US (12 nm) are requested to comply with appropriate measures to the extent these measures do no conflict with status of forces agreements. Non-US participants involved in exercises beyond the territorial seas (12nm) are encouraged to comply with these measures to the extent the measures do not impair training, operations, or operational capabilities.

## 11.1 ASW Vessel Mitigation Measures

Effective training dictates that ship, submarine, and aircraft participants use their sensors and exercise weapons (i.e., torpedoes) to their optimum capabilities. The Navy recognizes that such use may cause behavioral disruption of some marine mammal species in the MIRC Study Area and is therefore incidental take statement from the National Marine Fisheries Service. This section describes the Navy's proposed mitigation measures that would be implemented to protect marine mammals during the proposed active sonar activities.

In addition, marine mammals may be exposed to sound energy levels sufficient to cause a physiological effect. As described in Section 6.1, certain received sound energy levels are associated with temporary threshold shift (TTS), a temporary hearing loss, or permanent threshold shift (PTS), a permanent hearing loss, over a subsection of an animal's hearing range. The mitigation measures described in this section will limit potential exposures within the range of sonar use that could result in physiological effects.

The typical ranges, or distances, from the most powerful and common active sonar sources used in Mariana Islands Range Complex (MIRC) to received sound energy levels associated with TTS and PTS are shown in Table 11-1. Due to spreading loss, sound attenuates logarithmically from the source, so the area in which an animal could be exposed to potential injury (PTS) is small. Because the most powerful sources would typically be used in deep water and the range to effect is limited, spherical spreading is assumed for 195 decibels referenced to 1 micro-Pascal squared second (dB re 1µPa$^2$-s) and above. Also, due to the limited ranges, interactions with the bottom or surface ducts are rarely an issue.

**Table 11-1. Range to Effects for Active Sonar**

| Active Sonar Source | Range To TTS (ft/m) | Range to PTS (ft/m) |
|---|---|---|
| SQS-53 ship | 459/140 | 33/10 |
| SQS-56 ship | 108/33 | 11/3.2 |

Current protective measures employed by the Navy include applicable training of personnel and implementation of activity specific procedures resulting in minimization and/or avoidance of interactions with protected resources.

Navy shipboard lookout(s) are highly qualified and experienced observers of the marine environment. Their duties require that they report all objects sighted in the water to the Officer of the Deck (e.g., trash, a periscope, a marine mammal) and all disturbances (e.g., surface disturbance, discoloration) that may be indicative of a threat to the vessel and its crew. There are personnel serving as lookouts on station at all times (day and night) when a ship or surfaced submarine is moving through the water.

Navy lookouts undergo extensive training. This training includes on-the-job instruction under the supervision of an experienced lookout, followed by completion of the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects and night observation techniques). In addition to these requirements, many Fleet lookouts periodically undergo a 2-day refresher training course.

The Navy includes marine species awareness as part of its training for its bridge lookout personnel on ships and submarines. Marine Species Awareness Training (MSAT) was updated in 2005, and the additional training materials are now included as required training for Navy lookouts. This training addresses the lookout’s role in environmental protection, laws governing the protection of marine species, Navy stewardship commitments, and general observation information to aid in avoiding interactions with marine species. Marine species awareness and training is reemphasized by the following means:

- **Bridge personnel on ships and submarines**—Personnel utilize marine species awareness training techniques as standard operating procedure, they have available a marine species visual identification aid when marine mammals are sighted, and they receive updates to the current marine species awareness training as appropriate.

- **Aviation units**—Pilots and air crew personnel whose airborne duties during ASW training activities include searching for submarine periscopes would be trained in marine mammal spotting. These personnel would also be trained on the details of the mitigation measures specific to both their platform and that of the surface combatants with which they are associated.

- **Sonar personnel on ships, submarines, and ASW aircraft**—Both passive and active sonar operators on ships, submarines, and aircraft utilize protective measures relative to their platform. The Navy issues a Letter of Instruction for each Major Exercise which mandates specific actions to be taken if a marine mammal is detected, and these actions are standard operating procedure throughout the exercise.

Implementation of these protective measures is required of all units. The activities undertaken on a Navy vessel or aircraft are highly controlled. The chain of command supervises these activities. Failure to follow orders can result in disciplinary action.

As noted previously, on January 23, 2007, the Deputy Secretary of Defense issued National Defense Exemption (NDE) II exempting all military readiness activities that employ MFA sonar during Major Exercises or within established Department of Defense (DoD) maritime ranges or established operating areas (OPAREAs) from the permitting requirements of MMPA. This exemption covers activities for 2 years from the signing of NDE II. To adhere with NDE II, all exempt military readiness activities employing MFA sonar must follow the required 29 mitigation measures detailed below under three topic headings: Personnel Training (Section 11.1.1); Lookout Responsibilities (Section 11.1.2); and Operating Procedures (Section 11.1.3). One Operating Procedure involving Safety Zones varies slightly from the NDE II text based on coordination between Navy and NMFS and is captured in its current form in Section 11.1.3. The NDE II language is provided in footnotes. Procedures involving coordination and reporting (the remaining three measures stipulated in the NDEII) are presented in the subsequent section titled Coordination and Reporting since they are not mitigation measures per se.

### 11.1.1 Personnel Training

All lookouts onboard platforms involved in ASW training events will review the NMFS approved MSAT material prior to MFA sonar use.

All Commanding Officers, Executive Officers, and officers standing watch on the Bridge will have reviewed the MSAT material prior to a training event employing the use of MFA sonar.

Navy personnel will undertake extensive training in order to qualify as a lookout in accordance with the Lookout Training Handbook (Naval Education and Training [NAVEDTRA] 12968-B).

Lookout training will include on-the-job instruction under the supervision of a qualified, experienced lookout. Following successful completion of this supervised training period, Lookouts will complete the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects). This does not preclude personnel being trained as lookouts from being counted as those listed in previous measures so long as supervisors monitor their progress and performance.

Lookouts will be trained in the most effective means to ensure quick and effective communication within the command structure in order to facilitate implementation of protective measures if marine species are spotted.

### 11.1.2 Lookout Responsibilities

On the bridge of surface ships, there will always be at least three people on watch whose duties include observing the water surface around the vessel.

In addition to the three personnel on watch noted previously, all surface ships participating in ASW exercises will have at all times during the exercise at least two additional personnel on watch as lookouts.

Personnel on lookout and officers on watch on the bridge will have at least one set of binoculars available for each person to aid in the detection of marine mammals.

On surface vessels equipped with MFA sonar, pedestal mounted “Big Eye” (20x110) binoculars will be present and in good working order to assist in the detection of marine mammals in the vicinity of the vessel.

Personnel on lookout will employ visual search procedures employing a scanning methodology in accordance with the Lookout Training Handbook (NAVEDTRA 12968-B).

After sunset and prior to sunrise, lookouts will employ Night Lookouts Techniques in accordance with the Lookout Training Handbook.

Personnel on lookout will be responsible for reporting all objects or anomalies sighted in the water (regardless of the distance from the vessel) to the Officer of the Deck, since any object or disturbance (e.g., trash, periscope, surface disturbance, discoloration) in the water may be indicative of a threat to the vessel and its crew or indicative of a marine species that may need to be avoided as warranted.

### 11.1.3 Operating Procedures

A Letter of Instruction, Mitigation Measures Message or Environmental Annex to the Operational Order will be issued prior to the exercise to further disseminate the personnel training requirement and general marine mammal protective measures.

Commanding Officers will make use of marine species detection cues and information to limit interaction with marine species to the maximum extent possible consistent with safety of the ship.

All personnel engaged in passive acoustic sonar use (including aircraft, surface ships, or submarines) will monitor for marine mammal vocalizations and report the detection of any marine mammal to the appropriate watch station for dissemination and appropriate action.

During MFA sonar use, personnel will utilize all available sensor and optical systems (such as night vision goggles) to aid in the detection of marine mammals.

Navy aircraft participating in exercises at sea will conduct and maintain, when operationally feasible 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.

Aircraft with deployed sonobuoys will use only the passive capability of sonobuoys when marine mammals are detected within 200 yards of the sonobuoy.

Marine mammal detections will be immediately reported to assigned Aircraft Control Unit for further dissemination to ships in the vicinity of the marine species as appropriate where it is reasonable to conclude that the course of the ship will likely result in a closing of the distance to the detected marine mammal.

Safety Zones—When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically), the Navy will ensure that MFA transmission levels are limited to at least 6 dB below normal operating levels if any detected animals are within 1,000 yards of the sonar dome (the bow).[1]

(i) Ships and submarines will continue to limit maximum MFA transmission levels by this 6-dB factor until the marine mammal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards beyond the location of the last detection.

(ii) The Navy will ensure that MFA sonar transmissions will be limited to at least 10 dB below the equipment's normal operating level if any detected animals are within 500 yards of the sonar dome. Ships and submarines will continue to limit maximum ping levels by this 10-dB factor until the marine mammal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards beyond the location of the last detection.[2]

(iii) The Navy will ensure that MFA sonar transmissions will cease if any detected animals are within 200 yards of the sonar dome. MFA sonar will not resume until the animal

---

[1] NDE II language provides as follows: When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) within 1,000 yards of the sonar dome (the bow), the ship or submarine will limit MFA transmission levels to at least 6 decibels (dB) below normal operating levels.

[2] NDE II language provides as follows: Should a marine mammal be detected within or closing to inside 500 yards of the sonar dome, MFA sonar transmissions will be limited to at least 10 dB below the equipment's normal operating level. Ships and submarines will continue to limit maximum ping levels by this 10-dB factor until the marine mammal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards beyond the location of the last detection.

has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards beyond the location of the last detection.[3]

(iv) Special conditions applicable for dolphins and porpoises only: If, after conducting an initial maneuver to avoid close quarters with dolphins or porpoises, the Officer of the Deck concludes that dolphins or porpoises are deliberately closing to ride the vessel's bow wave, no further mitigation actions are necessary while the dolphins or porpoises continue to exhibit bow wave riding behavior.

(v) If the need for MFA sonar power-down should arise as detailed in "Safety Zones" above, the ship or submarine shall follow the requirements as though they were operating MFA sonar at 235 dB—the normal operating level (i.e., the first power-down will be to 229 dB, regardless of at what level above 235 dB the MFA sonar was being operated).

Prior to start up or restart of MFA sonar, operators will check that the Safety Zone radius around the sound source is clear of marine mammals.

MFA sonar levels (generally)**—**the ship or submarine will operate MFA sonar at the lowest practicable level, not to exceed 235 dB, except as required to meet tactical training objectives.

Helicopters shall observe/survey the vicinity of an ASW exercise for 10 minutes before the first deployment of active (dipping) sonar in the water.

Helicopters shall not dip their sonar within 200 yards of a marine mammal and shall cease pinging if a marine mammal closes within 200 yards after pinging has begun.

Submarine sonar operators will review detection indicators of close-aboard marine mammals prior to the commencement of ASW events involving MFA sonar.

Increased vigilance during major ASW training with tactical MFA sonar when critical conditions are present.

Based on lessons learned from strandings in the Bahamas (2000), Madeira (2000), the Canaries (2002), and Spain (2006), beaked whales are of particular concern since they have been associated with MFA sonar use. The Navy should avoid planning major ASW training with MFA sonar in areas where they will encounter conditions that, in their aggregate, may contribute to a marine mammal stranding event.

The conditions to be considered during exercise planning include:

(i) Areas of at least 1,094 yards (1,000-meter [m]) depth near a shoreline where there is a rapid change in bathymetry on the order of 1,096 to 6,562 yards (1,000 m to 6,000 m) occurring across a relatively short horizontal distance (e.g., 5 nautical miles [nm]).

(ii) Cases for which multiple ships or submarines (≥ 3) operating MFA sonar in the same area over extended periods of time (≥ 6 hours) in close proximity (≤ 10 nm apart).

(iii) An area surrounded by land masses, separated by less than 35 nm and at least 10 nm in length, or an embayment, wherein events involving multiple ships/subs (≥ 3) employing

---

[3] NDE II language provides as follows: Should the marine mammal be detected within or closing to inside 200 yards of the sonar dome, MFA sonar transmissions will cease. MFA 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 2,000 yards beyond the location of the last detection.

MFA sonar near land may produce sound directed toward the channel or embayment that may cut off the lines of egress for marine mammals.

(iv) Although not as dominant a condition as bathymetric features, the historical presence of a strong surface duct (i.e., a mixed layer of constant water temperature extending from the sea surface to 100 or more feet).

If the Major Exercise must occur in an area where the above conditions exist in their aggregate, these conditions must be fully analyzed in environmental planning documentation. The Navy will increase vigilance by undertaking the following additional protective measure:

A dedicated aircraft (Navy asset or contracted aircraft) will undertake reconnaissance of the embayment or channel ahead of the exercise participants to detect marine mammals that may be in the area exposed to active sonar. Where practical, advance survey should occur within about 2 hours prior to MFA sonar use, and periodic surveillance should continue for the duration of the exercise. Any unusual conditions (e.g., presence of sensitive species, groups of species milling out of habitat, any stranded animals) shall be reported to the Officer in Tactical Command, who should give consideration to delaying, suspending, or altering the exercise.

All safety zone power-down requirements described in Measure 20 apply. The post-exercise report must include specific reference to any event conducted in areas where the above conditions exist, with exact location and time/duration of the event, and noting results of surveys conducted.

### 11.1.4 Current mitigation measures associated with events using EER/IEER Sonobuoys

The following are mitigation measures for use with Extended Echo Ranging/Improved Extended Echo Ranging (EER/IEER) given an explosive source generates the acoustic wave used in this sonobuoy.

1. Crews will conduct visual reconnaissance of the drop area prior to laying their intended sonobuoy pattern. This search should be conducted below 500 yards at a slow speed, if operationally feasible and weather conditions permit. In dual aircraft training activities, crews are allowed to conduct coordinated area clearances.

2. Crews shall conduct a minimum of 30 minutes of visual and aural monitoring of the search area prior to commanding the first post detonation. This 30-minute observation period may include pattern deployment time.

3. For any part of the briefed pattern where a post (source/receiver sonobuoy pair) will be deployed within 1,000 yards of observed marine mammal activity, deploy the receiver ONLY and monitor while conducting a visual search. When marine mammals are no longer detected within 1,000 yards of the intended post position, co-locate the explosive source sonobuoy (AN/SSQ-110A) (source) with the receiver.

4. When able, crews will conduct continuous visual and aural monitoring of marine mammal activity. This is to include monitoring of own-aircraft sensors from first sensor placement to checking off station and out of communication range of these sensors.

5. Aural Detection: If the presence of marine mammals is detected aurally, then that should cue the aircrew to increase the diligence of their visual surveillance. Subsequently, if no marine mammals are visually detected, then the crew may continue multi-static active search.

6. Visual Detection:

   a. If marine mammals are visually detected within 1,000 yards of the explosive source sonobuoy (AN/SSQ-110A) intended for use, then that payload shall not be detonated. Aircrews may utilize this post once the marine mammals have not been re-sighted for 30 minutes, or are observed to have moved outside the 1,000 yards safety buffer.

   b. Aircrews may shift their multi-static active search to another post, where marine mammals are outside the 1,000 yards safety buffer.

7. Aircrews shall make every attempt to manually detonate the unexploded charges at each post in the pattern prior to departing the training area by using the “Payload 1 Release” command followed by the “Payload 2 Release” command. Aircrews shall refrain from using the “Scuttle” command when two payloads remain at a given post. Aircrews will ensure that a 1,000 yards safety buffer, visually clear of marine mammals, is maintained around each post as is done during active search training activities.

8. Aircrews shall only leave posts with unexploded charges in the event of a sonobuoy malfunction, an aircraft system malfunction, or when an aircraft must immediately depart the area due to issues such as fuel constraints, inclement weather, and in-flight emergencies. In these cases, the sonobuoy will self-scuttle using the secondary or tertiary method.

9. Ensure all payloads are accounted for. Explosive source sonobuoys (AN/SSQ-110A) that cannot be scuttled shall be reported as unexploded ordnance via voice communications while airborne, then upon landing via naval message.

10. Mammal monitoring shall continue until out of own-aircraft sensor range.

### 11.1.5 Evaluation of Current Mitigation Measures

The Navy’s current mitigation measures reflect the use of the best available science, balanced with the Navy’s training needs. To understand the development of these mitigation measures, it is necessary to review the events arising out of the MMPA Incidental Harassment Authorization (IHA) that Navy obtained for Rim of the Pacific (RIMPAC) 2006.

The 2006 RIMPAC IHA was issued on June 27, 2006. It set forth mitigation measures regarding personnel training, use of aviation units to look for marine mammals, use of sonar personnel using passive indicators to check for marine mammals, limits on the sonar levels (generally), coastal exclusion zones, exclusion areas, safety zones, restrictions associated with “choke-points,” surface ducting conditions and low visibility, stranding response and reporting protocols. Most of the measures, especially the ones later determined to have been most effective, were already Navy standard operating procedure.

Three days after issuance of the IHA (on June 30, 2006), following consultations with the DOC and pursuant to Title 16, Section 1371(f) of the U.S.C., the DoD authorized an NDE for a period of six months. The NDE exempted military readiness activities from compliance with the requirements of the MMPA involving the use of MFA sonar during major training exercises and on established ranges and operating areas. The Deputy Secretary of Defense required RIMPAC 2006 activities to adhere to the mitigation measures in the 2006 RIMPAC IHA.

Because the RIMPAC 2006 IHA was the first authorization issued by NMFS for MFA sonar use, the mitigation measures required by NMFS in the IHA were purposefully inclusive of all potential mitigation measures without knowledge of either their effectiveness or impact on training fidelity. The IHA recognized the uncertainty associated with the effectiveness of the mandated mitigation measures and therefore required that a report be generated after RIMPAC 2006 that would provide “an assessment of the effectiveness of the mitigation and monitoring measures with recommendations on how to improve them.”

In December 2006, the Navy produced the *2006 RIMPAC After-Action Report,* which it subsequently provided to NMFS. The assessment consisted of a review of compiled data from operators involved in the exercise, exercise reconstructions, and details of marine mammal detections by exercise participants, shore-based observers, and an aerial marine mammal survey. The report concluded that certain measures in the IHA should be removed from future consideration because they proved not feasible, presented a safety risk, provided no known or unambiguous protective benefit (having no basis in scientific fact), and/or because they impacted the effectiveness of the required training.

Following the issuance of the *2006 RIMPAC After-Action Report* and consultation between the Navy and NMFS, NDE II was issued. The NDE II included 29 mitigation measures, which incorporated and refined the Navy's standard operating procedures and the measures set forth in the 2006 RIMPAC IHA and NDE I. All of the mandatory mitigation measures contained within NDE II have been utilized in all Navy training in the MIRC conducted since January 2007.

After action reports for recent exercises in the Hawaii Range Complex (DoN 2008) indicate that protective measures have resulted in the minimization of sonar exposure to detected marine mammals. There have been no known instances of marine mammals behaviorally reacting to the use of sonar during these exercises.

The current measures are effective because the typical distances to a received sound energy level associated with TTS are typically within 656 ft. (200 m) of the most powerful active sonar (the AN/SQS 53 MFA sonar); The current safety zone for implementation of power-down and shut-down procedures begins when marine mammals come within 1,000 yards of that sonar.

The Navy has continued to revise mitigation measures based on the best available scientific data, the Navy's training requirements, and evolving regulations. The Navy has previously analyzed and eliminated from further consideration several mitigation measures, many of which were suggested during the public comment period. Potential alternative mitigation or protective measures were assessed based on supporting science, their likely effectiveness in avoiding harm to marine mammals, the extent to which they would adversely impact military readiness activities, including personnel safety, and the practicality of implementation, and impact on the effectiveness of the military readiness activity. These measures, many which were considered previously by the Navy, are discussed in the following section.

## 11.2 Alternative and/or additional mitigation measures

A number of possible alternative and/or additional mitigation measures have been reviewed in the past in the development of the current measures or have suggested during the public comment period. This section presents those measures and an evaluation based on known science, likely effectiveness, impact to military readiness activities personnel safety, and the practicality of implementation. Alternative measures in addition to those currently in use include the following:

- Using non-Navy personnel onboard Navy vessels to provide surveillance of ASW or other training events to augment Navy lookouts.
- Use non-Navy observers for visual surveillance.
- Survey before, during, and after training events to preclude sonar use.
- Avoid areas seasonally.
- Avoid areas with problematic complex/steep bathymetry and/or seamounts.
- Avoid particular habitats.
- Use active sonar with output levels as low as possible consistent with mission requirements.

- Use active sonar only when necessary.
- Suspending training at night, periods of low visibility, and in high sea-states when marine mammals are not readily visible.
- Reducing power in strong surface duct conditions.
- Scaling down training to meet core aims.
- Limiting the active sonar event locations.
- Use passive acoustic monitoring to detect and avoid marine mammals.
- Use ramp-up to attempt to clear an exercise area prior to the use of sonar.
- Reduce vessel speed.
- Reporting marine mammal sightings to augment scientific data collection.
- Use of new technology (e.g., unmanned reconnaissance aircraft, underwater gliders, instrumented ranges) to detect marine animals.
- Use of larger shut-down zones.
- Restricting Navy training in “choke-points.”
- Adopt mitigation measures of foreign nation navies.

### 11.2.1 Evaluation of Alternative and/or additional mitigation measures

There is a distinction between effective and feasible monitoring procedures for data collection and measures employed to prevent impacts or otherwise serve as mitigation. The discussion below is in reference to those procedures meant to serve as mitigation measures.

- Using non-Navy personnel onboard Navy vessels to provide surveillance of ASW or other training events to augment Navy lookouts.
  - The protection of marine mammals is provided by a lookout sighting the mammal and prompting immediate action. The premise that Navy personnel cannot or will not do this is unsupportable. Navy lookouts are extensively trained in spotting items at or near the water surface and utilizing chain of command to initiate action. Navy lookouts utilize their skills more frequently than many third party trained marine mammal observers.
  - Use of Navy lookouts is the most effective means to ensure quick and effective communication within the command structure and facilitate implementation of mitigation measures if marine species are spotted. A critical skill set of effective Navy training is communication via the chain of command. Navy lookouts are trained to report swiftly and decisively using precise terminology to ensure that critical information is passed to the appropriate supervisory personnel.
  - Berthing space during Major Exercises is very limited. With exercise lengths of 1 to 3 weeks, and given limited at sea transfer, this option would mean that even if berthing is available, a biologist would have to depart with the ship as it leaves port and stay the duration of the exercise. Berthing on non-MFA sonar (i.e., carrier and amphibious assault ships) is more available, but distance from MFA sonar training activities would not provide the desired mitigation given the distance to the MFA sources.
  - Lengthy and detailed procedures that would be required to facilitate the integration of information from non-Navy observers into the command structure.

  - Some training will span one or more 24-hour period with events underway continuously in that timeframe. It is not feasible to maintain non-Navy surveillance of these events given the number of non-Navy observers that would be required onboard for the minimally required, three 8-hour shifts.
  - Some surface ships having MFA sonar may have limited berthing capacity. Exercise planning includes careful consideration of this berthing capacity in the placement of exercise controllers, data collection personnel, and Afloat Training Group personnel on ships involved in the training event. Inclusion of non-Navy observers onboard these ships would require that, in some cases, there would be no additional berthing space for essential Navy personnel required to fully evaluate and efficiently use the training opportunity to accomplish the training objectives.
  - Security clearance issues would have to be overcome to allow non-Navy observers onboard event participants.

- Visual surveillance as mitigation using non-Navy observers from non-military aircraft or vessels to survey before, during, and after training events to preclude sonar use in areas where marine mammals may be present.
  - These measures do not result in increased protection to marine species given that the size of the areas, the time it takes to survey, and the movement of marine species preclude real-time mitigation. Contiguous ASW events may cover many hundreds of square miles in a few hours given the participants are usually not visible to each other (separated by many tens of miles) and are constantly in motion. The number of civilian ships and/or aircraft required to monitor the area around these events would be considerable (in excess of a thousand of square miles). It is, thus, not feasible to survey or monitor the large areas in the time required to ensure these areas are devoid of marine mammals. In addition, marine mammals may move into or out of an area, if surveyed before an event, or an animal could move into an area after an event took place. Therefore, surveillance of the "exercise area" would be impracticable as a mitigation measure given that it will not result in precluding marine mammals from being in the "exercise area."
  - Surveillance of an exercise area during an event raises safety issues with multiple, slow civilian aircraft operating in the same airspace as military aircraft engaged in combat training. In addition, most of the training events take place far from land, limiting both the time available for civilian aircraft to be in the training area and presenting a concern should aircraft mechanical problems arise.
  - Scheduling civilian vessel or aircraft surveillance to coincide with training events would negatively impact training effectiveness, if the exercise was contingent on completion of such surveillance. Exercise event timetables cannot be precisely fixed, but are instead based on the free-flow development of tactical situations to closely mimic real combat action. Waiting for civilian aircraft or vessels to complete surveys, refuel, or be on station would interrupt the necessary spontaneity of the exercise and would negatively impact the effectiveness of the military readiness activity.
  - The vast majority of MIRC training events involve a Navy aerial asset with crews specifically training to detect objects in the water. The capability of sighting from both surface and aerial platforms provides excellent survey capabilities using Navy training assets participating in the event.

- Avoidance of marine mammal habitats is not possible given that the full habitat requirements the marine mammals in the Mariana Islands are unknown. Accordingly, there is no information available on possible alternative exercise locations or environmental factors that would otherwise be less important to marine mammals in the Mariana Islands. In addition, these exercise locations were very carefully chosen by exercise planners based on training requirements and the ability of ships, aircraft, and submarines to operate safely. Moving the exercise events to alternative locations would impact the effectiveness of the training and has no known benefit (especially as there is no scientific data available to determine which specific areas should be avoided).

- Using active sonar with output levels as low as possible consistent with mission requirements and use of active sonar only when necessary.
    - Operators of sonar equipment are trained to be cognizant of the environmental variables affecting sound propagation. In this regard the sonar equipment power levels are always set consistent with mission requirements.
    - Active sonar is only used when required by the mission since it has the potential to alert opposing forces to the sonar platform’s presence. Passive sonar and all other sensors are used in concert with active sonar to the maximum extent practical when available and when required by the mission.

- Suspending training at night, periods of low visibility and in high sea-states when marine mammals are not readily visible.
    - It is imperative that the Navy train to be able to operate at night, in periods of low visibility, and in high sea-states using the full potential of sonar as a sensor.
    - It would be extremely wasteful for Navy forces at sea to only operate in daylight hours or to wait for weather to clear before undertaking necessary training,

Navy vessels use radar and night vision goggles to detect any object, be it a marine mammal, a periscope of an adversary submarine, trash, debris, or another surface vessel

- The Navy must train as expected to fight, and adopting this prohibition would eliminate this critical military readiness requirement.

- Reduce power in strong surface ducting conditions:
    - Strong surface ducts are conditions under which ASW training must occur to ensure sailors learn to identify the conditions, how they alter the abilities of MFA sonar systems, and how to deal with strong surface duct effects on MFA sonar systems. The complexity of ASW requires the most realistic training possible for the effectiveness and safety of the sailors. Reducing power in strong surface duct conditions would not provide this training realism because the unit would be operating differently than it would in a combat scenario, reducing training effectiveness and the crew’s ability.
    - Additionally and most importantly, water conditions in the exercise areas on the time and distance scale necessary to implement this measure are not uniform and can change over the period of a few hours as effects of environmental conditions such as wind, sunlight, cloud cover, and tide changes alter surface duct conditions. In fact, this mitigation measure cannot be accurately and uniformly employed given the many variations in water conditions across a typical exercise area that the determination of “strong surfacing ducting” is continually changing mitigation requirements and so cannot be accurately implemented.

  - Surface ducting alone, does not increase the risk of MFA sonar impacts to marine mammals. While it is true that surface ducting causes sound to travel farther before losing intensity, simple spherical and cylindrical spreading losses result in a received level of no more than 175 dB at 1,000 meters, even in significant surface ducting conditions.
  - There is no scientific evidence that this mitigation measure is effective or that it provides additional protection for marine mammals than the protection provided through “safety zones.”

- Scaling down the exercise to meet core aims.
  - Training events are always constrained by the availability of funding, resources, personnel, and equipment with the result being they are always scaled down to meet only the core requirements.

- Limiting the active sonar use to a few specific locations.
  - Areas where events are scheduled to occur are carefully chosen to provide for the safety of events and to allow for the realistic tactical development of the training scenario. Otherwise limiting the training event to a few areas would adversely impact the effectiveness of the training.
  - Limiting the exercise areas would concentrate all sonar use, resulting in unnecessarily prolonged and intensive sound levels vice the more transient exposures predicted by the current planning that makes use of multiple exercise areas.
  - Major Exercises using integrated warfare components require large areas of the littorals and open ocean for realistic and safe training.

- Passive acoustic detection and location of marine mammals.
  - As noted in the preceding section, passive detection capabilities are used to the maximum extent practicable consistent with the mission requirements to alert training participants to the presence of marine mammals in an event location.
  - Implementation of this measure in and of itself is not more protective of the marine mammals because current technology does not allow for the real time detection and location of marine mammals.
  - Requires that marine mammals be vocalizing to be detected to be of any utility

- Using ramp-up to attempt to clear an area prior to the conduct of training events.
  - Ramp-up procedures involving slowly increasing the sound in the water to necessary levels have been utilized in other non-DoD activities. Ramp-up procedures are not a viable alternative for training events, as the ramp-up would alert opponents to the participants’ presence and not allow the Navy to train realistically, thus adversely impacting the effectiveness of the military readiness activity.
  - This would constitute additional unnecessary sound introduced into the marine environment, in and of itself constituting harassment.
  - This measure does not account for the movement of the ASW participants over the period of time when ramp up would be implemented.
  - The implicit assumption is that animals would have an avoidance response to the low power sonar and would move away from the sound and exercise area; however, there is no data to indicate this assumption is correct. The Navy is currently gathering data and assessing it regarding the potential usefulness of this procedure as a mitigation measure.

However, given there is only limited data to indicate that this is even minimally effective and because ramp-up would have an impact on the effectiveness of the military readiness activity, it was eliminated from further consideration.

- Vessel speed reduction.
  - Vessels engaged in training use extreme caution and operate at a slow, safe speed consistent with mission and safety. Ships and submarines need to be able to react to changing tactical situations in training as they would in actual combat. Placing arbitrary speed restrictions would not allow them to properly react to these situations. Training differently than what would be needed in an actual combat scenario would decrease training effectiveness and reduce the crew's abilities.
- Use of new technology (e.g., unmanned reconnaissance aircraft, underwater gliders, instrumented ranges) to detect and avoid marine animals.
  - Although the Navy provides considerable funding into research on new technologies and devices (e.g., underwater gliders, radar, lasers, etc.) to date (2008), they are not developed to the point where they are effective or could be used as an actual mitigation tool.
- Use of larger shut-down zones.

  The current power down and shut down zones are based on scientific investigations specific to MFA sonar for a representative group of marine mammals. It is also based on the source level, frequency, and sound propagation characteristics of MFA sonar. The zones are designed to preclude direct physiological effect from exposure to established marine mammal thresholds. Specifically, the current power-downs at 500 yards and 1,000 yards (457 and 914 meters [m]), as well as the 200 yards (183 m) shut-down safety zones were developed to minimize exposing marine mammals to sound levels that could cause TTS or PTS. These sound level thresholds were established experimentally and are supported by the scientific community. Implementation of the safety zones discussed above were designed to prevent exposure to sound levels greater than that for onset TTS (195 dB re 1 µPa) for animals detected in the zone. Given that the distance to TTS from a single nominal sonar ping is less than 200 yards, there are additional protective buffers built into the safety zone with power-down of the sonar beginning when marine mammals are within 1,000 yards of the sonar (approximately five times the distance to TTS).

  The safety zone the Navy has developed is also based on a lookouts ability to realistically maintain situational awareness over a large area of the ocean and the lookouts ability to detect marine mammals at that distance during most conditions at sea.

  - It should also be noted that lookouts are responsible for reporting all objects or anomalies sighted in the water regardless of the distance from the vessel. Any sighting is reported to the Officer of the Deck since any object, disturbance, or discoloration in the water may be indicative of a threat to the vessel and its crew or indicative of a marine species that may require some action be taken.
  - Requirements to implement procedures when marine mammals are present well beyond 1,000 yards require that lookouts sight marine mammals at distances that, in reality, they cannot. These increased distances also greatly increase the area that must be monitored to implement these procedures. For instance, if a power down zone increases from 1,000 to 4,000 yards, the area that must be monitored increases sixteenfold.

- Avoid or limit the use of MFA sonar during ASW training events while conducting transits between islands
    - Conducting ASW training events while transiting between Mariana Islands does not present the same conditions as those that resulted in the Bahamas' stranding. Most importantly, there is no limited egress for marine mammals for events that occur between the Mariana Islands.
- Adopt mitigation measures of foreign nation navies
    - Some of these foreign nations' measures (such as predictive modeling) are not applicable to the MIRC given the lack of information upon which to base any modeling. In a similar manner, avoidance of particular seasons or areas of known habitat are not transferable to the MIRC context.
    - Other nation's navies do not have the same critical mission to train in ASW as does the Navy. For example, other navies do not possess an integrated Strike Group. As a result, many foreign nations' measures would impact the effectiveness of ASW training to an unacceptable degree. The Navy's ASW training is built around the integrated warfare concept and is based on the Navy's sensor capabilities, the threats faced, the operating environment, and the overall mission.

#### 11.2.1.1 After Action reports and Assessment

Since RIMPAC 2006, the Navy has completed a number of After Action Reports (AARs). Many of these AARs have contained research data collected during aerial and vessel marine species monitoring surveys which were conducted during Valiant Shield (2007) as well as several USWEX. The surveys have not detected any behavioral responses, strandings, or change in marine species distribution. In part, these reports may assess the effectiveness of the preceding mitigation measures.

#### 11.2.1.2 Coordination and Reporting

There are three procedures in the NDE II (designated by the numbers 27-29 in the NDE II) that are procedures for coordination and reporting of issues involving marine mammals with NMFS as the regulator. These procedures from NDE II are as follows:

The Navy will coordinate with the local NMFS Stranding Coordinator for any unusual marine mammal behavior and any stranding, beached live or dead cetacean(s) or floating marine mammals that may occur at any time during or within 24 hours after completion of MFA sonar use associated with ASW training.

The Navy will submit a report to the Office of Protected Resources, NMFS, within 120 days of the completion of a Major Exercise. This report must contain a discussion of the nature of the effects, if observed, based on both modeled results of real-time events and sightings of marine mammals.

If a stranding occurs during an ASW exercise, NMFS and the Navy will coordinate to determine if MFA sonar should be temporarily discontinued while the facts surrounding the stranding are collected.

## 11.3 Underwater Detonations

To ensure protection of marine mammals and sea turtles during underwater detonation training and mining activities, the surveillance area must be determined to be clear of marine mammals and sea turtles prior to detonation. Implementation of the following mitigation measures continue to ensure that marine mammals would not be exposed to TTS of hearing, PTS or hearing, or injury from physical contact with training mine shapes during Major Exercises.

### 11.3.1 Demolition and Ship MCM Training Activities (up to 20 Pounds)

#### 11.3.1.1 Exclusion Zones

All MIW and MCM training activities involving the use of explosive charges must include exclusion zones for marine mammals and sea turtles to prevent physical and/or acoustic effects on those species. These exclusion zones shall extend in a 700-yard arc radius around the detonation site.

#### 11.3.1.2 Pre-Exercise Surveillance

For Demolition and Ship MCM training activities, pre-exercise surveillance shall be conducted within 30 minutes prior to the commencement of the scheduled explosive event. The surveillance may be conducted from the surface, by divers, and/or from the air, and personnel shall be alert to the presence of any marine mammal or sea turtle. Should such an animal be present within the surveillance area, the exercise shall be paused until the animal voluntarily leaves the area.

#### 11.3.1.3 Post-Exercise Surveillance

Surveillance within the same radius shall also be conducted within 30 minutes after the completion of the explosive event.

#### 11.3.1.4 Reporting

Any evidence of a marine mammal or sea turtle that may have been injured or killed by the action shall be reported immediately to Commander, Navy Marianas who will contact the Commander, Pacific Fleet.

### 11.3.2 SINKEX, Gunnery Exercise, MISSILEX and BOMBEX

The selection of sites suitable for SINKEXs involves a balance of operational suitability, requirements established under the Marine Protection, Research and Sanctuaries Act (MPRSA) permit granted to the Navy (40 Code of Federal Regulations §229.2), and the identification of areas with a low likelihood of encountering ESA listed species. To meet operational suitability criteria, locations must be within a reasonable distance of the target vessels' originating location. The locations should also be close to active military bases to allow participating assets access to shore facilities. For safety purposes, these locations should also be in areas that are not generally used by non-military air or watercraft. The MPRSA permit requires vessels to be sunk in waters which are at least 1,000 fathoms (3,000 m) deep and at least 50 nm from land.

In general, most listed species prefer areas with strong bathymetric gradients and oceanographic fronts for significant biological activity such as feeding and reproduction. Typical locations include the shelf-edge.

Although the siting of the location for the exercise is not regulated by a permit, the range clearance procedures used for Gunnery Exercise (GUNEX), MISSILEX, and BOMBEX are the same as those described below for a SINKEX.

### 11.3.3 Underwater detonations Mitigation Procedures

The Navy has developed range clearance procedures to maximize the probability of sighting any ships or protected species in the vicinity of an exercise, which are as follows:

- All weapons firing would be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.

Extensive range clearance procedures would be conducted in the hours prior to commencement of the exercise, ensuring that no shipping is located within the hazard range of the longest-range weapon being fired for that event.

An exclusion zone with a radius of 1.0 nm would be established around each target. This exclusion zone is based on calculations using a 990-pound (lb) H6 net explosive weight high explosive source detonated

5 feet (ft) below the surface of the water, which yields a distance of 0.85 nm (cold season) and 0.89 nm (warm season) beyond which the received level is below the 182 dB re: 1 micropascal squared-seconds (μ$Pa^2$-s) threshold established for the *WINSTON S. CHURCHILL* (DDG 81) shock trials (DoN 2001b). An additional buffer of 0.5 nm would be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which extends from the exclusion zone at 1.0 nm out an additional 0.5 nm, would be surveyed. Together, the zones extend out 2 nm from the target.

A series of surveillance over-flights would be conducted within the exclusion and the safety zones, prior to and during the exercise, when feasible. Survey protocol would be as follows:

a. Overflights within the exclusion zone would be conducted in a manner that optimizes the surface area of the water observed. This may be accomplished through the use of the Navy's Search and Rescue Tactical Aid, which provides the best search altitude, ground speed, and track spacing for the discovery of small, possibly dark objects in the water based on the environmental conditions of the day. These environmental conditions include the angle of sun inclination, amount of daylight, cloud cover, visibility, and sea state.

b. All visual surveillance activities would be conducted by Navy personnel trained in visual surveillance. At least one member of the mitigation team would have completed the Navy's marine mammal training program for lookouts.

c. In addition to the overflights, the exclusion zone would be monitored by passive acoustic means, when assets are available. This passive acoustic monitoring would be maintained throughout the exercise. Potential assets include sonobuoys, which can be utilized to detect vocalizing marine mammals (particularly sperm whales) in the vicinity of the exercise. The sonobuoys would be re-seeded as necessary throughout the exercise. Additionally, passive sonar onboard submarines may be utilized to detect any vocalizing marine mammals in the area. The Officer Conducting the Exercise (OCE) would be informed of any aural detection of marine mammals and would include this information in the determination of when it is safe to commence the exercise.

d. On each day of the exercise, aerial surveillance of the exclusion and safety zones would commence 2 hours prior to the first firing.

e. The results of all visual, aerial, and acoustic searches would be reported immediately to the OCE. No weapons launches or firing would commence until the OCE declares the safety and exclusion zones free of marine mammals and threatened and endangered species.

f. If a protected species observed within the exclusion zone is diving, firing would be delayed until the animal is re-sighted outside the exclusion zone, or 30 minutes have elapsed. After 30 minutes, if the animal has not been re-sighted it would be assumed to have left the exclusion zone. This is based on a typical dive time of 30 minutes for traveling listed species of concern. The OCE would determine if the listed species is in danger of being adversely affected by commencement of the exercise.

g. During breaks in the exercise of 30 minutes or more, the exclusion zone would again be surveyed for any protected species. If protected species are sighted within the exclusion zone, the OCE would be notified, and the procedure described above would be followed.

h. Upon sinking of the vessel, a final surveillance of the exclusion zone would be monitored for 2 hours, or until sunset, to verify that no listed species were harmed.

Aerial surveillance would be conducted using helicopters or other aircraft based on necessity and availability. The Navy has several types of aircraft capable of performing this task; however, not all types are available for every exercise. For each exercise, the available asset best suited for identifying objects on and near the surface of the ocean would be used. These aircraft would be capable of flying at the slow safe speeds necessary to enable viewing of marine vertebrates with unobstructed, or minimally obstructed, downward and outward visibility. The exclusion and safety zone surveys may be cancelled in the event that a mechanical problem, emergency search and rescue, or other similar and unexpected event preempts the use of one of the aircraft onsite for the exercise. The exercise would not be conducted unless the exclusion zone could be adequately monitored visually.

In the unlikely event that any listed species are observed to be harmed in the area, a detailed description of the animal would be taken, the location noted, and if possible, photos taken. This information would be provided to National Oceanic and Atmospheric Administration (NOAA) Fisheries via the Navy's regional environmental coordinator for purposes of identification.

An AAR detailing the exercise's time line, the time the surveys commenced and terminated, amount, and types of all ordnance expended, and the results of survey efforts for each event would be submitted to NOAA Fisheries.

## 11.4 Aircraft Training Activities Involving Non-Explosive Devices

Non-explosive devices such as some sonobuoys, inert bombs, and Mining Training Activities involve aerial drops of devices that have the potential to hit marine mammals and sea turtles if they are in the immediate vicinity of a floating target. The exclusion zone, therefore, shall be clear of marine mammals and sea turtles around the target location. Pre- and post-surveillance and reporting requirements outlined for underwater detonations shall be implemented during Mining Training Activities.

## 11.5 Conditions Associated with the Biological Opinion

The Navy will comply with reasonable and prudent measures and terms and conditions when the Biological Opinion for MIRC training events is issued by NMFS.

## 11.6 MIRC Stranding Response Plan

Navy and NMFS are coordinating on whether a stranding response plan specific to Mariana Islands will be implemented and, if so, the contents of that plan. Upon completion of this coordination, appropriate information concerning the overall plan will be included in a draft plan and incorporated herein.

# 12 MINIMIZATION OF ADVERSE EFFECTS ON SUBSISTENCE USE

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

# 13 MONITORING AND REPORTING MEASURES

A Letter of Instruction, Mitigation Measures Message, or Environmental Annex to the Operational Order, will be issued prior to each exercise to further disseminate the personnel training requirement and general marine mammal mitigation measures including monitoring and reporting. The Navy will continue to fund marine mammal research as outlined in this Chapter and Chapter 14.

## 13.1 Monitoring Plan

Navy and NMFS are coordinating on the need for development of a monitoring plan specific to the MIRC. Upon completion of this coordination, appropriate information concerning the overall plan will be included in a draft plan and incorporated herein.

# 14 RESEARCH

The Navy provides a significant amount of funding and support to marine research. The agency provided 26.4 million dollars in 2008 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 the following:

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

This research is directly applicable to Navy training activities, particularly with respect to the investigations of the potential effects of underwater noise sources on marine mammals and other protected species. Proposed training activities employ sonar and underwater explosives, which introduce sound into the marine environment.

The Marine Life Sciences Division of the Office of Naval Research currently coordinates six programs that examine the marine environment and are devoted solely to studying the effects of noise and/or the implementation of technology tools that will assist the Navy in studying and tracking marine mammals. The six programs are as follows:

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

The Navy has also developed many of the technical reports referenced within this document, which include the Marine Resources Assessment for the Mariana Islands. Additionally, the Navy funded MISTCS to support environmental planning in the region given there had been no systematic marine mammal and sea turtle surveys undertaken by NMFS.

The Navy has sponsored several workshops to evaluate the current state of knowledge and potential for future acoustic monitoring of marine mammals. 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 and will continue to investigate the feasibility of passive acoustics as a potential mitigation and monitoring tool.

# 15 LIST OF PREPARERS

## Government Contributors/Reviewers

Edward J. Lynch, CDR JAGC USN (ret), Kaya Associates, Inc.
U.S. Pacific Fleet EIS Project Manager
Juris Doctor, 1978

Julie Rivers, U. S. Pacific Fleet
Fish and Wildlife Biologist
B.S. Biology, 1989, Beloit College

Nora Macariola-See, P.E., Naval Facilities Engineering Command Pacific
Navy Technical Representative
B.S. Chemical Engineering

Lori Mazzuca, Naval Facilities Engineering Command Pacific
Marine Resource Specialist

## Naval Facilities Engineering Command ContractorPreparers

Elizabeth Becker, ManTech SRS
Ph.D., Biology, 2007, University of California at Santa Barbara
Years of Experience: 20

Conrad Erkelens, Senior Scientist, KAYA Associates, Inc
M.A., Anthropology, 1993, University of Hawaii
B.A., Anthropology, 1989, University of Hawaii
Years of Experience: 13

Wesley S. Norris, Managing Senior, KAYA Associates, Inc.
B.S., 1976, Geology, Northern Arizona University
Years of Experience: 30

John Pitcher, Director, ESD Business Ops, ManTech SRS
M.B.A., Management, University of Virginia
B.S., Chemical Engineering, Massachusetts Institute of Technology
Years of Experience: 19

Philip H. Thorson, Senior Research Biologist, ManTech SRS Technologies
Ph.D., 1993, Biology, University of California at Santa Cruz
Years of Experience: 27

Karen M. Waller, Senior Program Manager, ManTech SRS Technologies
B.S., 1987, Environmental Affairs, Indiana University
Years of Experience: 19

# 16 REFERENCES

Abend, A.G. and T.D. Smith. 1999. Review of Distribution of the Long-finned Pilot Whale (*Globicephala melas*) in the North Atlantic and Mediterranean. NOAA Technical Memorandum NMFS-NE-117.

Aburto, A., D.J., Roundtry, and D.L. Danzer, 1997 Behavioral response of blue whales to active signals. Technical Report, Naval Command, Control and Ocean Surveillance Center, San Diego, CA.

Acevedo-Gutierrez, A, D.A. Croll and B.R. Tershy. 2002. High feeding costs limit dive time in the largest whales. Journal of Experimental Biology. 205:1747-1753.

Advisory Committee On Acoustic Impacts To Marine Mammals. 2006. Report submitted to the U.S. Marine Mammal Commission. February 1, 2006. 136 pp.

Aguilar, A. 2002. Fin whale Balaenoptera physalus. Pages 435-438 in Perrin, W. F., B. Würsig, and J. G. M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Aguilar, A. and S. Lens. 1981. Preliminary report on Spanish whaling activities. Reports of the Internatinal Whaling Commission. 31:639-643.

Aguilar, A. and C.Lockyer. 1987. Growth, physical maturity, and mortality of fin whales *(Balaenoptera physalus)* inhabiting the temperate waters of the northeast Atlantic. Canadian Journal of Zoology. 65:253-264.

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.

Allen, K.R. 1980. Conservation and management of whales. Seattle, WA: University of Washington Press.

Alling, A.K. and R. Payne. 1991. In*:* Leatherwood, S. (ed.). Song of the Indian Ocean blue whale, *Balaenoptera musculus.* Special issue on the Indian Ocean sanctuary.

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.

Amemiya, T. 1981. Qualitative response models: a survey. Journal of Economic Literature. 19:1483-1536.

Amesbury, S., R. Bonito, R. Chang, L. Kirkendale, C. Meyer, G. Paulay, R. Ritson-Williams, and T. Rongo. 2001. Marine biodiversity resource survey and baseline reef monitoring survey of the Haputo Ecological Reserve Area, COMNAVMARIANAS. Final. Mangilao, Guam: Marine Laboratory, University of Guam.

André, M., M. Terada, and Y. Watanabe. 1997. Sperm Whale (*Physeter macrocephalus*) Behavioral Response after the Playback of Artificial Sounds. Reports of the International Whaling Commission. 47:499-504.

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. 3:65-70.

Andrews, K.R., L. Karczmarski, W.W.L. Au, S.H. Rickards, C.A. Vanderlip, and R.J. Toonen. 2006. Patterns of genetic diversity of the Hawaiian spinner dolphin. Atoll Research Bulletin 543:65-73.

Angliss, R.P.and R.B. Outlaw. 2007. Alaska Marine Mammal Stock Assessments, 2006. NOAA Technical Memorandum NMFS-AFSC-168. 255pp.

Anonymous. 2002. Baffling boing identified. Science. 298:2125.

ANSI. 1976. American National Standards Institute, Inc. American National Standard Acoustical Terminology. New York.

ANSI. 1992. Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Intensity. ANSI-S12.12-1992

Archer, F.I. and W.F. Perrin, 1999. *Stenella coeruleoalba*. Mammalian Species 603:1-9.

Arons, A.B. 1954. Underwater Explosion Shock Wave Parameters at Large Distances from the Charge. Journal of the Acoustical Society of America. 26:343.

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). 171 pp.

Arveson, P.T. and D.J. Vendittis. 2006. Radiated noise characteristics of a modern cargo ship. Journal of the Acoustic Society of America. 107:118-129.

Ashford, J.R., P.S. Rubilar, and A.R. Martin. 1996. Interactions between cetaceans and long-line fishery operations around South Georgia. Marine Mammal. Science. 12:452-457.

Atkins, N. and S.L. Swartz (eds.). 1989. Proceedings of the Workshop to Review and Evaluate Whale Watching Programs and Management Needs. November 14-16, 1988, Monterey, California. Center for Marine Consetvation, Washington D.C. 53 pp.

Au, W.W.L. 1993. The sonar of dolphins. Springer-Verlag, New York. 277 pp.

Au, W.W.L. and M. Green. 2000. Acoustic Interaction of Humpback Whales and Whale-watching Boats. Marine Environmental Research. 49:469-481.

Au, D.W.K. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. Fishery Bulletin. 83:623-643.

Au, W.W.L., A.N. Popper, and R.R. Fay 2000. Hearing by whales and dolphins. New York, New York: Springer-Verlag.

Au, W.W.L., J. Darling, and K. Andrews. 2001. High-frequency harmonics and source level of humpback whale songs. Journal of the Acoustical Society of America. 110:2770.

Au, W.W.L. and D. Herzing. 2003.Echolocation signals of wild Atlantic spotted dolphin (*Stenella frontalis*). Journal of the Acoustical Society of America. 113:598-604.

Au, W.W.L., J.K.B. Ford, J.K. Horne, K.A. Newman Allman. 2004. Echolocation signals of free-ranging killer whales (*Orcinus orca*) and modeling of foraging for Chinook salmon (*Oncorhynchus tshawytscha*). Journal of the Acoustical Society of America. 115:901-909.

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

AUTEC ER. 1995. Environmental Review for the Atlantic Undersea Test and Evaluation Center (AUTEC), Department of the Navy, Naval Undersea Warfare Center, Key West, FL.

Baillie, J. and B. Groombridge. 1996. 1996 ICUN red list of threatened animals. International Union for the Conservation of Nature. 312 pp.

Baird, R.W. 1998. An interaction between Pacific white-sided dolphins and a neonatal harbor porpoise. Mammalia. 62:129-134.

Baird, R.W. 2000. The killer whale: Foraging specializations and group hunting. Pages 127-153 in J.Mann, R.C. Connor, P.L. Tyack and H. Whitehead, eds. Cetacean societies: Field studies of dolphins and whales. Chicago: University of Chicago Press.

Baird, R.W. 2002. False killer whale *Pseudorca crassidens*. Pages 411-412 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Baird, R.W. 2005. Sightings of dwarf (*Kogia sima*) and pygmy (*K. breviceps*) sperm whales from the main Hawaiian Islands. Pacific Science. 59:461-466.

Baird, R.W., D. Nelson, J. Lien, and D.W. Nagorsen. 1996. The status of the pygmy sperm whale, *Kogia breviceps*, in Canada. Canadian Field-Naturalist. 110:525-532.

Baird, R.W., A.D. Ligon, and S.K. Hooker. 2000. Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: A preliminary report. Report prepared for the Hawaii Wildlife Fund, Paia, Hawaii.

Baird, R.W., A.D. Ligon, S.K. Hooker and A.M. Gorgone. 2001. Subsurface and nighttime behavior of pantropical spotted dolphins in Hawai'i. Canadian Journal of Zoology. 79:988-996.

Baird, R.W., J.F. Borsani, M.B. Hanson and P.L. Tyack. 2002. Diving and night-time behavior of long-finned pilot whales in the Ligurian Sea. Marine Ecology Progress Series. 237:301-305.

Baird, R.W., D.J. McSweeney, D.L. Webster, A.M. Gorgone, and A.D. Ligon. 2003a. Studies of odontocete population structure in Hawaiian waters: Results of a survey through the main Hawaiian Islands in May and June 2003. Report prepared for the National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, Washington.

Baird, R.W., M.B. Hanson, E.E. Ashe, M.R. Heithaus and G.J. Marshall. 2003b. 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 the NMFS-NMML.

Baird, R.W., D.J. McSweeney, A.D. Ligon, and D.L. Webster. 2004. Tagging feasibility and diving of Cuvier's beaked whales (*Ziphius cavirostris*) and Blainville's beaked whales (*Mesoplodon densirostris*) in Hawaii. Order No. AB133F-03-SE-0986. Prepared for Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, California by Hawaii Wildlife Fund, Volcano, Hawaii.

Baird, R.W., M.B. Hanson and L.M. Dill. 2005. Factors influencing the diving behaviour of fish-eating killer whale: Sex differences and diel and interannual variation in diving rates. Canadian Journal of Zoology. 83:257-267.

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. 84:1120-1128.

Baker, C.S. and L.M. Herman. 1987. Alternative population estimates of humpback whales (*Megaptera novaeangliae*) in Hawaiian waters. Canadian Journal of Zoology. 65:2818-2821.

Baker, C.S. and L.M. Herman. 1981. Migration and local movement of humpback whales (*Megaptera novaeangliae*) through Hawaiian waters. Canadian Journal of Zoology. 59:460-469.

Baker, C.S., L. Medrano-Gonzalez, J. Calambokidis, A. Perry, F. Pichler, H. Rosenbaum, J.M. Straley, J. Urban-Ramirez, M. Yamaguchi, and O. Von Ziegesar. 1998. Population structure of nuclear and mitochondrial DNA variation among humpback whales in the North Pacific. Molecular Ecology. 7:695-707.

Baker, J.D. and T.C. Johanos. 2004. Abundance of the Hawaiian monk seal in the main Hawaiian Islands. Biological Conservation. 116:l03-110.

Balcomb, K.C. 1987. The whales of Hawaii, including all species of marine mammals in Hawaiian and adjacent waters. San Francisco: Marine Mammal Fund.

Balcomb, K.C. 1989. Baird's beaked whale *Berardius bairdii Stejneger*, 1883: Arnoux's beaked whale *Berardius arnuxii Duvernoy*, 1851. Pages 261-288 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals, Volume 4: River dolphins and the larger toothed whales. London: Academic Press.

Ballance, L.T., R.L. Pitman, and P.C. Fiedler. 2006. Oceanographic influences on seabirds and cetaceans of the eastern tropical Pacific: A review. Progress in Oceanography. 69:360-390.

Banister, J.L. and E. Mitchell. 1980. North Pacific sperm whale stock identity: distributional evidence from Maury and Townsend charts. Reports of the International Whaling Commision. Special Issue. 2:219–223.

Baraff L.S. and M.T. Weinrich. 1993. Separation of humpback whale mothers and calves on a feeding ground in early autumn. Marine Mammal Science. 7:49-54

Bargu, S., C.L. Powell, Z. Wang, G.J. Doucette, and M.W. Silverc. 2008. Note on the occurrence of Pseudo-nitzschia australis and domoic acid in squid from Monterey Bay, CA (USA). Harmful Algae. 7:45-51.

Bartberger, C.L. 1965. Lecture Notes on Underwater Acoustics, NADC Report NADC=WR-6509, Naval Air Development Center Technical Report, Johnsville, PA, 17 May (AD 468 869).

Barlow, J. 1999. Trackline detection probability for long-diving whales. Pages 209-221 in G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson, eds. Marine mammal survey and assessment methods. Brookfield, Vermont: A.A. Balkema.

Barlow, J. 2003. Cetacean abundance in Hawaiian waters during summer/fall of 2002. Southwest Fisheries Science Center Administrative Report LJ-03-13. La Jolla, California: National Marine Fisheries Service.

Barlow, J. 2006. Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. Marine Mammal Science. 22:446–464.

Barlow, J. and T. Gerrodette. 1996. Abundance of cetaceans in California waters based on 1991 and 1993 ship surveys. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-SWFSC-233. 15pp.

Barlow, J. and B.L. Taylor. 2005. Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey. Marine Mammal Science. 21:429-445.

Barlow, J., S. Rankin, E. Zele, and J. Appler. 2004. Marine mammal data collected during the Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS) conducted aboard the NOAA ships McArthur and David Starr Jordan, July - December 2002. NOAA Technical Memorandum NMFS-SWFSC-362:1-39.

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

Barlow, J. and K.A. Forney. 2007. Abundance and population density of cetaceans in the California Current ecosystem. Fisheries Bulletin. 105:509–526.

Bartberger, C.L. 1965. Lecture Notes on Underwater Acoustics. NADC Report NADC-WR-6509, Naval Air Development Center, Johnsville, PA, 17 May 1965 (AD 468 869).

Bartholomew, G.A., and C.L. Hubbs. 1960. Population growth and seasonal movements of the northern elephant seal, *Mirounga angustirostris* (1). Mammalia. 24:313-324.

Bartholomew, G.A. and N.E. Collias. 1962. The role of vocalization in the social behavior of the northern elephant seal. Animal Behaviour. 10:7-14.

Bauer, G.B. 1986. The behavior of humpback whales in Hawaii and modifications of behavior induced by human interventions. Univ. Hawaii, Honolulu, Dissertation.

Bauer, G. B. and L.M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawaii. Final Report to the National Marine Fisheries Services. 151 pp.

Bauer, G.B., M. Fuller, A. Perry, J.R. Dunn, and J. Zoeger. 1985. Magnetoreception and biomineralization of magnetite in cetaceans. In: J.L. Kirschvink, D.S. Jones and B.J. MacFadden, eds. Magnetite Biomineralization and Magnetoreception in Organisms. Plenum Press, New York. pp. 489-507.

Bauer, G.B., J.R. Mobley, and L.M. Herman. 1993. Responses of wintering humpback whales to vessel traffic. Journal of the Acoustical Society of America. 94:1848.

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. 13:614-638.

Baumgartner, M.F., K.D. Mullin, L.N. May, and T.D. Leming. 2001. Cetacean habitats in the northern Gulf of Mexico. Fishery Bulletin. 99:219-239.

Baumgartner, M.F. and B.R. Mate. 2003. Summertime foraging ecology of North Atlantic right whales. Marine Ecology Progress Series. 264:123-135.

Bazua-Duran and W.W.L. Au. 2002. The whistles of Hawaiian spinner dolphins. Journal of the Acoustical Society of America. 112:3064-3972.

Beach, D.W. and M.T. Weinrich. 1989. Watching the Whales: Is An Educational Adventure for Humans Turning Out to be Another Threat for Endangered Species? Oceanus. 32:84-88.

Beamish, P. and E. Mitchell. 1973. Short pulse length audio frequency sounds recorded in the presence of a minke whale (*Balaenoptera acutorostrata*). Deep-Sea Research. 20:375-386.

Bejarano, A.C., F.M. Van dolah, F.M. Gulland, and L. Schwacke. 2007. Expousre assessment of the biotoxin domoci acid in California sea lions: application of a bioenergetic model. Marine Ecology Progress Series. 345:293-304.

Benoit-Bird, K.J. 2004. Prey caloric value and predator energy needs: foraging predictions for wild spinner dolphins. Marine Biology. 45:435–444.

Benoit-Bird, K.J., W.W.L. Au, R.E. Brainard, and M.O. Lammers. 2001. Diel horizontal migration of the Hawaiian mesopelagic boundary community observed acoustically. Marine Ecology Progress Series. 217:1-14.

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.

Benoit-Bird, K.J. and W.W.L. Au. 2004. Diel migration dynamics of an island-associated sound-scattering layer. Deep-Sea Research I. 51:707-719.

Benson, S.R., D.A.Croll, B.B.Marinovic, F.P.Chavez, and J.T.Harvey. 2002. Changes in the cetacean assemblage of a coastal upwelling ecosystem during El Nino 1997-98 and La Nina 1999. Progress in Oceanography. 54:279-291.

Beranek, L.L. 1986. Acoustics. American Institute of Physics, Inc., New York.

Bernard, H.J. and S.B. Reilly. 1999. Pilot whales Globicephala Lesson, 1828. Pages 245-279 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Berzin, A. A., and A. A. Rovnin. 1966. The distribution and migrations of whales in the northeastern part of the Pacific, Chukchi and Bering Seas. Izvestiya Tikhookeanskogo Nauchno-Issledovatel’skogo Institut Rybnogo Khozyaistva I Okeanografii 58:179-207. (Translated by Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, Seattle, 1968, pp. 103-136. *In* K. I. Panin (ed.), Soviet Research on Marine Mammals of the Far East.).

Best, P.B. 1992. Catches of fin whales in the North Atlantic by the M.V. *Sierra* (and associated vessels). Reports of the International Whaling Commision. 42:697-700.

Best, P.B. 1993. Increase rates in severely depleted stocks of baleen whales. ICES Journal of Marine Science. 50:169-186.

Best, P.B., and C.H. Lockyer. 2002. Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa in the 1960s. South African Journal of Marine Science. 24:111-133.

Best, P.B., D.S. Butterworth, and L.H. Rickett. 1984. An assessment cruise for the South African inshore stock of Bryde's whales (*Balaenoptera edeni*). Reports of the International Whaling Commission. 34:403-423.

Birkeland, C. 1977. Surrounded by whales. Press Release: Islander, 12 June, pp. 13-15.

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.

Bonnell, M.L. and M.D. Dailey. 1993. Marine mammals. Pp. 604–681 *in* Ecology of the Southern California Bight. (M.D. Dailey, D.J. Reish, and J.W. Anderson, eds.), University of California Press, CA. 926 pp.

Borggaard, D., J. Lien, and P. Stevick. 1999. Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). Aquatic Mammals. 25:149-161.

Borell, A. 1993. PCB and DDTs in blubber of cetaceans from the northeastern North Atlantic. Marine Pollution Bulletin. 26:146-151.

Borrooah, V.K. 2002. Logit and probit. Ordered and multinomial models. SAGE Publications, Inc., Newbury Park, California.

Bowen, W.D., C.A. Beck, and D.A. Austin. 2002. Pinniped ecology. Pages 911-921 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Boyd, J., J. Craig, K. Rye, J. Sigurdson and R. Thrun. 2004. Very shallow water explosion tests at Naval Amphibious Base, Coronado CA and San Clemente Island CA: Conditions, results, and model predictions. Technical Report prepared for the Navy Southwest Div. 45 pp.

Brabyn, M.W. and I.G. McLean. 1992. Oceanography and Coastal Topography of Herd-Stranding Sites for Whales in New Zealand. Journal of Mammalogy. 73:469-476.

Brabyn, M.W. and R.V.C. Frew. 1994. New Zealand Herd Stranding Sites Do Not Relate to Geomagnetic Topography. Marine Mammal Science. 10:195-207.

Bradshaw, C.J.A., K, Evans, and M.A. Hindell. 2006. Mass Cetacean Strandings – a Plea for Empiricism. Conservation Biology. 20:584-586.

Braun, R. 2005. Robert Braun, DVM., description of the Hanalei Bay melon-headed whale unusual event on 4 July, 2004, sent to Robert Brownell, NOAA-NMFS.

Brodie, E.C., F.M.D. Gulland, D.J. Greig, M. Hunter, J. Jaakola, J. St. Leger, T.A. Leighfield, and F.M. Van Dolah. 2006. Domoic acid causes reproductive failure in California sea lions (*Zalophus californianus*). Marine Mammal Science. 22:700–707.

Brownell, R.L., A.V. Yablokov, and V.A. Zemsky. 1998. USSR pelagic catches of North Pacific sperm whales, 1949-1979: conservation implications. Unpublished report submitted to International Whaling Commission. (SC/50/CAWS/27). 12 pp.

Brownell, R.L., P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. Journal of Cetacean Research and Management, Special Issue. 2:269-286.

Brownell, R.L., T. Yamada, J.G. Mead, and A.L. van Helden, 2004. Mass strandings of Cuvier's beaked whales in Japan: U.S. Naval acoustic link Paper SC/56/E37 presented to the IWC Scientific Committee (unpublished). 10pp. Available from the Office of the Journal of Cetacean Research and Management.

Brownell, R.L., J.G. Mead, A.L. van Helden, A. Frantzis, and T.K. Yamada. 2006. Beaked whale mass strandings after 1961: Increasing evidence implicating anthropogenic sound. Journal of Cetacean Research and Management.

Buck, J.R. and P.L. Tyack. 2000. Response of gray whales to low-frequency sounds. 139th Meeting of the Acoustical Society of America, Atlanta, GA. June 2000.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance sampling. Chapman and Hall: London. 446 p.

Buckland, S.T., D.R Anderson, K.P Burnham, J.L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling. Estimating Abundance of Biological Populations. Oxford University Press: Oxford.).

Budelmann, B.U. 1992a. Hearing in crustacea. In: The Evolutionary Biology of Hearing D.B. Webster, R.R. Fay, and A.N. Popper (eds.), Spinger-Verlag: New York, NY Pp. 131-139.

Budelmann, B.-U. 1992b. Hearing of nonarthropod invertebrates. In: Webster, D.B., Fay, R.R. and Popper, A.N. eds. Comparative Evolutionary Biology of Hearing, Springer Verlag, NY. Pp. 141-155.

Burgess, W.C., P.L. Tyack, B.J. Le Boeuf, and D.P. Costa. 1998. A programmable acoustic recording tag and first results from free-ranging northern elephant seals. Deep-Sea Research II. 45:1327-1351.

Burtenshaw, J.C., E.M. Oleson, J.A. Hildebrand, M.A. McDonald, R.K. Andrew, B.M. Howe, and J.A. Mercer, 2004. Acoustic and satellite remote sensing of blue whale seasonality and habitat in the northeast Pacific. Deep Sea Research II. 15:967-986.

Calambokidis, J. 1995. Blue whales off California. Whalewatcher, Journal of the American Cetacean Society. 29:3-7.

Calambokidis, J., G.H. Steiger, J.C. Cubbage, K.C. Balcomb, C. Ewald, S. Kruse, R. Wells, and R. Sears. 1990. Sightings and movements of blue whales off central California, 1986–88 from photo-identification of individuals. Reports of the International Whaling Commission, Special Issue 12:343-348.

Calambokidis, J., G.H. Steiger, J.M. Straley, T.J. Quinn II, L.M. Herman, S. Cerchio, D.R. Salden, M. Yamaguchi, F. Sato, J. Urban R., J.K. Jacobsen, O. Von Ziegesar, K.C. Balcomb, C.M. Gabrielle, M.E. Dahlheim, N. Higahsi, S. Uchida, J.K.B. Ford, Y. Miyamura, P.L. de Guevara P., S.A. Mizroch, L. Schlender, and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Unpublished contract report to the National Marine Fisheries Service, La Jolla, California.

Calambokidis, J., G.H. Steiger, K. Rasmussen, J. Urbán R., K.C. Balcomb, P.L. de Guevara P., M. Salinas Z., J.K. Jacobsen, C.S. Baker, L.M. Herman, S. Cerchio, and J.D. Darling. 2000. Migratory destinations of humpback whales that feed off California, Oregon, and Washington. Marine Ecology Progress Series. 192:295-304.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J.R. Urbán, J.K. Jacobsen, O. Von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Mlyamura, P. Ladrón de guevara, M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow. 2001. Movements and population structure of humpback whales in the North Pacific. Marine Mammal Science. 17:769-794.

Calambokidis, J., T. Chandler, E. Falcone, and A. Douglas. 2004. Research on large whales off California, Oregon, and Washington in 2003. Annual Report for 2003. Contract number 50ABNF100065. Prepared for Southwest Fisheries Science Center, La Jolla, California by Cascadia Research, Olympia, Washington.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán R., D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Final report for Contract AB133F-03-RP-00078. Submitted to U.S. Dept of Commerce Western Administrative Center, Seattle, Washington. 57 pp.

Caldwell, D. K. and M. C. Caldwell. 1983. Whales and Dolphins. Pages 767-812. In: Alfred A. Knopf (ed.). The Audubon Society Field Guide to North American Fishes, Whales and Dolphins. Alfred A. Knopf, Inc., New York, NY.

Caldwell, D.K. and M.C. Caldwell. 1989. Pygmy sperm whale *Kogia breviceps* (de Blainville, 1838): Dwarf sperm whale *Kogia simus* Owen, 1866. Pages 253-260 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. London: Academic Press.

Campagna, C., V. Falabella, and M. Lewis. 2007. Entanglement of southern elephant seals in squid fishing gear. Marine Mammal Science. 23:414-418.

Capoulade, F. 2002. Whales and ferries in the Ligurian Sanctuary: captain’s experience and owner’s actions. European Cetacean Society Newsletter. 40:18–25 (special issue).

Carder, D.A. and S. Ridgway. 1990. Auditory brainstem response in a neonatal sperm whale. Journal of the Acoustical Society of America. 88:Supplement 1:S4

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, 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. 66:21-30.

Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker, B. Hanson, and M. Lowry. 2005. U.S. Pacific marine mammal stock assessments: 2004. NOAA Technical Memorandum NMFS-SWFSC- 375:1-31 6.

Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker, B. Hanson, and M.S. Lowry. 2006. U.S. Pacific Marine Mammal Stock Assessments: 2005. U.S. Department of Commerce, NOAA-TM-NMFS-SWFSC–388.

Carretta, J.V., K.A. Forney, M.S. Lowry, J. Barlow, J. Baker, B. Hanson, and M.M. Muto. 2007. U.S. Pacific Marine Mammal Stock Assessments: 2007. US Department of Commerce, NOAA Technical Memorandum, NMFS-SWFSC-414. 320 pp.

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

CETAP (Cetacean and Turtle Assessment Program). 1982. Characterization of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. outer continental shelf. Final report to the U.S. Bureau of Land Management, Washington, D.C., from the Graduate School of Oceanography, University of Rhode Island, Kingston. NTIS PB83-215855.

Chambers, S. and R.N. James. 2005. Sonar termination as a cause of mass cetacean strandings in Geographe Bay, south-western Australia. Acoustics 2005, Acoustics in a Changing Environment. Proceedings of the Annual Conference of the Australian Acoustical Society, November 9 - 11, 2005, Busselton, Western Australia.

Charif, R.A., D.K. Mellinger, K.J. Dunsmore, K.M. Fristrup, and C.W. Clark. 2002. Estimated source levels of fin whale (*Balaenoptera physalus*) vocalizations: Adjustments for surface interference. Marine Mammal Science. 18:81-98.

Cherfas, J. 1989. The hunting of the whales. Harmondsworth: Penguin.

Chivers, S.J., R.W. Baird, D.J. McSweeney, D.L. Webster, N.M Hedrick, and J.C. Salinas. 2007. Genetic variation and evidence for population structure in eastern North Pacific false killer whales (*Pseudorca crassidens)*. Canadian Journal of Zoology. 85:783-794.

Christian, E.A. and J.B. Gaspin. 1974. Swimmer Safe Standoffs from Underwater Explosions. NSAP Project PHP-11-73, Naval Ordnance Laboratory, Report NOLX-89, 1 July.

Clapham, P. J., L. S. Baraff, C. A. Carlson, M. A. Christian, D. K. Mattila, C. A. Mayo, M. A. Murphy, and S. Pittman, 1993. Seasonal occurrence and annual return of humpback whales, Megaptera novaeangliae, in the southern Gulf of Maine. Canadian Journal of Zoology. 71:440-443.

Clapham, P.J., S. Leatherwood, I. Szczepaniak, and R.L. Brownell. 1997. Catches of humpback and other whales from shore stations at Moss Landing and Trinidad, California, 1919-1926. Marine Mammal Science. 13:368-394.

Clapham, P.J. and J.G. Mead. 1999. Megaptera novaeangliae. Mammalian Species. 604:1-9.

Clapham, P.J., C. Good, S.E. Quinn, R.R. Reeves, J.E. Scarff, and R.L. Brownell. 2004. Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. Journal of Cetacean Research and Management. 6:1-6.

Clark, C.W. and R.A. Charif. 1998. Acoustic monitoring of large whales to the west of Britain and Ireland using bottom-mounted hydrophone arrays, October 1996-September 1997. JNCC Report 281. Joint Nature Conservation Committee, Aberdeen, UK.

Clark, C.W. and P.J. Clapham. 2004. Acoustic monitoring on a humpback whale (*Megaptera novaeangliae*) feeding ground shows continual singing into late spring. Proceedings of the Royal Society of London, Part B. 271:1051-1057.

Clark, C.W. and G.C. Gagnon. 2004. Low-frequency vocal behaviors of baleen whales in the North Atlantic: Insights from IUSS detections, locations and tracking from 1992 to 1996. Journal of Underwater Acoustics. 52(3).

Clark, C.W. and K.M. Fristrup. 1997. Whales '95: A combined visual and acoustic survey of blue and fin whales off southern California. Reports of the International Whaling Commission. 47:583-600.

Clark, C. W., and W. T. Ellison, 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: Evidence from models and empirical measurements. Pages 564-582 in Thomas, J. A., C. F. Moss, and M. Vater, eds. Echolocation in bats and dolphins. Chicago, Illinois: University of Chicago Press.

Clarke, M.R. 1996. Cephalopods as prey. III. Cetaceans. Philosophical Transactions of the Royal Society of London. 351:1053-1065.

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: J. Mann, R.C. Conner, P.L. Tyack, and H. Whitehead, eds. Cetacean Societies: Field Studies of Dolphins and Whales. 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. Marine Mammal Science. 14:324-330.

Cook, M.L.H., R.A. Varela, J.D. Goldstein, S.D. McCulloch, G.D. Bossart, J.J. Finneran, D. Houser, D.A. Mann. 2006. Beaked whale auditory evoked potential hearing measurements. Journal of Comparative Physiology A. 192:489–495.

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

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.

Corkeron, P.J. and S.M. Van Parijs. 2001. Vocalizations of eastern Australian Risso's dolphins, *Grampus griseus*. Canadian Journal of Zoology. 79:160-164.

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. 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. Marine Ecology Progress Series. 309:1-10

Crocker, M.J. 1997. Editor, *Encyclopedia of Acoustics*, John Wiley and Sons, Inc., New York.

Crocker, M.J. and F. Jacobsen. 1997. Sound Intensity. In, Crocker, M.J. Editor, Encyclopedia of Acoustics. John Wiley and Sons, Inc., New York.

Croll, D.A., B.R. Tershy, A. Acevedo, and P. Levin. 1999. Marine vertebrates and low frequency sound. Technical report for LFA EIS. Marine Mammal and Seabird Ecology Group, Institute of Marine Sciences, University of California at Santa Cruz.

Croll, D. A., B. R. Tershy, R. P.Croll, D.A., B.R. Tershy, R.P. Hewitt, D.A. Demer, P.C. Fiedler, S.E. Smith, W. Armstrong, J.M. Popp, T. Kiekhefer, V.R. Lopez, J. Urban, and D. Gendron. 1998. An integrated approach to the foraging ecology of marine birds and mammals. Deep-Sea Research II. 45:1353-1371.

Croll, D.A., A. Acevedo-Gutiérrez, B.R. Tershy, and J. Urbán-Ramírez. 2001a. The diving behavior of blue and fin whales: Is dive duration shorter than expected based on oxygen stores? Comparative Biochemistry and Physiology, Part A. 129:797-809.

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

Croll, D.A., C.W. Clark, A. Acevedo, B. Tershy, S. Flores, J. Gedamke, and J. Urban. 2002. Only male fin whales sing loud songs. Nature. 417:809.

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.

Crum, L.A., M.R. Bailey, J. Guan, P.R. Hilmo, S.G. Kargl, T.J. Matula and O.A. Sapozhnikov. 2005. Monitoring bubble growth in supersaturated blood and tissue ex vivo and the relevance to marine mammal bioeffects. Acoustics Research Letters Online. 6:214-220.

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

Cummings, W.C. 1985. Bryde’s whale *Balaenoptera edeni* Anderson, 1878. Pages 137-154 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. San Diego: Academic Press.

Cummings, W.C. and P.O. Thompson. 1971. Underwater sounds from blue whale, *Balaenoptera musculus*. Journal of the Acoustical Society of America. 50:1193-1198.

Curry, B.E. 1999. Stress in mammals: The potential influence of fishery-induced stress on dolphins in the eastern tropical Pacific Ocean. NOAA Technical Memorandum NOAA-TMNMFS-SWFSC-260: 1-121.

Dahlheim, M.E., S. Leatherwood, and W.F. Perrin. 1982. Distribution of killer whales in the warm temperate and tropical eastern Pacific. Reports of the International Whaling Commission 32:647-653.

Dahlheim, M.E. and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). Pages 281-322 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Daily, M.D. 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 Wildlife Diseases. 27:164-165.

Dalebout, M.L., G.J.B. Ross, C.S. Baker, R.C. Anderson, P.B. Best, V.G. Cockcroft, H.L. Hinsz, V. Peddemors, and R.L. Pitman. 2003. Appearance, distribution, and genetic distinctiveness of Longman's beaked whale, *Indopacetus pacificus*. Marine Mammal Science. 19:421-461.

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. 111:2462A.

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

D'Amico, A., A. Bergamasco, P. Zanasca, S. Carniel, E Nancini, N. Portunato, V. Teloni, C, Mori, and R. Barbanti. 2003. Qualitative correlation of marine mammals with physical and biological parameters in the Ligurian Sea. IEEE Journal of Oceanographic Engineering. 28:29-43.

Darling, J.D. and S. Cerchio. 1993. Movement of a humpback whale (*Megaptera novaeangliae*) between Japan and Hawaii. Marine Mammal Science. 9:84-91.

Davis, P.Z.R. 2004. Current status of knowledge of dugongs in Palau: A review and project summary report. The Nature Conservancy Pacific Islands Countries Report No. 7/04:1-39.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Marine Mammal Science. 14:490-507.

Dean, F.C., C.M. Jurasz, V.P. Palmer, C.H. Curby, and D.L. Thomas. 1985. Analysis of humpback , whale *(Megaptera novaeangliae)* blow interval data/Glacier Bay Alaska, 1976-1979. Report from the University of Alaska, Fairbanks, AK, for the U.S. National Park Service, Anchorage, AK, 224 pp.

Deeke, V.B. 2006. Studying marine mammal cognition in the wild: a review of four decades of playback experiments. Aquatic Mammals. 32:461-482.

DeLong, R.L., G.L. Kooyman, W.G. Gilmartin, and T.R. Loughlin. 1984. Hawaiian monk seal diving behavior. Acta Zoologica Fennica. 172: 129-1 31.

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.

Department of Commerce and Department of the Navy. 2001. Joint Interim Report, Bahamas Marine Mammal Stranding Event of 15-16 March 2000. December.

Department of the Navy (DoN). 1996. Environmental Assessment of the Use of Selected Navy Test Sites for Development Tests and Fleet Training Exercises of the MK 48 Torpedoes. Program Executive Office Undersea Warfare, Program Manager for Undersea Weapons.

Department of the Navy. 1997. Environmental Impact Statement for Shock Testing the Seawolf Submarine.

Department of the Navy. 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 pp.

Department of the Navy. 1999. Request for letter of authorization for the incidental take of marine mammals associated with the employment of surveillance towed array sensor system low frequency active (SURTASS LFA) sonar. U.S. Navy, Chief of Naval Operations, Washington, DC. 79 pp.

Department of the Navy. 2001a. Environmental Impact Statement for the Shock Trial of the *Winston S. Churchill*, (DDG-81), Department of the Navy.

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

Department of the Navy. 2004. 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 2004.

Department of the Navy. 2005a. Marine Resources Assessment for the Marianas Operating Area. Department of the Navy, Commander. U.S. Pacific Fleet. 416 pp.

Department of the Navy. 2005b. Draft Overseas Environmental Impact Statement/Environmental Impact Statement (OEIS/EIS), Undersea Warfare Training Range. Department of the Navy, Commander, U.S. Atlantic Fleet.

Department of the Navy. 2006a. 2006 Supplement to the 2002 RIMPAC Programmatic Environmental Assessment. Department of the Navy, Commander, Third Fleet.

Department of the Navy. 2006b. Undersea Warfare Exercise (USWEX) EA/OEA. Department of the Navy, Commander, Third Fleet.

Department of the Navy. 2007a. 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. May 2007.

Department of the Navy. 2007b. Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of the Northern Mariana Islands. U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii.

Department of the Navy. 2007c. Undersea Warfare Exercise Programmatic Environmental Assessment. U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii.

Department of the Navy. 2007d. Joint Task Force Exercises and Composite Unit Training Exercises. Environmental Assessment/Overseas Environmental Assessment. U.S. Pacific Third Fleet.

Department of the Navy. 2008. Department of the Navy, Chief of Naval Operations, Final Environmental Impact Statement/Overseas Environmental Impact Statement , Hawaii Range Complex. May 2008.

Department of Navy/Department of Commerce. 2001. Joint Interim Report Bahamas Marine Mammal Stranding Event of 15-16 March 2000. D.L. Evans, U.S. Dept. of Commerce, Secretary; G.R. England, Secretary of the Navy. December, 2001.

De Swart, R.L., T.C. Harder, P.S. Ross, H.W. Vos, and A.D.M.E. Osterhaus. 1995. Morbilliviruses and morbillivirus diseases of marine mammals. Infectious Agents and Disease. 4:125-130.

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.

Dietz, R., J. Teilmann, M.-P.H. Jørgensen, and M.V. Jensen. 2002. Satellite tracking of humpback whales in West Greenland. National Environmental Research Institute Technical Report 411:1-38. Copenhagen, Denmark: National Environmental Research Institute.

Di Guardo, G. and G. Marruchella. 2005. Sonars, Gas Bubbles, and Cetacean Deaths. Letters to the Editor. Veterinary Pathology. 42:517-518.

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

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. 19:1-19.

Dollar, S. and R. Grigg. 2004. Anthropogenic and natural stresses on selected coral reefs in Hawaii: A multi-decade synthesis of impact and recovery. Pacific Science. 58:281-304.

Dolphin, W.F. 1987. Ventilation and dive patterns of humpback whales, *Megaptera novaeangliae*, on their Alaskan feeding grounds. Canadian Journal of Zoology. 65:83-90.

Domingo, M., J. Visa, M. Pumarola, A. J. Marco, L. Ferrer, R. Rabanal, and S. Kennedy. 1992. Pathologic and immunocytochemical studies of morbillivirus infection in striped dolphins (*Stenella coeruleoalba*). Veterinary Pathology. 29**:**1–10.

Domjan, M. 1998. The Principles of Learning and Behavior, 4th edition. Brooks-Cole Publishing, Pacific Grove.

Donaldson, T.J. 1983. Further investigations of the whales *Peponocephala electra* and *Globicephala macrorhynchus* reported from Guam. Micronesica. 19:173-181.

Donovan, G.P. 1991. A review of IWC stock boundaries. Reports of the International Whaling Commission, Special Issue. 13:39-63.

Dorne, J.L. and A.G. Renwick. 2005. The refinement of uncertainty/safety factors in risk assessment by the incorporation of data on toxicokinetic variability in humans. Toxicological Sciences. 86:20-26.

Dorsey, E.M. 1983. Exclusive adjoining ranges in individually identified minke whales (*Balaenoptera acutorostrata*) in Washington state. Canadian Journal of Zoology. 61:174-181.

Douglas, A.B., J. Calambokidis, S. Raverty, S.J. Jeffries, D.M. Lambourn, and S.A. Norman. 2008. Incidence of ship strikes of large whales in Washington State. Journal of the Marine Biological Association of the United Kingdom. 1-12.

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. 7:223-238.

D'Vincent, C.G., R.M. Nilson, and R.E. Hanna. 1985. Vocalization and coordinated feeding behavior of the humpback whale in southeastern Alaska. Scientific Reports of the Whales Research Institute 36:41-47.

Dudok van Heel, W.H. 1966. Navigation in cetacean. in Whales, Dolphins, and Porpoises, edited by K. S. Norris (University of California Press, Berkeley), pp. 597-606.

Dufault, S., H. Whitehead, and M. C. Dillon, 1999. An examination of the current knowledge on the stock structure of sperm whales (*Physeter macrocephalus*). Journal of Cetacean Research and Management. 1:1-10.

Dunn, J.L., J.D. Buck, and T.R. Robeck. 2001. 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.

Edds, P.L. 1982. Vocalizations of the blue whale, Balaenoptera musculus, in the St. Lawrence River. Journal of Mammalogy. 63:345-347.

Edds, P.L.; T.J. MacIntyre, and R. Naveen. 1984. Notes on a sei whale (*Balaenoptera borealis* Lesson) sighted off Maryland. Cetus**. 5**:4–5.

Edds, P.L. 1988. Characteristics of finback Balaenoptera physalus vocalizations in the St. Lawrence Estuary. Bioacoustics. 1:131-149.

Edds-Walton, P. L. 1997. Acoustic communication signals of mysticete whales. Bioacoustics 8:47-60.

Edds, P.L. and J.A.F. Macfarlane. 1987. Occurrence and general behavior of balaenopterid cetaceans summering in the St. Lawrence Estuary, Canada. Bioacoustics. 1:131-149.

Eldredge, L.G. 1983. Summary of environmental and fishing information on Guam and the Commonwealth of the Northern Mariana Islands: Historical background, description of the islands, and review of the climate, oceanography, and submarine topography. NOAA Technical Memorandum NMFS-SWFC-40:1-181.

Eldredge, LG. 1991. Annotated checklist of the marine mammals of Micronesia. Micronesica. 24:217-230.

Eldredge, L.G. 2003. The marine reptiles and mammals of Guam. Micronesica. 35-36:653-660.

Eliason, S.R. 1993. Maximum likelihood estimation. Logic and practice. SAGE Publications, Inc., Newbury Park, California.

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

Etnoyer, P., D. Canny, B.R. Mate, L.E. Morgan, J.G. Ortega-Ortiz and W.J. Nichols. 2006. Sea-surface temperature gradients across blue whale and sea turtle foraging trajectories off the Baja California Peninsula, Mexico. Deep Sea Research Part II: Topical Studies in Oceanography. 53:340-358.

Evans, D.L. and G.R. England, 2001. Joint Interim Report; Bahamas Marine Mammal Stranding Event of 15-16 March 2000, National Oceanic and Atmospheric Administration.

Evans, K., Thresher, R., Warneke, R.M., Bradshaw, C.J.A., Pook, M., Thiele, D., and Hindell, M.A. 2005. Periodic variability in cetacean strandings: links to large-scale climate events. Biology Letters 1, 147-150.

Evans, P.G.H. 2002. Habitat pressures. Pages 545-548 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen,eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Evans, P.G.H. and L.A. Miller, 2003. Proceedings of the Workshop on Active Sonar and Cetaceans, Las Palmas, Gran Canaria, 8 March 2003. ECS Newsletter. 42 (Special Issue)*:*78 pp.

Evans, P.G.H., Anderwald, P., and Baines, M.E. 2003. UK Cetacean Status Review. Final Report to English Nature & Countryside Council for Wales. Sea Watch Foundation, Oxford, UK. 150pp.

Evans, W. E. 1971. Orientation Behavior of Delphinids: Radio-telemetric Studies. In: Orientation: Sensory Basis, pp. 142-160, ed. H. E. Adler, Annals New York Acad. Sci., vol. 188.

Evans, W.E. 1994. Common dolphin, white-bellied porpoise *Delphinus delphis* Linnaeus, 1758. Pages 191-224 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

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.

Fahy, F.J. 1995. Sound Intensity. E&FN Spon, London.

Fair, P.A. and P.R. Becker. 2000. Review of stress in marine mammals. Journal of Aquatic Ecosystem Stress and Recovery. 7:335-354.

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

Farris, T., 2004. Hawaiian Melon-headed Whale *(Peponacephala electra)*Mass Stranding Event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31, April 2006.

Fay, R.R., 1988. Hearing in vertebrates: a psychophysics data book. Hill-Fay Associates, Winnetka, Illinois.

Ferguson, M.C. 2005. Cetacean population density in the eastern Pacific Ocean: Analyzing patterns with predictive spatial models. Ph.D. dissertation, University of California, San Diego.

Ferguson, M.C. and J. Barlow. 2001. Spatial distribution and density of cetaceans in the eastern tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-1996. Southwest Fisheries Science Center Administrative Report LJ-01-04. La Jolla, California: National Marine Fisheries Service.

Ferguson, M.C. and J. Barlow. 2003. Addendum: Spatial Distribution and Density of Cetaceans in the Eastern Tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-96. Administrative Report LJ-01-04, available from Southwest Fisheries Science Center, 8604 La Jolla Shores Dr., La Jolla, CA 92037.

Ferguson, M.C., J. Barlow, S.B. Reilly, and T. Gerrodette. 2006. Predicting Cuvier's (*Ziphius cavirostris*) and Mesoplodon beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. Journal of Cetacean Research and Management. 7:287-299.

Fernandez, A., J.F. Edwards, F. Rodriguez, A. Espinosa de los Monteros, P. Herraez, P. Castro, J.R. Jaber, V. Martin, and M. Arbelo. 2005. Gas and fat embolic syndrome Involving a mass stranding of beaked whales (Family Ziphiidae) exposed to anthropogenic sonar signals. Veterinary Pathology. 42:446-457.

Ferrero RC, Hodder J, Cesarone J (1994) Recent strandings of rough-toothed dolphins (*Steno bredanensis*) on the Oregon and Washington coasts. Marine Mammal Science. 10:114-116.

Ferrero, R.C., S.E. Moore, and R.C. Hobbs. 2000. Development of beluga whale capture and satellite tagging protocol in Cook Inlet, Alaska. Marine Fisheries Review. 62:112–123.

Finneran, J.J. and C.E. Schlundt. 2004. Effects of intense pure tones on the behavior of trained odontocetes. Space and Naval Warfare Systems Center, San Diego, Technical Document. September.

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. 108:417-431.

Finneran, J.J., D.A. Carder, and S.H. Ridgway. 2001. Temporary threshold shift (TTS) in bottlenose dolphins *Tursiops truncatus* exposed to tonal signals. Journal of the Acoustical Society of America. 1105:2749(A), 142nd Meeting of the Acoustical Society of America, Fort Lauderdale, FL. December.

Finneran, J.J., R. Dear, D.A. Carder, and S.H. Ridgway. 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. 111:2929-2940.

Finneran, J.J., C.E. Schlundt, D.A. Carder, and S.H. Ridgway. 2002. Auditory filter shapes for the bottlenose dolphin (*Tursiops truncatus*) and the white whale (*Delphinapterus leucas*) derived with notched noise. Journal of the Acoustical Society of America. 112:7.

Finneran, J.J., D.A. Carder, and S.H. Ridgway. 2003. Temporary threshold shift measurements in bottlenose dolphins *Tursiops truncatus*, belugas *Delphinapterus leucas*, and California sea lions *Zalophus californianus*. Environmental Consequences of Underwater Sound (ECOUS) Symposium, San Antonio, TX, 12-16 May 2003.

Finneran, J.J. and C.E. Schlundt. 2004. Effects of intense pure tones on the behavior of trained odontocetes. TR 1913, February 2004. SPAWAR Systems Center (SSC), San Diego.

Finneran, J.J., D.A. Carder, C.E. Schlundt and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. Journal of Acoustical Society of America. 118:2696-2705.

Finneran, J.J. and D.S. Houser. 2006. Comparison of in-air evoked potential and underwater behavioral hearing thresholds in four bottlenose dolphins (*Tursiops truncatus*). Journal of the Acoustical Society of America. 119:3181-3192.

Finney, D.J. 1971. Probit Analysis, Third Edition. London: Cambridge University Press.

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

Fish, J.F. and C.W. Turl. 1976. Acoustic source levels of four species of small whales. Naval Undersea Center Report, NUC-TP 547.

Fletcher, S., B.J. Le Boeuf, D.P. Costa, P.L. Tyack, and S.B. Blackwell. 1996. Onboard acoustic recording from diving northern elephant seals. Journal of the Acoustical Society of America. 100:2531-2539.

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. Van Dolah, and J.H. Landsberg. 2005. Red tides and marine mammal mortalities. Nature. 435:755-756.

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.

Ford, J.K.B. 2002. Killer whale *Orcinus orca*. Pages 669-676 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Forney, K.A. 2004. Estimates of cetacean mortality and injury in two U.S. Pacific longline fisheries, 1994- 2002. Southwest Fisheries Science Center Administrative Report LJ-04-07. La Jolla, California: National Marine Fisheries Service.

Forney, K.A., D.J. St. Aubin and S.J. Chivers. 2002. Chase encirclement stress studies on dolphins involved in eastern tropical pacific ocean purse-seine operations during 2001. NMFS-SWFSC. Administrative Report LJ-02-32. 27 pp.

Frankel A.S and C.W. Clark. 1998. Results of low frequency m sequence noise playbacks to humpback whales in Hawai'i. Canadian Journal of Zoology.76:521–535.

Frankel, A.S. and C.W. Clark. 2000. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. Journal of the Acoustical Society of America. 108:1930-1937.

Frankel, A.S. and C.W. Clark. 2002a. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. Journal of the Acoustical Society of America. 108:1930-1937.

Frankel, A.S. and C.W. Clark. 2002b. ATOC and other factors affecting the distribution and abundance of humpback whales (*Megaptera novaeangliae*) off the north shore of Kauai. Marine Mammal Science. 18:644–662

Frantzis, A. 1998. Does acoustic testing strand whales? Nature. 392:29.

Frantzis, A. 2004. The first mass stranding that was associated with the use of active sonar (Kyparissiakos Gulf, Greece, 1996). In: Proceedings of the workshop. Active sonar and cetaceans. 8 March 2003, Las Palmas, Gran Canaria. ECS newsletter 42(Special Issue):14 – 20.

Frazer, L.N. and E. Mercado. 2000. A Model for humpback whale sonar. IEEE. Journal of Ocean Engineering. 25**:**160–182.

Freitas, L. 2004. The stranding of three Cuvier's beaked whales *Ziphius cavirostris* in Madeira archipelago – May 2000. ECS Newsletter. 42(Special Issue):28 – 32.

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 *U.S.S. SHOUP* Transmissions in the Haro Strait on 5 May 2003. Naval Research Laboratory briefing of 2 September 2004.

Fujimori, L. 2002. Elephant seal visits Hawaii shores: The young male is the first of its kind to be seen in the islands. Honolulu Star-Bulletin News, 18 January.

Fujimori, L. 2005. Seal steals the show on busy Waikiki Beach. Honolulu Star-Bulletin News, 22 January.

Fulling, G.L., J.C. Cotton, J.A. Rivers, and P.H. Thorson. 2007. Sei (*Balaenoptera borealis*) and Bryde's (*B.edeni/brydei*) whale co-occurrence in the Mariana Islands during the boreal winter. Seventeenth Biennial Confernce on the Biology of Marine Mammals. Cape Town, South Africa. 29 November to 3 December 2007.

Gabriele, C., A. Frankel, and T. Lewis, 2001. Frequent humpback whale songs recorded in Glacier Bay, Alaska in Fall 2000. Pages 77-78 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. November - 3 December 2001. Vancouver, British Columbia.

Gambell, R. 1979. The Blue Whale. Biologist. 26:209-215.

Gambell, R., 1985. Fin whale *Balaenoptera physalus* (Linneaus, 175 1 8). Pages 171-192 in Ridgway, S.H. and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. San Diego, California: Academic Press.

Gannier, A. 2000. Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated surveys. Aquatic Mammals. 26:111-126.

Gannier, A. 2002. Cetaceans of the Marquesas Islands (French Polynesia): Distribution and relative abundance as obtained from a small boat dedicated survey. Aquatic Mammals. 28:198-210.

Garrigue C. and Greaves J. 2001. Cetacean records for the New Caledonian area. Micronesica. 34: 27-33.

Gaskin, D.E. 1982. The ecology of whales and dolphins. Portsmouth, New Hampshire: Heinemann.

Gedamke, J., D.P. Costa, and A. Dunstan. 2001. Localization and visual verification of a complex minke whale vocalization. Journal of the Acoustical Society of America. 109:3038-3047.

Geraci, J.R. and D.J. St. Aubin. 1987. Effects of parasites on marine mammals. International Journal of Parasitology. 17:407-414.

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: 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. Conservation and Management of Marine Mammals. Ed. J.R. Twiss and R.R. Reeves. 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.

Gillespie, D. and R. Leaper. 2001. Right whale acoustics: Practical applications in conservations. Workshop report. Yarmouth Port, Massachusetts: International Fund for Animal Welfare.

Gilmartin, M. and N. Revelante. 1974. The 'island mass' effect on the phytoplankton and primary production of the Hawaiian Islands. Journal of Experimental Marine Biology and Ecology. 16:181-204.

Gilmartin, W.G. and J. Forcada. 2002. Monk seals *Monachus monachus*, *M. tropicalis*, and *M. schauinslandi*. Pages 756-759 in W. F. Perrin, B. Wursig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Goddard, P., and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. Marine Mammal Science. 14:344-349.

Goertner, J.F. 1982. Prediction of underwater explosion safe ranges for sea mammals. NSWC/WOL TR-82-188. Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, MD. 25 pp.

Goertner, J.F. 1982. Prediction of Underwater Explosion Save Ranges for Sea Mammals. Naval Surface Warfare Center (NSWC) Report NSCW TR 82-188, NSWC, Dahlgren, VA.

Goldbogen, J.A., J. Calambokidis, , R.E. Shadwick, E.M. Oleson, M.A. McDonald, and J.A Hildebrand. 2006. Kinematics of foraging dives and lunge-feeding in fin whales. The Journal of Experimental Biology. 209:1231-1244.

Goldstein, T.2, J.A. K. Mazet, T.S. Zabka, G. Langlois, K.M. Colegrove, M. Silver, S. Bargu, F. Van Dolah, T. Leighfield, P.A. Conrad, J. Barakos, D.C. Williams, S. Dennison, M. Haulena, and F.M.D. Gulland. 2008. Novel symptomatology and changing epidemiology of domoic acid toxicosis in California sea lions (*Zalophus californianus*): an increasing risk to marine mammal health. Proceedings of the Royal Society B. 275:267–276.

Goodman-Lowe, G.D. 1998. Diet of the Hawaiian monk seal (*Monachus schauinslandi*) from the Northwestern Hawaiian Islands during 1991-1994. Marine Biology. 132:535-546.

Goold, J.C., 2000. A diel pattern in vocal activity of short-beaked common dolphins, *Delphinus delphis*. Marine Mammal Science. 16:240-244.

Goold, J.C. and S.E. Jones, S.E. 1995. Time and frequency domain characteristics of sperm whale clicks. Journal of the Acoustical Society of America. 98:1279-1291.

Gorga M.P., S.T. Neely, P.A. Dom, and D. Dierking. 2002. Evidence of upward spread of suppression in DPOAE measurement. Journal of the Acoustical Society of America. 112:2910–2920.

Grachev, M.A. V.P. Kumarev, L.Mamaev, V.L. Zorin, L.V. Baranova, N.N. Denikina, S.I. Belikov, E.A. Petrov, V.S. Kolesnik, R.S. Kolesnik, V.M. Dorofeev, A.M.Beim, V.N. Kudelin, F.G. Nagieva, and V.N. Sidorov. 1989. Distemper virus in Baikal seals. Nature. 338:209.

Green, D.M. and J.A. Swets. 1974. Signal Detection Theory and Psychophysics. Robert E. Krieger Publishing, Huntington.

Gregr, E.J. and A.W. Trites. 2001. Predictions of critical habitat for five whales species in the waters of coastal British Columbia. Canadian Journal of Fisheries and Aquatic Science. 58:1265-1285.

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. Aquatic Mammals 31:11-22.

Guerra, A., A.F. González and F. Rocha. 2004. A review of the records of giant squid in the north-eastern Atlantic and severe injuries in *Architeuthis dux* stranded after acoustic explorations ICES Annual Science Conference 22–25 September 2004, Vigo, Spain. ICES CM 2004 / CC: 29.

Guinet C, M.A. Lea, and S.D. Goldsworthy. 2000. Mass change in Antarctic fur seal (*Arctocephalus gazella*) pups in relation to maternal characterisitics at iles Kerguelen. Canadian Journal of Zoology. 78:476–483

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. 32 pp.

Gulland, F.M.D., M. Koski, L.J. Lowenstine, A. Colagross, L. Morgan, and T. Spraker. 1996. Leptospirosis in California sea lions (*Zalophus californianus*) stranded in central California, 1981-1994. Journal of Wildlife Diseases 32:572-580.

Gulland, F.M.D. and A.J. Hall. 2005. The Role of Infectious Disease in Influencing Status and Trends. IN: J.E. Reynolds III, W.F. Perrin, R.R. Reeves, S. Montgomery, T.J. Ragen. Marine Mammal Research. 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.

Gunther, E.R. 1949. The habits of fin whales. Discovery Reports. 24:115-141.

Hain, J. H. W., M. A. M. Hyman, R. D. Kenney, and H. E. Winn, 1985. The role of cetaceans in the shelf-edge region of the northeastern United States. Marine Fisheries Review. 47:13-17.

Hain, J. H. W., S. L. Ellis, R. D. Kenney, P. J. Clapham, B. K. Gray, M. T. Weinrich, and I. G. Babb, 1995. Apparent bottom feeding by humpback whales on Stellwagen Bank. Marine Mammal Science. 11:464-479.

Haines, M.M., S.A. Stansfeld, J. Head, and R.F.S. Job. 2002. Multilevel modeling of aircraft noise on performance tests in schools around Heathrow Airport London. Journal of Epidemiological and Community Health. 56:139-144.

Hamazaki, T, 2002. Spatiotemporal prediction models of cetacean habitats in the mid-western North Atlantic Ocean (from Cape Hatteras, North Carolina, U.S.A. to Nova Scotia, Canada). Marine Mammal Science. 18:920-939.

Hanson, M.T. and R.H. Defran. 1993. The behavior and feeding ecology of the Pacific coast bottlenose dolphin, *Tursiops truncatus*. Aquatic Mammals. 19:127-142.

Hardy, J.T. 1993. Phytoplankton. Pages 233-265 in M.D. Dailey, D.J. Reish, and J.W. Anderson, eds. Ecology of the Southern California Bight. Berkeley: University of California Press.

Harvell, C.D., K. Kim, J.M. Burkholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, E.E. Hofmann, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith, and G.R. Vasta. 1999. Emerging marine diseases-climate links and anthropogenic factors. Science. 285:1505-1510.

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.

Hastie, G.D., B. Wilson and P.M. Thompson. 2006. Diving deep in a foraging hotspot: acoustic insights into bottlenose dolphin dive depths and feeding behaviour. Marine Biology. 148:1181-1188.

Heimlich, S.L., D.K. Mellinger, S.L. Nieukirk, and C.G. Fox. 2005. Types, distribution, and seasonal occurrence of sounds attributed to Bryde's whales (*Balaenoptera edeni*) recorded in the eastern tropical Pacific, 1999-2001. Journal of the Acoustical Society of America. 118:1830-1837.

Heinze, G, and M. Schemper. 2002. A solution to the problem of separation in logistic regression. Statistics in Medicine 21:2409-2419.

Heithaus, M. R., 2001. Shark attacks on bottlenose dolphins (*Tursiops aduncus*) in Shark Bay, Western Australia:Attack rate, bite scar frequencies and attack seasonality. Marine Mammal Science. 17:526-539.

Helweg, D.A., A.S. Frankel, J.R. Mobley, and L.H. Herman. 1992. Humpback whale song: Our current understanding. In J.A. Thomas, R.A. Kastelein and Y.A. Supin (eds.), Marine mammal sensory systems. Plenum, New York, NY. 773 pp.

Hennessy, J.W., J.P. Heybach, J. Vernikos, S. Levine. 1979. Plasma corticosterone concentrations sensitively reflect levels of stimulus intensity in the rat. Physiology and Behavior. 22:821-825.

Herman, L.M. and R.C. Antinoja. 1977. Humpback whales in Hawaiian waters: Population and pod characteristics. Scientific Report of the Whales Research Institute. 29:59-85.

Herman, L.M., C.S. Baker, P.H. Forestell, and R.C. Antinoja. 1980. Right whale *Balaena glacialis* sightings near Hawaii: A clue to the wintering grounds? Marine Ecology Progress Series. 2: 271-275.

Hersh, S.L. and D.A. Duffield. 1990. Distinction between northwest Atlantic offshore and coastal bottlenose dolphins based on hemoglobin profile and morphometry. Pages 129-139 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego, California: Academic Press.

Herzing, D.L. 1996. Vocalizations and associated underwater behavior of free-ranging Atlantic spotted dolphins, *Stenella frontalis*. Aquatic Mammals 235:155-162.

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.

Heyning, J.E., and W.F. Perrin. 1994. Evidence for two species of common dolphins (genus *Delphinus*) from the eastern North Pacific. Contributions in Science, Natural History Museum of Los Angeles County. 442:1-35.

Heyning, J.E. and J.G. Mead. 1996. Suction feeding in beaked whales: Morphological and observational evidence. Contributions in Science, Natural History Museum of Los Angeles County. 464:1-12.

Hiby, A.R.and P.S. Hammond. 1989: Survey techniques for estimating abundance of cetaceans. Report of the International Whaling Commission. Special Issue 11: 47-80.

Hickie, B.E., P.S. Ross, R.W. MacDonald and J.K.B. Ford. 2007. Killer whales (*Orcinus orca*) face protracted health risks associated with lifetime exposure to PCBs. Environmental Science and Technology. 41:6613-6619.

Higgins, H.W. and D.J. Mackey. 2000. Algal class abundances, estimated from chlorophyll and carotenoid pigments, in the western Equatorial Pacific under El Niño and non-El Niño conditions. Deep-Sea Research I. 47:1461-1483.

Hildebrand, J., 2004. Sources of Anthropogenic Sound in the Marine Environment. Report to the Policy on Sound and Marine Mammals: An International Workshop. U.S. Marine Mammal Commission and Joint Nature Conservation Committee, UK. London, England. Online. [Available]: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf

Hill, P.S. and D.P. DeMaster. 1998. Alaska marine mammal stock assessments, 1998. U.S. Dep. Commerce, NOAA Technical Memorandum NMFS-AFSC-97. 166 p.

Hill, P.S. and D. P. DeMaster. 1999. Alaska marine mammal stock assessments, 1999. U.S. Department of Commerce. NOAA Technical Memorandum. NMFS-AFSC-110. 166 pp.

Hill, P.S. and E. Mitchell. 1998. Sperm whale interactions with longline vessels in Alaska waters during 1997. Unpublished document. Submitted to Fish. Bull., U.S. (Available upon request - P. S. Hill, Alaska Fisheries Science Center, 7600 Sand Point Way, NE, Seattle, WA 98115).

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).

Hoelzel, A.R., E.M. Dorsey, and S.J. Stern. 1989. The foraging specializations of individual minke whales. Animal Behaviour. 38:786-794.

Hoffman, J.P. 2004. Generalized linear models. An applied approach. Pearson Education, Inc. Boston, Massachusetts.

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, 222 pp.

Holt, R. and J. Powers. 1982. Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys to 1979. NOAA-TM-NMFS-SWFC- 23. 95 pp.

Hooker, S.K. and R.W. Baird. 1999. Deep-diving behaviour of the northern bottlenose whale, *Hyperoodon ampullatus* (Cetacean: Ziphiidae). Proceedings of the Royal Society, London B. 266:671-676.

Hooker, S.K., H. Whitehead, S. Gowans, and R.W. Baird, 2002. Fluctuations in distribution and patterns of individual range use of northern bottlenose whales. Marine Ecology Progress Series. 225:287-297.

Horwood, J. 1987. The sei whale: Population biology, ecology and management. London: Croom Helm.

Horwood, J. 1990. Biology and exploitation of the minke whale. Boca Raton, Florida: CRC Press.

Hosmer, D.W. and S. Lemeshow. 2000. Applied logistic regression. Second Edition. John Wiley and Sons, Inc., New York, New York.

Houser, D.S., D.A. Helweg, and P.W.B. Moore. 2001a. A bandpass filter-bank model of auditory sensitivity in the humpback whale. Aquatic Mammals. 27:82–91.

Houser, D. S., R. Howard, and S. Ridgway. 2001b. Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals? Journal of Theoretical Biology. 213:183-195.

Houser, D. 2007. Evaluation of Harbor Porpoise Behavioral Response Thresholds , U.S. Navy Marine Mammal Program, SPAWAR Systems Center, San Diego.

Houser, D.S., A. Gomez-Rubio, and J.J. Finneran. 2008. Evoked potential audiometry of 13 Pacific bottlenose dolphins (*Tursiops truncates gilli*). Marine Mammal Science. 24:28-41

Huber, H.R., A.C. Rovetta, L.A. Fry, and S. Johnston. 1991. Age-specific natality of northern elephant seals at the South Farallon Islands, California. Journal of Mammalogy. 72:525-534.

International Council for the Exploration of the Sea (ICES) 2005. Report for the Ad-hoc Group on Impacts of Sonar on Cetaceans and Fish (AGISC) CM 2006/ACE: 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.

Ivashin, M.V. and L.M. Votrogov. 1981. Minke whales, Balaenoptera acutorostrata davidsoni, inhabiting inshore waters of the Chukotka coast. Reports of the International Whaling Commission. 31:231.

IWC (International Whaling Commission). 2001. Report of the Workshop on the Comprehensive Assessment of Right Whales: A worldwide comparison. Journal of Cetacean Research and Management, Special Issue. 2:1-60.

Jansen, G. 1998. Physiological effects of noise. In Handbook of Acoustical Measurements and Noise Control, 3rd Edition. New York: Acoustical Society of America.

Jacquet, N., S. Dawson, and E. Slooten. 1998. Diving behaviour of male sperm whales: foraging implications. International Whaling Commission, Scientific Committee Doc. SC/50/CAWS 38, 20 pp.

Jaquet. N., S. Dawson, and E. Slooten. 2000. Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: Foraging implications. Canadian Journal of Zoology. 78:407-419.

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., S. Leatherwood, and M.A. Webber. 1993. FAO species identification guide. Marine mammals of the world. Rome: Food and Agriculture Organization of the United Nations.

Jefferson, T.A. and S. Leatherwood. 1994. *Lagenodelphis hosei*. Mammalian Species. 470:1-5.

Jefferson, T.A. and N.B. Barros. 1997. *Peponocephala electra*. Mammalian Species. 553:1-6.

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 dolphin (*Steno bredanensis*) at Rota, Northern Mariana Islands. Micronesica. 38:239-244.

Jensen, A. S. and G. K. Silber, 2004. Large Whale Ship Strike Database. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-OPR-25.

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. 425:575.

Jepson, P.D., R. Deaville, I.A.P. Patterson, A.M. Pocknell, H.M. Ross, J.R. Baker, F.E. Howie, R.J. Reid, A. Colloff, and A.A. Cunningham, 2005. "Acute and Chronic Gas Bubble Lesions in Cetaceans Stranded in the United Kingdom. Veterinary Pathology. 42:291-305.

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.

Johnson, M., P.T. Madsen, W.M.X. Zimmer, N. Aguilar de Soto and P.L. Tyack. 2004. Foraging Blainville's beaked whales (*Mesoplodon densirostris*) produce distinct click types matched to different phases of echolocation. Journal of Experimental Biology. 209:5038-5050.

Jones, D.M. and D.E. Broadbent. 1998. Chapter 24. Human performance and noise. Pages 24.21 - 24.24 In: C. M. Harris (ed.). Handbook of acoustical measurements and noise control. Acoustical Society of America, Woodbury, New York.

Jurasz, C.M. and V.P. Jurasz,.1979. Feeding modes of the humpback whale, *Megaptera novaeangliae*, in southeast Alaska. Scientific Reports of the Whales Research Institute 31:69-83.

Kami, H.T. and A.J. Hosmer. 1982. Recent beachings of whales on Guam. Micronesica18:133-135.

Kami, H.T. and R.J. Lujan 1976. Records of the dwarf sperm whale *Kogia simus* Owen from Guam. Micronesica. 12:327-332.

Kaminga, C. and J.G. van Velden. 1987. Investigations on cetacean sonar VIII/Sonar signals of *Pseudorca crassidens* in comparison with *Tursiops truncatus*. Aquatic Mammals. 13:43–49.

Kastak, D. and R. J. Schusterman. 1996. Temporary threshold shift in a harbor seal (*Phoca vitulina*). Journal of the Acoustical Society of America. 100:1905-1908.

Kastak, D. and R. J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise, and ecology. Journal of the Acoustical Society of America. 103:2216-2228.

Kastak, D. and R.J. Schusterman. 1999. In-air and underwater hearing sensitivity of a northern elephant seal (*Mirounga angustirostris*). Canadian Journal of Zoology. 77:1751-1758.

Kastak, D., R.J. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999a. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of Acoustical Society of America. 106:1142-1148.

Kastak, D., R.J. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999b. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of the Acoustical Society of America. 106:1142-1148.

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., M. Hagedoorn, W. W. L. Au, and D. De Haan, 2003. Audiogram of a striped dolphin (*Stenella coeruleoalba*). Journal of the Acoustical Society of America 113:1130-1137.

Kasuya, T. 1975. Past occurrence of *Globicephala melaena* in the western North Pacific. Scientific Reports of the Whales Research Institute. 27:95-110.

Kasuya, T. 1991. Density-dependent growth in North Pacific sperm whales. Marine Mammal Science. 7:230-257.

Kasuya, T. 2002. Giant beaked whales *Berardius bairdii* and *B. arnuxii*. Pages 519-522 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Kasuya, T., T. Miyashita, and F. Kasamatsu. 1988. Segregation of two forms of short-finned pilot whales off the Pacific Coast of Japan. Scientific Reports of the Whales Research Institute. 39:77-90.

Kato, H. 2002. Bryde's whales *Balaenoptera edeni* and *B. brydei*. Pages 171 -176 in W.F. Perrin, B. Wursig, and J.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. San Diego: Academic Press.

Katona, S.K. and S.D. Kraus. 1999. Efforts to conserve the North Atlantic right whale. In Conservation and Management of Marine Mammals, eds. J.R. Twiss, Jr. and R.R. Reeves, 311–331. Washington, DC: Smithsonian Institution Press.

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.

Keenan, R.E. 2000. An Introduction to GRAB Eigenrays and CASS Reverberation and Signal Excess. Science Applications International Corporation, MA.

Kennett, J.P. 1982. Marine geology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Kennedy, S., T. Kuiken, P.D. Jepson, R. Deaville, M. Forsyth, T. Barrett, M.W.G. vande 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.

Kenney, R.D. and H.E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. Continental Shelf Research. 7:107-114.

Kenney, R.D., P.M. Payne, D.W. Heinemann, and H.E. Winn. 1996. Shifts in northeast shelf cetacean distributions relative to trends in Gulf of Maine/Georges Bank finfish abundance. Pages 169-196 in K. Sherman, N.A. Jaworski, and T.J. Smayda, eds. The northeast shelf ecosystem: assessment, sustainability, and management. Boston: Blackwell Science.

Kenney, R.D., G.P. Scott, T.J. Thompson, and H.E. Winn. 1997. Estimates of prey consumption and trophic impacts of cetaceans in the USA Northeast Continental Shelf ecosystem. Journal of Northwest Atlantic Fishery Science. 22:155-171.

Ketten, D.R. 1992. The marine mammal ear: Specializations for aquatic audition and echolocation. Pages 717-750 in D. Webster, R. Fay, and A. Popper, eds. The evolutionary biology of hearing. Berlin: Springer-Verlag.

Ketten, D.R. 1997. Structure and functions in whale ears. Bioacoustics. 8:103-135.

Ketten, D.R. 1998. Marine mammal auditory systems: A summary of audiometric and anatomical data and its implications for underwater acoustic impacts. NOAA-TM-NMFS-SWFSC-256, Department of Commerce.

Ketten, D.R. 2000. Cetacean Ears. In: Hearing by Whales and Dolphins. Eds. W.W.L. Au, A.N. Popper, and R.R. Fay. Springer-Verlag, Inc., New York, NY. Pp 43-108.

Ketten, D.R. 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.

Kinsey, D., P. Olson, and T. Gerrodette. 2000. Marine mammal data collection procedures on research ship line-transect surveys by the Southwest Fisheries Science Center. SWFSC Administrative Report. LJ-00-08. 32p.

Kinsler, L.E. and A.R. Frey. 1962. Fundamentals of Acoustics. John Wiley and Sons, New York

Kirshvink, J.L. 1990. Geomagnetic sensitivity in cetaceans: an update with live stranding records in the United States. Sensory Abilities of Cetaceans: Laboratory and Field Evidence. Eds. J.A. Thomas and R.A. Kastelein. Plenum Press, NY. Pp 639-649.

Kirshvink, J.L., A.E. Dizon, and J.A. Westphal. 1986. Evidence from strandings for geomagnetic sensitivity in cetaceans. Journal of Experimental Biology. 120:1-24.

Kishiro, T. 1996. Movements of marked Bryde's whales in the western North Pacific. Reports of the International Whaling Commission. 46:421-428.

Kiyota, M., N. Baba, and M. Mouri. 1992. Occurrence of an elephant seal in Japan. Marine Mammal Science. 8:433.

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. 88:59-66.

Klinowska, M. 1985. Cetacean stranding sites relate to geomagnetic topography. Aquatic Mammals. 1:27-32.

Klinowska, M. 1986. Cetacean Live Stranding Dates Relate to Geomagnetic Disturbances. Aquatic Mammals. 11:109-119.

Knowlton, A.R., C.W. Clark, and S.D. Kruse. 1991. Sounds recorded in the presence of sei whales, *Balaenoptera borealis*. Abstract. Ninth Biennial Conference on the Biology of Marine Mammals, Chicago, IL. pp. 76.

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 Kraus. S.D. 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.

Kooyman, G.L., D.D. Hammond, and J.P. Schroeder. 1970. Brochograms and tracheograms of seals under pressure. Science. 169:82-84.

Kooyman G.L. and F. Trillmich. 1986. Diving behavior of Galapagos fur seals. IEn: Gentry, RL & GL Kooman (eds), Fur seals: maternal strategies on land and at sea, pp. 186-195. Princeton Univ. Press. USA.

Kooyman, G.L., R.W. Davis, and J.P. Croxall. 1986. Diving behavior of Antarctic fur seals. In: R.L. Gentry and G.L. Kooyman: Fur seals - Maternal strategies on land and at sea, pp.: 115-125, Princeton University Press.

Kopelman, A.H., and S.S. Sadove. 1995. Ventilatory rate differences between surface-feeding and nonsurface-feeding fin whales (*Balaenoptera physalus*) in the waters off eastern Long Island, New York, U.S.A., 1981-1987. Marine Mammal Science. 11:200-208.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss, M. B. Hanson, B. L. Taylor, G. M. Ylitalo, M. E. Dahlheim, J. E. Stein, and R. S. Waples, 2004, 2004 status review of southern resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC-62:1-73.

Krausman, P.R., L.K. Harris, C.L. Blasch, K.K. G. Koenen, and J. Francine. 2004. Effects of military operations on behavior and hearing of endangered Sonoran pronghorn. Wildlife Monographs. 1-41.

Krewski, D., C. Brown, and D. Murdoch. 1984. Determining "safe" levels of exposure: safety factors or mathematical models? Toxicological Sciences. 4:383-394.

Krieger, K. J., and B. L. Wing. 1986. Hydroacoustic monitoring ofprey to determine humpback whale movements. U.S. Department Commerce NOAA Techical Memorandum. NMFS FINWC-98. 62 pp.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). Pages 183-212 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

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. 48:513-523.

Kryter, K.D. 1970. The Effects of Noise on Man. Academic Press, New York.

Kubota, G. 2004. Sealing the attention. Honolulu Star-Bulletin News, 28 December.

Jaquet, N., S. Dawson, and E. Slooten. 2000. Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: Foraging implications. Canadian Journal of Zoology. 78:407-419.

Lafortuna, C.L., M. Jahoda, A. Azzellino, F. Saibene, and A. Colombini. 2003. Locomotor behaviours and respiratory pattern of the Mediterranean fin whale (*Balaenoptera physalus*). European Journal of Applied Physiology. 90:387-395.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science. 17:35–75.

Lammers, M.O., W.W.L. Au, and D.L. Herzing. 2003. The broadband social acoustic signaling behavior of spinner and spotted dolphins. Journal of the Acoustical Society of America. 114:1629-1639.

Lammers, M.O. 2004. Occurrence and behavior of Hawaiian spinner dolphins (*Stenella longirostris*) along Oahu's leeward and south shores. Aquatic Mammals. 30:237-250.

Lagerquist, B.A., K.M. Stafford, and B.R. Mate. 2000. Dive characteristics of satellite-monitored blue whales (*Balaenoptera musculus*) off the central California coast. Marine Mammal Science. 16:375-391.

Laurinolli, M.H., A.E. Hay, F. Desharnais, and C.T. Taggart. 2003. Localization of North Atlantic right whale sounds in the Bay of Fundy using a sonobuoy array. Marine Mammal Science. 19:708-723.

Leatherwood, S. and R. R. Reeves. 1983. The Sierra Club handbook of whales and dolphins. San Francisco, California: Sierra Club Books.

Leatherwood, S., and R. Reeves. 1982. Pelagic Sightings of Risso's Dolphin, *Grampus griseus*, in the Gulf of Mexico and Atlantic Ocean Adjacent to Florida. Journal of Mammalogy, Vol 63.

Leatherwood, S., C. L. Hubbs, and M. Fisher. 1979. First records of Risso's dolphin (*Grampus griseus*) from the Gulf of California with detailed notes on a mass stranding. Transactions of the San Diego Society of Natural History. 19:45-51.

Leatherwood, S., T.A. Jefferson, J.C. Norris, W.E. Stevens, L.J. Hansen, and K.D. Mullin. 1993. Occurrence and sounds of Fraser's dolphin (*Lagenodelphis hosei*) in the Gulf of Mexico. Texas Journal of Science. 45:349-354.

Le Boeuf, B.J., R.J. Whiting, and R.F. Gannt. 1972. Perinatal behavior of northern elephant seal females and their young. Behaviour. 43:121-156.

Le Boeuf, B.J. and L.F. Petrinovich. 1974. Dialects of northern elephant seals, *Mirounga angustirostris*: Origin and reliability. Animal Behavior. 22:656-663.

Le Boeuf, B.J., Y. Naito, A.C. Huntley, and T. Asaga. 1989. Prolonged, continuous, deep diving by northern elephant seals. Canadian Journal of Zoology. 67:2514-2519.

Le Boeuf, B.J. and J. Reiter. 1991. Biological effects associated with El Nino Southern Oscillation, 1982-83 on northern elephant seals breeding at Ano Nuevo, California. In: F. Trillmich and K.A. Ono, eds. Pinnipeds and El Nino: Responses to Environmental Stress, Springer-Verlag, Berlin. Pp. 206-218.

Le Boeuf, B.J., D.E. Crocker, D.P. Costa, S.B. Blackwell, P.M. Webb, and D.S. Houser. 2000. Foraging ecology of northern elephant seals. Ecological Monographs. 70:353-382.

LeDuc, R.G., W.L. Perryman, Gilpatrick, Jr., J.W., J. Hyde, C. Stinchcomb, J.V. Carretta, and R.L. Brownell. 2001. A note on recent surveys for right whales in the southeastern Bering Sea. Journal of Cetacean Research and Management, Special Issue. 2:287-289.

Lee, T. 1993. Summary of cetacean survey data collected between the years of 1974 and 1985. NOAA Technical Memorandum NMFS-SWFSC-181. 85 pp.

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.

Liao, T.F. 1994. Interpreting probability models. Logit, probit, and other generalized linear models. SAGE Publications, Inc. Newbury Park, California.

Ljungblad, D.K., B. Würsig, S.L. Swartz, and J.M. Keene. 1988. Observations on the behavioral responses of Bowhead whales (*Balaena mysticetes*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic. 41:183-194.

Macfarlane, J.A.F. 1981. Reactions of whales to boat traffic in the area of the confluence of the Saguenay and St. Lawrence rivers, Quebec. Manuscript cited in Richardson et al. 1995. 50 pp.

MacLeod, C.D. 1999. A review of beaked whale acoustics, with inferences on potential interactions with military activities. European Research on Cetaceans. 13:35-38.

MacLeod, C.D. 2000. Review of the distribution of *Mesoplodon* species (Order Cetacea, Family Ziphiidae) in the North Atlantic. Mammal Review. 30:1-8.

MacLeod, C.D., N. Hauser, and H. Peckham. 2004. Diversity, relative density and structure of the cetacean community in summer months east of Great Abaco, Bahamas. Journal of the Marine Biological Association of the U.K. 84:469-474.

Madsen, P.T., D.A. Carder, W.W.L. Au, P.E. Nachtigall, B. Møhl, and S.H. Ridgway. 2003. Sound production in neonate sperm whales (L). Journal of the Acoustical Society of America. 113:2988-2991.

MacLeod, C.D., W.F. Perrin, R. Pittman, J. Barlow, L. Balance, A. D’Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D.L. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). Journal of Cetacean Research Management. 7:271-286.

Madsen, P.T., I. Kerr, and R. Payne. 2004. Echolocation clicks of tow free-ranging delphinids with different food preferences: false killer whales (*Pseudorca crassidens*) and Risso's dolphin (*Grampus griseus*). Journal of Experimental Biology. 207:1811-1823.

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. 120:2366-2379.

Magrab, E.B. 1975. Environmental Noise Control. John Wiley and Sons, New York

Maldini, D. 2003. Abundance and distribution patterns of Hawaiian odontocetes: Focus on Oahu. Ph.D dissertation, University of Hawaii, Manoa.

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.

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 & Newman Inc., Cambridge, MA, for U.S. Minerals Management Service, Anchorage, AK. NTIS PB86-174174. Var.p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack and J.E. Bird. 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. Report from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Management Service, Anchorage, AK. NTIS PB86-218377.

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack, 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. Pp. 55-73 in Port and Ocean Engineering Under Arctic Conditions, Volume III (W.M. Sackinger, M.O. Jeffries, J.L. Imm, and S.D. Treacy eds.) (University of Alaska, Fairbanks).

Marine Mammal Commission. 2003. Workshop on the management of Hawaiian monk seals on beaches in the Main Hawaiian Islands. Final report of a workshop held 29-31 October in Koloa, Kauai, Hawaii. Bethesda, Maryland: Marine Mammal Commission.

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

Marten, K. and S. Psarakos. 1999. Long-term site fidelity and possible long-term associations of wild spinner dolphins (*Stenella longirostris*) seen off Oahu, Hawaii. Marine Mammal Science. 15:329-336.

Mate, B.R., S.L. Nieukirk, and S.D. Kraus. 1997. Satellite-monitored movements of the northern right whale. Journal of Wildlife Management. 61:1393-1405.

Mate, B.R., B.A. Lagerquist, and J. Calambokidis. 1999. Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. Marine Mammal Science. 15:1246-1257.

Matthews, J.N., S. Brown, D. Gillespie, M. Johnson, R. McLanaghan, A. Moscrop, D. Nowacek, R. Leaper, T. Lewis, and P. Tyack. 2001. Vocalisation rates of the North Atlantic right whale (*Eubalaena glacialis*). Journal of Cetacean Research and Management. 3:271-282.

Mattila, D.K., L.N. Guinee, and C.A. Mayo. 1987. Humpback whale songs on a North Atlantic feeding ground. Journal of Mammalogy. 68:880-883.

May-Collado, L.J., I. Agnarsson, D. Wartzok. 2007. Reexamining the relationship between body size and tonal signals frequency in whales: a comparative approach using a novel phylogeny. Marine Mammal Science. 23:524-552.

Maybaum, H.L. 1989. Effects of a 3.3 kHz sonar system on humpback whales, *Megaptera novaeangliae*, in Hawaiian waters. M.S. Thesis, University of Hawaii, Manoa. 112 pp.

Maybaum, H.L. 1990. Effects of a 3.3 kHz sonar system on humpback whales, *Megaptera novaeangliae*, in Hawaiian waters. Eos. 71:92.

Maybaum, H.L. 1993. Responses of humpback whales to sonar sounds. Journal of the Acoustical Society of America. 94:1848-1849.

Mazzuca, L., S. Atkinson, B. Keating, and E. Nitta. 1999. Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998. Aquatic Mammals. 25:105-114.

McAlpine, D.F. 2002. Pygmy and dwarf sperm whales Kogia breviceps and K. sima. Pages 1007-1009 in W.F. Perrin, B. Wursig, and J.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. San Diego: Academic Press.

McCullagh, P. and J.A. Nedler. 1989. Generalized linear models. Second Edition. Chapman and Hall; London, United Kingdom.

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, 2000. 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.

McCulloch, C.E. and S.R. Searle. 2001. Generalized, linear, and mixed models. John Wiley and Sons, Inc.; New York, New York.

McCowan, B., and D. Reiss, 1995. Maternal aggressive contact vocalizations in captive bottlenose dolphins (*Tursiops truncatus*): Wide-band, low frequency signals during mother/aunt-infant interactions. Zoo Biology. 14:293-309.

McDonald MA, Hildebrand JA, Webb SC 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. Journal of the Acoustical Society of America. 98:712–721.

McDonald, M.A., J.A. Hildebrand, S.M. Wiggins, D. Thiele, D. Glasgow, and S.E. Moore. 2005. Sei whale sounds recorded in the Antarctic. Journal of the Acoustical Society of America. 118:3941-3945.

McDonald, M.A. and C.G. Fox. 1999. Passive acoustic methods applied to fin whale population density estimation. Journal of the Acoustical Society of America. 105:2643-2651.

McDonald, M.A., J. Calambokidis, A.M. Teranishi, and J.A. Hildebrand. 2001. The acoustic calls of blue whales off California with gender data. Journal of the Acoustical Society of America 109:1728-1735.

McDonald, M.A., and S.E. Moore. 2002. Calls recorded from North Pacific right whales (*Eubalaena japonica*) in the eastern Bering Sea. Journal of Cetacean Research and Management. 4:261-266.

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. 120:711-718.

McGrath, J.R. 1971. Scaling Laws for Underwater Exploding Wires. Journal of the Acoustical Society of America. 50:1030-1033.

Mead, J.G. 1989. Beaked whales of the genus - *Mesoplodon*. Pages 349-430 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. London: Academic Press.

Mellinger, D.K., C.D. Carson, and C.W. Clark. 2000. Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico. Marine Mammal Science. 16:739-756.

Mellinger, D.K., and C.W. Clark. 2003. Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic. Journal of the Acoustical Society of America. 114:1108-1119.

Mellinger, D.K., K.M. Stafford, S.E. Moore, L. Munger, and C.G. Fox. 2004. Detection of North Pacific right whale (*Eubalaena japonica*) calls in the Gulf of Alaska. Marine Mammal Science. 20:872-879.

Menard, S. 2000. Coefficients of determination for multiple logistic regression analysis. The American Statistician. 54:17-24.

Menard, S. 2002. Applied logistic regression analysis. Second Edition. SAGE Publications, Inc., Newbury Park, California.

Mesnick, S.L., B.L. Taylor, B. Nachenberg, A. Rosenberg, S. Peterson, J. Hyde, and A.E. Dizon. 1999. Genetic relatedness within groups and the definition of sperm whale stock boundaries from the coastal waters off California, Oregon and Washington. Southwest Fisheries Center Administrative Report LJ-99-12:1-10. La Jolla, California: National Marine Fisheries Service.

McGraw-Hill Dictionary of Physics and Mathematics (MHDPM). 1978. D.N. Lapedes (Editor in Chief), McGraw-Hill Book Company, New York

Miksis J.L., Grund, M.D., Nowacek, D.P., Solow, A.R., Connor R.C. and Tyack, P.L. 2001. Cardiac Responses to Acoustic Playback Experiments in the Captive Bottlenose Dolphin, *Tursiops truncatus*. Journal of Comparative Psychology. 115:227-232.

Miller, E.H. and D.A. Job. 1992. Airborne acoustic communication in the Hawaiian monk seal, *Monachus schauinslandi*. Pages 485-531 in J.A. Thomas, R.A. Kastelein and A.Y. Supin, eds. Marine mammal sensory systems. New York, New York. Plenum Press.

Miller, J.D., C.S. Watson, and W.P. Covell. 1963. Deafening effects of noise on the cat. Acta Oto-Laryngologica Supplement. 176:1–91.

Miller, J.D. 1974. Effects of noise on people. Journal of the Acoustical Society of America. 56:729–764.

Miller, P.J.O., M.P. Johnson, and P.L. Tyack. 2004. Sperm whale behaviour indicates the use of echolocation click buzzes ‘creaks’ in prey capture. Proceedings of the Royal Society of London, Part B: 271:2239-2247.

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 Society of America. 65:1238–1248.

Mitchell, E. 1975. Report of the meeting on smaller cetaceans, Montreal, April 1-11, 1974. Subcommittee on small cetaceans, Scientific Committee, International Whaling Commission. Journal of the Fisheries Research Board of Canada. 32:889-983.

Miyashita, T. 1993. Abundance of dolphin stocks in the western North Pacific taken by the Japanese drive fishery. Reports of the International Whaling Commission 43:417-437.

Miyashita, T., H. Kato, and T. Kasuya. 1995. Worldwide map of cetacean distribution based on Japanese sighting data. Volume 1. Shimizu, Shizuoka, Japan: National Research Institute of Far Seas Fisheries.

Miyashita, T., T. Kishiro, N. Higash, F. Sato, K. Mori, and H. Kato. 1996. Winter distribution of cetaceans in the western North Pacific inferred from sighting cruises 1993-1995. Reports of the International Whaling Commission. 46:437-441.

Miyazaki, N. and S. Wada. 1978. Observation of Cetacea during whale marking cruise in the western tropical Pacific. Scientific Reports of the Whales Research Institute. 30:179-195.

Miyazaki, N. and W.F. Perrin. 1994. Rough-toothed dolphin-*Steno bredanensis* (Lesson, 1828). Pages 1-21 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego, California: Academic Press.

Mizroch, S.A., D.W. Rice, D. Zwiefelhofer, J. Waite, and W.L. Perryman. 1999. Distribution and movements of fin whales (*Balaenoptera physalus*) in the Pacific Ocean. Page 127 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Maui.

Moberg, G.P. 2000. Biological response to stress: implications for animal welfare. Pages 1 - 21 In: G. P. Moberg, and J. A. Mench, editors. The biology of animal stress. Basic principles and implications for animal welfare. Oxford University Press, Oxford, United Kingdom.

Mobley, J.R. 2004. Results of marine mammal surveys on U.S. Navy underwater ranges in Hawaii and Bahamas. Final Report to Office of Naval Research, 27 pp.

Mobley, J.R. 2005. Results of 2005 Aerial Surveys of Humpback Whales North of Kauai. Report from Marine Mammal Research Consultants, Ltd. 15 pp.

Mobley, J.R. 2006. Results of 2006 RIMPAC Aerial Surveys of Marine Mammals in Kaulakahi and Alenuihaha Channels. Final Report Submitted to Environmental Division Commander, U.S. Pacific Fleet. 12 pp.

Mobley, J.R., M. Smultea, T. Norris, and D. Weller. 1996. Fin whale sighting north of Kauai, Hawaii. Pacific Science. 50:230-233.

Mobley, J.R., G.B. Bauer, and L.M. Herman. 1999. Changes over a ten-year interval in the distribution and relative abundance of humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters. Aquatic Mammals. 25:63-72.

Mobley, J.R., S.S. Spitz, K.A. Forney, R. Grotefendt, and P.H. Forestell. 2000. Distribution and abundance of odontocete species in Hawaiian waters: Preliminary results of 1993-98 aerial surveys. Southwest Fisheries Science Center Administrative Report LJ-00-14C. La Jolla, California: National Marine Fisheries Service.

Mobley, J.R., S.S. Spitz, and R. Grotefendt. 2001a. Abundance of humpback whales in Hawaiian waters: Results of 1993-2000 aerial surveys. Report prepared for the Hawaii Department of Land and Natural Resources and the Hawaiian Islands Humpback Whale National Marine Sanctuary, NOAA, U.S. Department of Commerce.

Mobley, J.R., L.L. Mazzuca, A.S. Craig, M.W. Newcomer, and S.S. Spitz. 2001b. Killer whales (*Orcinus orca*) sighted west of Niihau, Hawaii. Pacific Science. 55:301-303.

Mobley, J.R., S.W. Martin, D. Fromm, and P.E. Nachtigall. 2007. Lunar influences as possible cause for simultaneous aggregations of melon-headed whales in Hanalei Bay, Kauai and Sasanhaya Bay, Rota. Seventeenth Biennial Confernce on the Biology of Marine Mammals. Cape Town, South Africa. 29 November to 3 December 2007.

Møhl, B., M. Wahlberg, P. T. Madesen, A. Heerfordt, and A. Lund, 2003. The monopulsed nature of sperm whale clicks. Journal of the Acoustical Society of America. 114:1143-1154.

Moore, S.E., J.M. Waite, L.L. Mazzuca, and R.C. Hobbs. 2000. Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. Journal of Cetacean Research and Management. 2:227-234.

Moore, S.E. and J.T. Clarke. 2002. Potential impact of offshore human activities on gray whales. *Eschrichtius robustus*. Journal of Cetacean Research Management. 4:19-25.

Nachtigall, P.E., W.W.L. Au, J.L. Pawloski, and P.W.B. Moore. 1995. Risso's dolphin (*Grampus griseus*) hearing thresholds in Kaneohe Bay, Hawaii. Pages 49-53 in R.A. Kastelein, J.A. Thomas, and P.E. Nachtigall, eds. Sensory systems of aquatic mammals. Woerden, The Netherlands: De Spil Publishers.

Nachtigall, P.E., D.W. Lemonds, and H.L. Roitblat. 2000. Psychoacoustic studies of dolphins and whales in Hearing by Dolphins and Whales, W.W.L. Au, A.N. Popper, and R.R. Fay, eds. Springer, New York. Pp. 330-363.

Nachtigall, P.E., J.L. Pawloski, and W.W.L. Au. 2003. Temporary threshold shift and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). 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 truncatus*) measured using evoked auditory potential. Marine Mammal Science. 20:673-687.

Nachtigall, P.E., M.M.L. Yuen, T.A. Mooney, and K.A. Taylor. 2005. Hearing measurements from a stranded infant Risso's dolphin, *Grampus griseus*. The Journal of Experimental Biology. 208:4181-4188.

Nachtigall, P.E. and A.Y. Supin. 2008. A false killer whale adjusts its hearing when it echolocates. Journal of Experimental Biology. 211:1714-1718.

National Marine Fisheries Service (NMFS). 1988. Critical habitat; Hawaiian monk seal; Endangered Species Act. Federal Register. 53: 18,988-18,998.

National Marine Fisheries Service. 1998a. Recovery plan for the blue whale (*Balaenoptera musculus*). Prepared by R.R. Reeves, P.J. Clapham, R.L. Brownell, and G.K. Silber. Silver Spring, Maryland: National Marine Fisheries Service.

National Marine Fisheries Service. 1998b. Draft recovery plan for the fin whale (*Balaenoptera physalus*) and sei whale (*Balaenoptera borealis*). Prepared by R.R. Reeves, G.K. Silber, and P.M. Payne for the Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland. 47 pp.

National Marine Fisheries Service. 2001. Interim Findings on the Stranding of Beaked Whales in the Bahamas – December 20,2001. http://www.nmfs.noaa.gov/bahamasbeakedwhales.htm. Accessed 1/24/07.

National Marine Fisheries Service. 2002. Endangered and threatened species: Determination on a petition to revise critical habitat for northern right whales in the Pacific. Federal Register 67:7660-7665.

National Marine Fisheries Service, Office of Protected Resources. 2005. Assessment of Acoustic Exposures on Marine Mammals in Conjunction with *U.S.S. SHOUP* Active Sonar Transmissions in the Eastern Strait of Juan de Fuca and Haro Strait, Washington, 5 May 2003.

National Marine Fisheries Service. 2005b. Pygmy Sperm Whale (*Kogia breviceps*): Western North Atlantic Stock. Stock Assessment Report. December, 2005.

National Marine Fisheries Service. 2005c. Long-Finned Pilot Whale (*Globicephala melas*): Western North Atlantic Stock. Stock Assessment Report. December, 2005.

National Marine Fisheries Service. 2005d. False Killer Whale (*Pseudorca crassidens*): Northern Gulf of Mexico Stock. Stock Assessment Report. December, 2005.

National Marine Fisheries Service. 2005e. Dwarf Sperm Whale (*Kogia sima*): Western North Atlantic Stock. Stock Assessment Report. December, 2005.

National Marine Fisheries Service. 2005f. Harbor Porpoise (*Phocoena phocoena*): Gulf of Maine/Bay of Fundy Stock. Stock Assessment Report. December, 2005.

National Marine Fisheries Service. 2005g. Bottlenose Dolphin (*Tursiops truncatus*): Gulf of Mexico Bay, Sound, and Estuarine Stocks. Stock Assessment Report. December, 2005.

National Marine Fisheries Service. 2005h. Incidental Harassment Authorization for Conducting the Precision Strike Weapon (PSW) Testing and Training by Eglin Air Force Base. Federal Register 70, No. 160, 48675-48691.National Marine Fisheries Service. 2006a. Endangered and threatened species: Revision of critical habitat for the northern right whale in the Pacific Ocean. Federal Register 71, No. 129, 38277-38297.

National Marine Fisheries Service. 2006b. Final Rule, for Conducting the Precision Strike Weapon (PSW) Testing and Training by Eglin Air Force Base. Federal Register 71, No. 226, 67810-67824.

National Marine Fisheries Service 2006c. Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species- October 1, 2004 – September 30, 2006. Office of Protected Resources, National Marine Fisheries Service, Silver Springs, MD. 185 pp.

National Marine Fisheries Service. 2007a. http://www.nmfs.noaa.gov/pr/pdfs/health/stranding_fact_sheet.pdf. Accessed 1/29/07

National Marine Fisheries Service. 2007b. http://www.nmfs.noaa.gov/pr/health/faq.htm. Accessed 1/30/07.

National Marine Fisheries Service. 2007c, http://www.nmfs.noaa.gov/pr/health/. Accessed 1/30/07.

National Marine Fisheries Service. 2007e. http://seahorse.nmfs.noaa.gov/msdbs/class/seahorse_public.htm. Accessed 2/2/07.

National Marine Fisheries Service. 2007f. 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

National Marine Fisheries Service. 2007g. http://www.afsc.noaa.gov/NMML/education/cetaceans/cetaceastrand.htm Accessed 1/31/07.

National Marine Fisheries Service. 2007h. National Marine Fisheries Service, Office of Protected Resources. 2005 Multispecies Mass Stranding in North Carolina. Accessed 2/16/07. http://www.nmfs.noaa.gov/pr/health/mmume/event2005jan.htm.

National Marine Fisheries Service. 2007i. Multi-species Unusual Mortality Event in North Carolina Fact Sheet. Accessed 2/16/07. http://www.nmfs.noaa.gov/pr/pdfs/health/ume_jan_2005_fact_sheet.pdf

National Marine Fisheries Service. 2007j. National Marine Fisheries Service, Office of Protected Resources. July 2004 mass Stranding of Melon-Headed Whales in Hawai'i. Accessed 2/16/07. http:www.nmfs.noaa.gov/pr/health/mmume/event2004jul.html.

National Marine Fisheries Service. 2007k. July 2004 Mass Stranding of Melon-Headed Whales in Hawai'i Fact Sheet for Final Report. Accessed 2/16/07. http://www.nmfs.noaa.gov /pr/pdfs/health/stranding_melonheadedwhales_july2004.pdf.

National Marine Fisheries Service. 2007l. Brevetoxin & Florida Red Tides. Accessed 2/16/07. http://www.nmfs.noaa.gov/pr/pdfs/health/brevetoxin.pdf.

National Marine Fisheries Service. 2007m. 2004 Bottlenose Dolphin Unusual Mortality Event Along the Florida Panhandle. Accessed 2/16/07. http://www.nmfs.noaa.gov/pr/health/mmume/event2004.htm

National Marine Fisheries Service. 2007n. STRANDINGS Newsletter of the Southeast United States Marine Mammal Health and Stranding Network. Winter 2006/Spring 2007. NOAA Tech Memo NMFS-SEFSC-545. Accessed 2/16/07.http://www.sefsc.noaa.gov/PDFdocs/ SNewsletter112806.pdf.

National Marine Fisheries Service, 2007o. Draft Programmatic Environmental Impact Statement for the Marine Mammal Health and Stranding Response Program, National Marine Fisheries Service, Office of Protected Resources, p. 1006.

National Marine Fisheries Service. 2008. National Marine Fisheries Office of Protected Resources memorandum to Chief of Naval Operations Environmental Readiness. 19 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; NMFS, FR 66, No. 87, 22450-67.

National Oceanic and Atmospheric Administration. 2002a. Final Rule SURTASS LFA Sonar. *Federal Register*, Department of Commerce; NMFS, FR 67, 136, 46712-89, 16 July.

National Oceanic and Atmospheric Administration. 2002b. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans. NOAA Fisheries, Silver Spring, Maryland. April 2002.

National Oceanic and Atmospheric Administration. 2006a. National Marine Fisheries Service Biological Opinion for RIMPAC, 2006.

National Oceanic and Atmospheric Administration. 2006b. IHA Permit for RIMPAC 2006.

National Oceanic and Atmospheric Administration. 2006a. NOAA Fisheries Service Releases Necropsy Report: Cause of 2005 Marine Mammal Strandings Unclear. NOAA News NOAA06-030, March 29, 2006.

National Oceanic and Atmospheric Administration. 2006b. NOAA Fisheries Service Releases Final Report on 2004 Stranding of Melon-headed Whales in Hawaii. NOAA News NOAA06-046, April 27, 2006.

National Oceanic and Atmospheric Administration. 2006c. Hawaiian Melon-headed Whale (*Peponocephala electra*) Mass Stranding Event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31, April, 2006.

National Oceanic and Atmospheric Administration. 2007. Taking and Importing Marine Mammals Incidental to the U,.S. Nav Operations of Surveillance Towed Array Sensor System Low Frequency Active Sonar. Federal Register, Vol. 72, No. 161, pp. 46845-46893, 21 August 2007.

NOAA Fisheries Service Releases Final Report on 2004 Stranding of Melon-headed Whales in Hawaii. NOAA News NOAA06-046, April 27, 2006.

National Research Council. 2003. Ocean noise and marine mammals. The National Academic Press, Washington D.C. 208 pp.

National Research Council. 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. The National Academic Press, Washington D.C. 126 pp.

Naval Sea Systems Command, NAVSEA Instruction 3150.2: Safe Diving Distances from Transmitting Sonar.

Nawojchik, R., D.J. St. Aubin and A. Johnson. 2003. Movements and dive behavior of two stranded, rehabilitated long-finned pilot whales (*Globicephala melas*) in the Northwest Atlantic. Marine Mammal Science. 19:232-239.

Nedler, J.A. and T.W.M. Wedderburn. 1972. Generalized linear models. Journal of the Royal Statistical 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. Subacoustech Ltd. Report, Ref. 19534R0213.

Nemoto, T. and A. Kawamura. 1977. Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. Reports of the International Whaling Commission, Special Issue. 1:80-87.

Norman, S.A. and J.G. Mead. 2001. *Mesoplodon europaeus*. Mammalian Species. 688:1-5.

Norman, S.A., S. Raverty, W. McClellan, A. Pabst, D. Ketten, M. Fleetwood, J.K. Gaydos, B. Norberg, L. Barre, 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-North West Region-34. 120 pp.

Norris, K.S. and J.H. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. University of California Publications in Zoology. 63:291-402.

Norris, K.S., B. Würsig, R.S. Wells, and M. Wursig. 1994. The Hawaiian spinner dolphin. Berkeley: University of California Press.

Norris, T.F., M.A. Smultea, A.M. Zoidis, S. Rankin, C. Loftus, C. Oedekoven, J.L. Hayes, and E. Silva. 2005. A preliminary acoustic-visual survey of cetaceans in deep waters around Niihau, Kauai, and portions of Oahu, Hawaii from aboard the WV Dariabar, February 2005. Final Technical and Cruise Report July 2005. Prepared for Geo-Marine, Inc., Plano, Texas, and NAVFAC Pacific, Pearl Harbor, Hawaii, by Cetos Research Organization, Bar Harbor, Maine. Contract #2057sa05-F.

Northrop, J., W.C. Cummings, and M.F. Morrison. 1971. Underwater 20-Hz signals recorded near Midway Island. Journal of the Acoustical Society of America. 49:1909-1910.

Northwest and Alaska Fisheries Center. 1978. Northern elephant seal appears on one of the Northwestern Hawaiian Islands.

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 of London, part B. 271:227-231.

Nowacek, D.P., L.H. Thoren, D.W. Johnson and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Review. 37:81-115.

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

Nuclear Regulatory Commission. 1997. Proceedings of a dose-modeling workshop. November 13 – 14, 1997. Washington, D.C.

Odell, D.K., and K.M. McClune. 1999. False killer whale *Pseudorca crassidens* (Owen, 1846). Pages 213-243 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Office of Naval Research (ONR) Workshop. 1998. Effects of Manmade Sound on the Marine Environment. 10-12 February 1998, Bethesda, MD.

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.

Ohizumi, H., T. Matsuishi, and H. Kishino. 2002. Winter sightings of humpback and Bryde's whales in tropical waters of the western and central and North Pacific. Aquatic Mammals. 28:73-77.

Ohizumi, H., T. Isoda, T. Kishiro, and H. Kato. 2003. Feeding habits of Baird’s beaked whale *Berardius bairdii*, in the western North Pacific and Sea of Okhotsk off Japan. Fisheries Science. 69:11-20.

Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. Report of the International Whaling Commission. 25:114-126.

Okamura, H., K. Matsuoka, T. Hakamada, M. Okazaki, and T. Miyashita. 2001. Spatial and temporal structure of the western North Pacific minke whale distribution inferred from JARPN sightings data. Journal of Cetacean Research and Management. 3:193-200.

Oleson, E., J. Barlow, C. Clark, J. Gordon, S. Rankin, and J. Hildebrand. 2003. Low frequency calls of Bryde’s whales. Marine Mammal Science. 19:407-419.

Oleson, E.M., J. Calambokidis, W.C. Burgess, M.A. McDonald, C.A. LeDuc, and J.A. Hildebrand, J.A. 2007. Behavioral context of call production by eastern North Pacific blue whales. Marine Ecology Progress Series. 330: 269-284.

Omura, H., S. Ohsumi, T. Nemoto, K. Nasu, and T. Kasuya. 1969. Black right whales in the North Pacific. Scientific Reports of the Whales Research Institute. 21:I-78.

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.

OSHA. 1996. Occupational noise exposure in OSHA safety and health standards 29 CFR 1910.95 Federal Register. 61. 9227, 7 March 1996.

O'Shea, T.J. and R.L. Brownell. 1994. Organochlorine and metal contaminants in baleen whales: a review and evaluation of conservation implications. Science of the Total Environment. 154:179-200.

Östman, J.S.O. 1994. Social organization and social behavior of Hawaiian spinner dolphins (*Stenella longirostris*). Ph.D dissertation., University of California at Santa Cruz.

Östman-Lind, J., A.D. Driscoll-Lind, and S.H. Rickards. 2004. Delphinid abundance, distribution and habitat use off the western coast of the island of Hawaii. Southwest Fisheries Science Center Administrative Report LJ-04-02C. La Jolla, California: National Marine Fisheries Service.

Oswald, J.N., J. Barlow, and T.F. Norris, 2003. Acoustic identification of nine delphinid species in the eastern tropical Pacific Ocean. Marine Mammal Science. 19:20-37.

Oswald J.N., S. Rankin and J. Barlow. 2007. First description of whistles of Pacific Fraser’s Dolphins *Lagenodelphis Hosei.* Bioacoustics. 16:99-111.

Pacific Missile Range Facility, Barking Sands. 1998. Final Environmental Impact Statement for the Pacific Missile Range Facility Enhanced Capability, December.

Palacios, D.M. and B.R. Mate. 1996. Attack by false killer whales (*Pseudorca crassidens*) on sperm whales (*Physeter macrocephalus*) in the Galapagos Islands. Marine Mammal Science. 12:582-587.

Pampel, F.C. 2000. Logistic regression. A primer. SAGE Publications, Inc. Newbury Park, California.

Panigada, S., M. Zanardelli, S. Canese, and M. Jahoda. 1999. Deep diving performances of Mediterranean fin whales. Page 144 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Maui.

Panigada, S., G. Pesante, M. Zanardelli and S. Oehen. 2003. Day and night-time behaviour of fin whales in the western Ligurian Sea. Proceedings of the Conference Oceans 2003, September 22-26, 2003, San Diego, CA. Pp 466-471.

Panigada, S., G. Pesante, M. Zanardelli, F. Capoulade, A. Gannier, M.T. Weinrich. 2006. Mediterranean fin whales at risk from fatal ship strikes. Marine Pollution Bulletin. 52:1287–1298

Parks, S.E., D.R. Ketten, J. Trehey O'Malley, and J. Arruda. 2004. Hearing in the North Atlantic right whale: Anatomical predictions. Journal of the Acoustical Society of America. 115:2442.

Parrish, F.A., M.P. Craig, TJ. Regan, G.J. Marshall and B.M. Buhleier. 2000. Identifying diurnal foraging habitat of endangered Hawaiian monk seals using a seal-mounted video camera. Marine Mammal Science. 18:244-258.

Parrish, F.A., K. Abernathy, G.J. Marshall, and B.M. Buhleier. 2002. Hawaiian monk seals (*Monachus schauinslandi*) foraging in deep-water coral beds. Marine Mammal Science. 18:244-258.

Parrish, F.A., G.J. Marshall, C.L. Littnan, M. Heithaus, S. Canja, B. Becker, R. Braun, and G.A. Antonelis. 2005. Foraging of juvenile monk seals at French Frigate Shoals, Hawaii. Marine Mammal Science. 21:93-107.

Payne, K., P. Tyack, and R. Payne. 1983. Progressive changes in the songs of humpback whales (*Megaptera novaengliae*): A detailed analysis of two seasons in Hawaii. Pp. 9-57 in R. Payne, ed. Communication and behavior in whales. Washington, D.C.: American Association for the Advancement of Science.

Payne, K. and R. Payne. 1985. Large scale changes over 19 years in songs of humpback whales in Bermuda. Zeitschrift fur Tierpsychologie. 68:89-114.

Payne, P.M., J.R. Nicolas, L. O'Brien, and K.D. Powers. 1986. The distribution of the humpback whale, *Megaptera novaeangliae*, on Georges Bank and in the Gulf of Maine in relation to densities of the sand eel, *Ammodytes americanus*. Fishery Bulletin. 84:271-277.

Perrin, W.F. and J. R. Geraci. 2002. Stranding. In W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. San Diego, Academic Press: pp. 1192-1197.

Perrin, W.F., and J.W. Gilpatrick. 1994. Spinner dolphin--*Stenella longirostris* (Gray, 1828). Pages 99-128 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., and A.A. Hohn. 1994. Pantropical spotted dolphin. *Stenella attenuata*. Pages 71-98 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., C.E. Wilson, and F.I. Archer. 1994a. Striped dolphin. *Stenella coeruleoalba* (Meyen, 1833). Pages 129-159 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., S. Leatherwood, and A. Collet, 1994b. Fraser's dolphin-*Lagenodelphis hosei* (Fraser, 1956). Pages 225-240 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., and R.L. Brownell. 2002. Minke whales *Balaenoptera acutorostrata* and *B. bonaerensis*. Pages 750-754 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999. The great whales: History and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. Marine Fisheries Review. 61:1-74.

Perryman, W.L. and T.C. Foster. 1980. Preliminary report on predation by small whales, mainly the false killer whale, *Pseudorca crassidens*, on dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific. Southwest Fisheries Science Center Administrative Report LJ-80-05. La Jolla, California: National Marine Fisheries Service.

Perryman, W.L., D.W.K. Au, S. Leatherwood, and T.A. Jefferson. 1994. Melon-headed whale. *Peponocephala electra* (Gray, 1846). Pages 363-386 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Philips, J.D., P.E. Nachtigall, W.W.L. Au, J.L. Pawloski, and H.L. Roitblat. 2003. Echolocation in the Risso's dolphin, *Grampus griseus*. Journal of the Acoustical Society of America 113:605-616.

Pianradosi, C.A. and E.D. Thalmann. 2004. Whales, sonar, and decompression sickness. Nature. 15 April 2004.

Pickard, G.L., and W.J. Emery. 1982. Descriptive physical oceanography: An introduction. 4th ed. Oxford, United Kingdom: Pergamon Press.

Pickles, J.O. 1998. An introduction to the physiology of hearing. Academic Press, London. 367 pp.

Pierce, A.D. 1989. Acoustics, An Introduction to Its Physical Principles and Applications, Acoustical Society of America. Woodbury, NY.

Pike, G.C. and I.B. MacAskie. 1969. Marine mammals of British Columbia, Bulletin 171, Fisheries Research Board of Canada, Ottawa.

Pitman, R.L. 2002. Mesoplodont whales *Mesoplodon* spp. Pages 738-742 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Pitman, R.L., D.M. Palacios, P.L.R. Brennan, B.J. Brennan, K.C. Balcomb, and T. Miyashita. 1999. Sightings and possible identity of a bottlenose whale in the tropical Indo-Pacific: *Indopacetus pacificus*? Marine Mammal Science. 15:531-549.

Pitman, R.L., L.T. Ballance, S.L. Mesnick, and S.J. Chivers. 2001. Killer whale predation on sperm whales: Observations and implications. Marine Mammal Science. 17:494-507.

Pivorunas, A. 1979. The feeding mechanisms of baleen whales. American Scientist. 67:432-440.

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. 7:251-261.

Polefka, S. 2004. Anthropogenic Noise and the Channel Islands National Marine Sanctuary. Report by Environmental Defense Center, Santa Barbara, CA. 51 pp.

Poole, M.M. 1995. Aspects of the behavioral ecology of spinner dolphins (*Stenella longirostris*) in the nearshore waters of Moorea, French Polynesia. Ph.D. dissertation., University of California, Santa Cruz.

Popov, V.V. and V.O. Klishin, 1998. EEG study of hearing in the common dolphin, *Delphinus delphis*. Aquatic Mammals. 24:13-20.

Popper, A.N. 2008. Effects of mid- and high-frequency sonars on fish. Report submitted to Naval Undersea Warfare Center Division, Newport, Rhode Island. Contract N66604-07m-6056. 53pp.

Popper, A.N., M. Salmon, K.W. Horch. 2001. Acoustic detection and communication by decapod crustaceans. Journal of Comparative Physiology. 187:83– 89.

Popper, A.N., M.B. Halvorsen, A. Kane, D.L. Miller, M.E. Smith, J. Song, P. Stein, and L.E. Wysocki. 2007. The effects of high intensity, low frequency active sonar on rainbow trout. Journal of the Acoustical Society of America. 122:623-635.

Quaranta, A., P. Portalatini, and D. Henderson. 1998. Temporary and permanent threshold shift: An overview. Scandinavian Audiology. 27:75–86.

Radenac, M. and M. Rodier. 1996. Nitrate and chlorophyll distributions in relation to thermohaline and current structures in the western tropical Pacific during 1985-1989. Deep-Sea Research II. 43:725-752.

Ragen, T.J. and M.A. Finn. 1996. Chapter 8: The Hawaiian monk seal on Nihoa and Necker Islands, 1993. Pages 90-94 in T.C. Johanos and T.J. Ragen, eds. The Hawaiian monk seal in the Northwestern Hawaiian Islands, 1993. NOAA Technical Memorandum NMFS-SWFSC 227:l-141.

Ragen, T.J. and D.M. Lavigne. 1999. The Hawaiian monk seal: Biology of an endangered species. Pages 224-245 in J.R. Twiss and R.R. Reeves, eds. Conservation and Management of Marine Mammals. Washington, D.C.: Smithsonian Institution Press.

Rankin, J.J. 1953. First record of the rare beaked whale, *Mesoplodon europaeus*, Gervais, from the West Indies. Nature. 172: 873-874.

Rankin, S. and J. Barlow. 2003. Discovery of the minke whale “boing” vocalization, and implications for the seasonal distribution of the North Pacific minke whale. Page 134 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December 2003. Greensboro, North Carolina.

Rankin, S. and J. Barlow. 2007a. Vocalizations of the sei whale *Balaenoptera Borealis* off the Hawaiian Islands. Bioacoustics. 16:137-145.

Rankin, S. and J. Barlow. 2007b. Sounds recorded in the presence of Blainville’s beaked whales, *Mesoplodon densirostris*, near Hawai’i (L). Journal of the Acoustical Society of America. 122:42-45.

Rankin, S., T.F. Norris, M.A. Smultea, C. Oedekoven, A.M. Zoidis, E. Silva, and J. Rivers. 2007. A Visual Sighting and Acoustic Detections of Minke Whales, *Balaenoptera acutorostrata* (Cetacea: Balaenopteridae), in Nearshore Hawaiian Waters. Pacific Science. 61:3:395–398.

Read, A.J., P. Drinker, and S. Northridge. 2006. Bycatch of Marine Mammals in U.S. and Global Fisheries. Conservation Biology. 20:63-169.

Redfern, J.V., M.C. Ferguson, E.A. Becker, K.D. Hyrenbach, C. Good, J. Barlow, K. Kaschner, M.F. Baumgartner, K.A. Forney, L.T. Ballance, P. Fauchald, P. Halpin, T. Hamazaki, A.J. Pershing, S. S. Qian, A. Read, S.B. Reilly, L. Torres, F. Werner. 2006. Techniques for cetacean–habitat modeling. Marine Ecology Progress Series. 310:271–295.

Reeder D.M. and K.M. Kramer. 2005. Stress in free-ranging mammals: integrating physiology, ecology, and natural history. Journal of Mammalogy. 86:225-235.

Reeves, R.R., S. Leatherwood, G.S. Stone, and L.G. Eldredge. 1999. Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). Apia, Samoa: South Pacific Regional Environment Programme.

Reeves, R.R., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. National Audubon Society guide to marine mammals of the world. New York: Alfred A. Knopf.

Reeves, R.R., B.D. Smith, E.A. Crespo, and G. Notarbartolo di Sciara. 2003. 2002-2010 conservation plan for the world’s cetaceans: Dolphins, whales, and porpoises. Gland, Switzerland: IUCN.

Reeves, R.R., W.F. Perrin, B.L. Taylor, C.S. Baker, and S.L. Mesnick. 2004. Report of the Workshop on Shortcomings of Cetacean Taxonomy in Relation to Needs of Conservation and Management, April 30 - May 2, 2004, La Jolla, California. NOAA Technical Memorandum NMFS-SWFSC 363:l-94.

Reijnders, P.J.H. and A. Aguilar. 2002. Pollution and Marine Mammals. In: W.F. Perrin, B. Würsig and J.G.M. Thewissen, Encyclopedia of Marine Mammals. Academic Press, San Diego, 948-956.

Reilly, S. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. Marine Ecology Progress Series. 66:1-11.

Reilly, S. and V.G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. Marine Mammal Science. 6:265-277.

Reilly, S.B., and P.C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: research vessel surveys, 1986 - 1990. Fishery Bulletin, U.S. 92:434-450.

Rendell, L. and H. Whitehead. 2004. Do sperm whales share coda vocalizations? Insights into coda usage from acoustic size measurement. Animal Behaviour. 67:865-874.

Rice, D.W. 1960. Distribution of the bottle-nosed dolphin in the Leeward Hawaiian Islands. Journal of Mammalogy. 41:407-408.

Rice, D.W. 1977. Synopsis of biological data on the sei whale and Bryde's whale in the eastern North Pacific. Reports of the International Whaling Commission, Special Issue. 1:92-97.

Rice, D.W. 1989. Sperm whale *Physeter macrocephalus* (Linnaeus, 1758). Pages 177-234 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. San Diego: Academic Press.

Rice, D.W. 1998. Marine mammals of the world: Systematics and distribution. Society for Marine Mammalogy Special Publication. 4:1-231.

Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). American Society of Mammalogists Special Publication. 3:1-142.

Richardson, W.J., C.R. Greene Jr., W.R. Koski, M.A. Smultea, G. Cameron, C. Holdsworth, G. Miller, T. Woodley, and B. Wursig. 1991. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska – 1990 phase. Report prepared by LGS Environmental Research Associates Ltd. for the U.S. Department of Interior, Minerals Management Service, Anchorage, Alaska. NTIS PB92-170430.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thompson. 1995. Marine mammals and noise. San Diego: Academic Press, Inc.

Ridgway, S.H. and M.D. Dailey. 1972. Cerebral and cerebellar involvement of trematode parasites in dolphins and their possible role in stranding. Journal of Wildlife Diseases. 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.

Ridgway, S.H. 2000. The auditory central nervous system. Pages 273-293 in W.W.L. Au, A.N. Popper, and R.R. Fay, eds. Hearing by whales and dolphins. New York: Springer-Verlag.

Ridgway, S.H., B.L. Scronce, and J. Kanwisher. 1969. Respiration and deep diving in the bottlenose porpoise. Science. 166:1651-1654.

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.

Ridgway, S.H. and D.A. Carder. 2001. Assessing hearing and sound production in cetaceans not available for behavioral audiograms: Experiences with sperm, pygmy sperm, and gray whales. Aquatic Mammals. 27:267-276.

Ridgway, S., D. Carder, J. Finneran, M. Keogh, T. Kamolnick, M. Todd, and A. Goldblatt. 2006. Dolphin continuous auditory vigilance for five days. Journal of Experimental Biology. 209:3621-3628

Rivers, J.A. 1997. Blue whale, *Balaenoptera musculus*, vocalizations from the waters off central California. Marine Mammal Science. 13:186-195.

Rivers, J.A., G.L. Fulling, P. Thorson, and C. Oedekoven. 2007. Humpback whale (*Megaptera novaengliae*) fluke photographs from the Northern Mariana Islands compared with other geographic areas. Seventeenth Biennial Confernce on the Biology of Marine Mammals. Cape Town, South Africa. 29 November to 3 December 2007.

Robertson, K.M. and S.J. Chivers. 1997. Prey occurrence in pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. Fishery Bulletin. 95:334-348.

Roden, C. L., and K. D. Mullin, 2000. Sightings of cetaceans in the northern Caribbean Sea and adjacent waters, winter 1995. Caribbean Journal of Science. 36:280-288.

Rogers, A.D. 1994. The biology of seamounts. Pages 306-350 in J.H. Blaxter, and A.J. Southward, eds. Advances in marine biology, volume . San Diego: Academic Press.

Romano, T.A., J.A. Olschowka, S.Y. Felten, V. Quaranta, S.H. Ridgway,and D.L. Felten. 2002. Immune response, stress, and environment: Implications for cetaceans. In: Cell and Molecular Biology of Marine Mammals. C.J. Pfeiffer (ed). Krieger Publishing Co., Inc. pp. 53-279.

Romano, T.A., M.J. Keogh, C. Kelly, P. Feng, L. Berk, C.E. Schlundt, D.A. Carder, and J.J. Finneran. 2004. Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. Canadian Journal of Fisheries and Aquatic Science. 61:1124-1134.

Rosenbaum, H.C., R.L. Brownell, M.W. Brown, C. Schaeff, V. Portway, B.N. Whiate, S. Malik, L.A. Pastene, N.J. Patenaude, C.S. Baker, M. Goto, P.B. Best, P.J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C.T. Tynan, J.L. Bannister, and R. DeSalle. 2000. World-wide genetic differentiation of *Eubalaena*: Questioning the number of right whale species. Molecular Ecology. 9:1793-1802.

Rosenbaum, H.C., M. Egan, P.J. Clapham, R.L. Brownell, S. Malik, M.W. Brown, B.N. White, P. Walsh, and R. DeSalle. 2000. Utility of North Atlantic right whale museum specimens for assessing changes in genetic diversity. Conservation Biology. 14:1837-1842.

Ross, D. 1987. Mechanics of Underwater Noise, Peninsula Publishing, Los Altos, CA.

Ross, D. 1976. Mechanics of underwater noise. Pergamon, New York. 375 pp.

Ross, G.J.B., and S. Leatherwood. 1994. Pygmy killer whale. *Feresa attenuata* Gray, 1874. Pages 387-404 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Rowntree, V., J. Darling, G. Silber, and M. Ferrari. 1980. Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. Canadian Journal of Zoology. 58:309-312.

Salden, D.R. 1988. Humpback whale encounter rates offshore of Maui, Hawaii. Journal of Wildlife Management. 52:301-304.

Salden, D.R. 1989. An observation of apparent feeding by a sub-adult humpback whale off Maui, Hawaii. Page 58 in Abstracts, Eighth Biennial Conference on the Biology of Marine Mammals. 7-11 December 1989. Pacific Grove, California.

Salden, D.R., and J. Mickelsen. 1999. Rare sighting of a North Pacific right whale (*Eubalaena glacialis*) in Hawaii. Pacific Science. 53:341-345.

Salden, D.R., L.M. Herman, M. Yamaguchi, and F. Sato. 1999. Multiple visits of individual humpback whales (*Megaptera novaeangliae*) between the Hawaiian and Japanese winter grounds. Canadian Journal of Zoology. 77:504-508.

Sanvito, S. and F. Galimberti. 2003. Source level of male vocalizations in the genus *Mirounga*: Repeatability and correlates. Bioacoustics. 14:47-59.

Sapolsky, R.M. 2005. The influence of social hierarchy on primate health. Science. 308: 648-652.

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.

Scarff, J.E. 1986. Historic and present distribution of the right whale (*Eubalaena glacialis*) in the eastern North Pacific south of 50°N and east of 180°W. Reports of the International Whaling Commission, Special Issue. 10:43-63.

Scarff, J.E. 1991. Historic distribution and abundance of the right whale (*Eubalaena glacialis*) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. Reports of the International Whaling Commission. 41:467-489.

SSC. 2004 See Finneran, J.J., and C.E. Schlundt. (2004). "Effects of intense pure tones on the behavior of trained odontocetes." TR 1913, SPAWAR Systems Center (SSC) San Diego, San Diego, CA. [see body of SSC research as reported in papers by Ridgway et al., Schlundt et al., Carder et al., and Finneran et al. sampled within this reference list.].

Schilling, M.R., I. Seipt, M.T. Weinrich, S.E. Frohock, A.E. Kuhlberg, and P.J. Clapham. 1992. Behavior of individually-identified sei whales *Balaenoptera borealis* during an episodic influx into the southern Gulf of Maine in 1986. Fishery Bulletin. 90:749-755.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterous leucas*, after exposure to intense tones. Journal of the Acoustical Society of America. 107: 3496-3508.

Schlundt, C.E., R.L. Dear, D.A. Carder, and J.J. Finneran. 2006. Growth and recovery of temporary threshold shifts in a dolphin exposed to mid-frequency tones with durations up to 128 s. Journal of the Acoustical Society of America. 120:3227A.

Schlundt, C.E., R.L. Dear, L. Green, D.S. Houser, and J.J. Finneran. 2007. Simultaneously measured behavioral and electrophysiological hearing thresholds in a bottlenose dolphin (*Tursiops truncatus*). Journal of the Acoustical Society of America. 122:615-622.

Schoenherr, J.R. 1991. Blue whales feeding on high concentrations of euphausiids around Monterey Submarine Canyon. Canadian Journal of Zoology. 69:583-594.

Schotten, M., W.W.L. Au, M.O. Lammers, and R. Aubauer. 2004. Echolocation recordings and localization of wild spinner dolphins (*Stenella longirostris*) and pantropical spotted dolphins (S. *attenuata*) using a four-hydrophone array. Pages 393-400 in J.A. Thomas, C.F. Moss and M. Vater, eds. Echolocation in bats and dolphins. Chicago, Illinois: University of Chicago Press.

Schreer, J.F., K.M. Kovacs, and R.J.O. Hines. 2001. Comparative diving patterns of pinnipeds and seabirds. Ecological Monographs. 71:137-162.

Schusterman, R. J., D. Kastak, D.H. Levenson, C.J. Reichmuth, and B.L. Southall. 2000. Why pinnipeds don't echolocate. Journal of the Acoustical Society of America. 107:2256-2264.

Schwartz, M., A. Hohn, A. Bernard, S. Chivers, and K. Peltier. 1992. Stomach contents of beach cast cetaceans collected along the San Diego County coast of California, 1972-1991. Southwest Fisheries Science Center Administrative Report LJ-92-18. La Jolla, California: National Marine Fisheries Service.

Scott, M.D. and K.L. Cattanach. 1998. Diel patterns in aggregations of pelagic dolphins and tuna in the eastern Pacific. Marine Mammal Science. 14:401-428. 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.

Scott, T. M., and S. S. Sadove. 1997. Sperm whale, *Physeter macrocephalus*, sightings in the shallow shelf waters off Long Island, New York. Marine Mammal Science. 13:317-321.

Scowcroft, G., K. Vigness Raposa, C. Knowlton, and J. Johnen, 2006. Discovery of Sound in the Sea. University of Rhode Island.

Sears, R., J.M. Williamson, F.W. Wenzel, M. Bérubé, D. Gendron, and P. Jones, 1990. Photographic identification of the blue whale (*Balaenoptera musculus*) in the Gulf of St. Lawrence, Canada. Reports of the International Whaling Commission, Special Issue. 12:335-342.

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. Marine Mammal Science. 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. 5:107-110.

Seyle, H. 1950. Stress and the general adaptation syndrome. British Medical Journal. 1383-1392.

Shallenberger, E.W. 1981. The status of Hawaiian cetaceans. Report prepared under Contract #MM7AC028 for the Marine Mammal Commission, Washington, D.C.

Shane, S.H. 1994. Occurrence and habitat use of marine mammals at Santa Catalina Island, California from 1983-91. Bulletin of the Southern California Academy of Sciences. 93:13-29.

Shane, S.H. and D. McSweeney. 1990. Using photo-identification to study pilot whale social organization. Reports of the International Whaling Commission, Special Issue. 12. 259-263.

Shelden, K.E.W., S.E. Moore, J.M. Waite, P.R. Wade, and D.J. Rugh. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. Mammal Review. 35:129-1 55.

Shipley, C., B.S. Stewart, and J. Bass. 1992. Seismic communication in northern elephant seals. Pages 553-562 in J.A. Thomas, R.A. Kastelein, and A.Y. Supin, eds. Marine mammal sensory systems. New York: Plenum Press.

SHOUP. 2004. See 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.

SHOUP. 2004. See Fromm, D. (2004b) EEEL Analysis of U.S.S. SHOUP Transmissions in the Haro Strait on 5 May 2003. Naval Research Laboratory briefing of 2 September 2004.

SHOUP. 2004. See Department of the Navy, Commander U.S. Pacific Fleet 2003. Report on the Results of the Inquiry into Allegations of Marine Mammal Impacts Surrounding the Use of Active Sonar by *U.S.S. SHOUP* (DDG 86) in the Haro Strait on or about 5 May 2003. 9 February 2003.

Silber, G.K. 1986. The relationship of social vocalizations to surface behavior and aggression in the Hawaiian humpback whale (*Megaptera novaeangliae*). Canadian Journal of Zoology. 64:2075-2080.

Simão, S.M. and S.C. Moreira. 2005. Vocalizations of a female humpback whale in Arraial do Cabo (RJ, Brazil). Marine Mammal Science. 21:150-153.

Simpson, J.H., P.B. Tett, M.L. Argote-Espinoza, A. Edwards, K.J. Jones, and G. Savidge. 1982. Mixing and phytoplankton growth around an island in a stratified sea. Continental Shelf Research. 1:15-31.

Simmonds, M.P. and L.F. Lopez-Jurado. 1991. Whales and the military. Nature. 351:448.

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 S.J. Mayer. 1997. An evaluation of environmental and other factors in some recent marine mammal mortalities in Europe: implication for conservation and management. Environmental Review. 5:89-98.

Širović, A., J.A. Hildebrand, and Sean M. Wiggins. 2007. Blue and fin whale call source levels and propagation range in the Southern Ocean. Journal of the Acoustical Society of America. 122:1208-1215.

Slijper, E.J., W.L. van Utrecht, and C. Naaktgeboren. 1964. Remarks on the distribution and migration of whales, based on observations from Netherlands ships. Bijdragen Tot de Dierkunde. 34:3-93.

Smith, M.E., A.S. Kane, and A.N. Popper. 2004. Acoustical stress and hearing sensitivity in fishes: does the linear threshold shift hypothesis hold water?. Journal of Experimental Biology. 207:3591-3602.

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. 22:690-699.

Southall, B.L., R.J. Schusterman, D. Kastak, and C. Reichmuth-Kastak. 2005. Reliability of underwater hearing thresholds in pinnipeds. ARLO. 6:243–249.

Southall, B. 2006. Declaration of Brandon L. Southall, Ph.D. Natural Resources Defense Council v Donald C. Winter (RIMPAC), June 30, 2006.

Southall, B.L., R. Braun, F.M. D. Gulland, A.D. Heard, R. Baird, S. Wilkin and T.K. Rowles. 2006. Hawaiian melon-headed whale (*Peponocephala electra*) mass stranding event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31. 73 pp.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals. 33:411-521.

Stacey, P.J. and R.W. Baird. 1991. Status of the false killer whale, *Pseudorca crassidens*, in Canada. Canadian Field-Naturalist. 105:189-197.

Stafford, K.M. 2003. Two types of blue whale calls recorded in the Gulf of Alaska. Marine Mammal Science. 19:682-693.

Stafford, K.M., C.G. Fox, and D.S. Clark. 1998. Long-range acoustic detection and localization of blue whale calls in the northeast Pacific Ocean. Journal of Acoustical Society of America. 104:3616-3625.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 1999. Low-frequency whale sounds recorded on hydrophones moored in the eastern tropical Pacific. Journal of Acoustical Society of America. 106:3687-3698.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 2001. Geographic and seasonal variation of blue whale calls in the North Pacific. Journal of Cetacean Research and Management. 3:65-76.

Stafford, K.M., S.E. Moore, and C.G. Fox. 2005. Diel variation in blue whale calls recorded in the eastern tropical Pacific. Animal Behaviour. 69:951-958.

Standard EIGER. 1995. Environmental Assessment of the Use of Underwater Acoustic and Explosive Sources during Exercise Standard EIGER, Department of the Navy, SSBN Security Program Office, 27 July.

Stern, J.S. 1992. Surfacing rates and surfacing patterns of minke whales (*Balaenoptera acutorostrata*) off central California, and the probability of a whale surfacing within visual range. Reports of the International Whaling Commission. 42:379-385.

Stevick, P.T., B.J. McConnell, and P.S. Hammond. 2002. Patterns of movement. Pages 185-216 in A.R. Hoelzel, ed. Marine mammal biology: An evolutionary approach. Oxford: Blackwell Science.

Stewart, B.S., P.K. Yochem, H.R. Huber, R.L. DeLong, R.J. Jameson, W.J. Sydeman, S.G. Allen, and B.J. Le Boeuf. 1994. History and present status of the northern elephant seal population. Pages 29-48 in B.J. Le Boeuf and R.M. Laws, eds. Elephant seals: Population ecology, behavior, and physiology. Berkeley: University of California Press.

Stewart, B. S. and S. Leatherwood, 1985. Minke whale Balaenoptera acutorostrata Lacepede, 1804. Pages 91-136 in Ridgway, S.H. and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. Academic Press: San Diego, California.

Stewart, B.S. and R.L. DeLong. 1995. Double migrations of the northern elephant seal, *Mirounga angustirostris*. Journal of Mammalogy. 76:196-205

Stewart, B.S. 1997. Ontogeny of differential migration and sexual segregation in northern elephant seals. Journal of Mammalogy. 78:1101-1116.

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. 8:255-263.

Stone, G.S., S.K. Katona, A. Mainwaring, J.M. Allen, and H.D. Corbett. 1992. Respiration and surfacing rates for finback whales (*Balaenoptera physalus*) observed from a lighthouse tower. Reports of the International Whaling Commission. 42:739-745.

Sullivan, M.J. and R.B. Conolly. 1988. Dose-response hearing loss for white noise in the Sprague-Dawley rat. Toxicological Sciences. 10:109-113

Summary Papers on Human and Animal Hearing Effects in Air. 1991. Special section in Journal of the Acoustical Society of America. 90:124-227.

Suter, G.W., L.W. Barnthouse, S.M. Bartell, T. Mill, D. Mackay, and S. Paterson. 1993. Ecological risk assessment. Lewis Publishers, Boca Raton, Florida.

Swartz, S.L. 1986. Gray whale migratory, social and breeding behavior. (*Eschrichtius robustus*). Reports of the International Whaling Commission, Special Issue. 8:207-229.

Swartz, S.L., A. Martinez, J. Stamates, C. Burks, and A.A. Mignucci-Giannoni. 2002. Acoustic and visual survey of cetaceans in the waters of Puerto Rico and the Virgin Islands: February-March 2001. NOAA Technical Memorandum NMFS-SEFSC-463:l-62.

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. Journal of Wildlife Diseases. 41:717-727.

Swingle, W.M., S.G. Barco, T.D. Pitchford, W.A. McLellan, and D.A. Pabst, 1993. Appearance of juvenile humpback whales feeding in the nearshore waters of Virginia. Marine Mammal Science. 9:309-315.

Swets, J.A. 1964. Signal Detection and Recognition by Human Observers, Contemporary Readings, John Wiley and Sons, New York.

Szymanski, M.D., D.E. Bain, K. Kiehl, S. Pennington, S. Wong, and K.R. Henry. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. Journal of the Acoustical Society of America. 106:1134-1141.

Thode, A., D.K. Mellinger, S. Stienessen, A. Martinez, and K. Mullin. 2002. Depth-dependent acoustic features of diving sperm whales (*Physeter macrocephalus*) in the Gulf of Mexico. Journal of the Acoustical Society of America. 112:308-321.

Thomas, J., N. Chun, W. Au, and K. Pugh. 1988. Underwater audiogram of a false killer whale (*Pseudorca crassidens*). Journal of the Acoustical Society of America. 84:936-940.

Thomas, J. and R. Kastelein. 1990. Sensory Abilities of Cetaceans. Plenum Press, New York.

Thomas, J., P. Moore, R. Withrow, and M. Stoermer. 1990. Underwater audiogram of a Hawaiian monk seal (*Monachus schauinslandi*). Journal of the Acoustical Society of America. 87:417-420.

Thompson, P.O. and W.A. Friedl. 1982. A long term study of low frequency sounds from several species of whales off Oahu, Hawaii. Cetology. 45:l-19.

Thompson, P.O., W.C. Cummings, and S.J. Ha. 1986. Sounds, source levels, and associated behavior of humpback whales, southeast Alaska. Journal of the Acoustical Society of America. 80:735-740.

Thompson, T.J., H.E. Winn, and P.J. Perkins. 1979. Mysticete sounds. In Behavior of marine animals, Volume 3. H.E. Winn and B.L. Olla, (eds.), Plenum, NY. 438 pp.

Thorson, P.H., G.L. Fulling, J.A. Rivers, S. Watterson, and K. Sawyer. 2007. Cetacean diversity, distribution and abundance in Marianas waters from a boreal winter survey in 2007. Seventeenth Biennial Confernce on the Biology of Marine Mammals. Cape Town, South Africa. 29 November to 3 December 2007.

Thurman, H.V. 1997. Introductory oceanography. Upper Saddle River, New Jersey: Prentice Hall.

Tomich, P.Q. 1986. Mammals in Hawaii: A synopsis and notational bibliography. Honolulu: Bishop Museum Press.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica. 19:1-50.

Tracey, R. 2000. Mass false killer whale beaching remains a mystery. Discovery Channel Canada's Website. Accessed 2/12/07. http://www.exn.ca/Stories/2000/06/05/56.asp

Trimper, P.G., N.M. Standen, L.M. Lye, D. Lemon, T.E. Chubbs, and G.W. Humphries. 1998. Effects of low-level jet aircraft noise on the behaviour of nesting osprey. The Journal of Applied Ecology. 35:9.

Turl, C.W. 1993. Low-frequency sound detection by a bottlenose dolphin. Journal of the Acoustical Society of America. 94:3006-3008.

Tyack, P. and H. Whitehead. 1983. Male competition in large groups of wintering humpback whales. Behaviour. 83:132-153.

Tyack, P.L., M. Johnson, N. Aguilar Soto, A. Sturlese, and P.T. Madsen. 2006. Extreme diving of beaked whales. Journal of Experimental Biology. 209:4238-4253.

Tyack, P.L., M.P. Johnson, W.M.X. Zimmer, P.T. Madsen, and M.A. de Soto. 2006a. Acoustic behavior of beaked whales, with implications for acoustic monitoring. Oceans. 2006.1-6.

Tynan, C.T., D.P. DeMaster, and W.T. Peterson. 2001. Endangered right whales on the southeastern Bering Sea shelf. Science. 294:1894.

Urian, K.W., D.A. Duffield, A.J. Read, R.S. Wells, and E.D. Shell, 1996. Seasonality of reproduction in bottlenose dolphins, *Tursiops truncatus*. Journal of Mammalogy. 77:394-403.

Urick, R.J. 1983. Principles of Underwater Sound for Engineers, McGraw-Hill, NY.

U.S. Air Force. 2002. Eglin Gulf Test and Training Range Programmatic Environmental Assessment. Air Armament Center, 46 TW/XPE Range Environmental Planning Office, Eglin Air Force Base, Florida.

Vanderlaan, A.S.M., A.E. Hay, and C.T. Taggart. 2003. Characterization of North Atlantic right-whale (*Eubalaena glacialis*) sounds in the Bay of Fundy. IEEE Journal of Oceanic Engineering. 28:164-173.

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: J.G. Vos, G.D. Bossart, M. Fournier, and T.J. O'Shea, eds. Toxicology of Marine Mammals, Taylor & Francis, London and New York. pp. 247-269.

Van Dolah, F.M. 2005. Effects of Harmful Algal Blooms. IN: J.E. Reynolds III, W.F. Perrin, R.R. Reeves, S. Montgomery, T.J. Ragen. Marine Mammal Research. John Hopkins University Press, Baltimore. pp. 85-99.

Veirs, V. 2004. Source levels of free-ranging killer whale (*Orcinus orca*) social vocalizations. Journal of the Acoustical Society of America. 116:2615.

Visser, I.K.G., J.S. Teppema, and A.D.M.E. Ostrhaus. 1991. Virus infections of seals and other pinnipeds. Reviews in Medical Microbiology. 2:105-114.

Visser, I.N. and F.J. Bonoccorso. 2003. New observations and a review of killer whale (*Orcinus orca*) sightings in Papua New Guinea waters. Aquatic Mammals. 29:150-172. 6

Von Saunder, A. and J. Barlow. 1999. A report of the Oregon, California and Washington line-transect experiment (ORCAWALE) conducted in West Coast waters during Summer/Fall 1996. NOAA Technical Memorandum NMFS-SWFSC-264:1-49.

Wade, L.S. and G.L. Friedrichsen. 1979. Recent sightings of the blue whale, *Balaenoptera musculus,* in the northeastern tropical Pacific. Fishery Bulletin. 76:915-919.

Wade, P.R and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. Reports of the International Whaling Commission. 43:477-493.

Wade, P., M.P. Heide-Jørgensen, K. Shelden, J. Barlow, J. Carretta, J. Durban, R. LeDuc, L. Munger, S. Rankin, A. Sauter, and C. Stinchcomb. 2006. Acoustic detection and satellite-tracking leads to discovery of rare concentration of endangered North Pacific right whales. Biological Letters. 3pp.

Wahlberg, M. 2002. The acoustic behaviour of diving sperm whales observed with a hydrophone array. Journal of Experimental Marine Biology and Ecology. 281:53-62.

Walker, M.M., J.L. Kirschvink, G. Ahmed, and A.E. Dicton. 1992. Evidence that fin whales respond to the geomagnetic field during migration. Journal of Experimental Biology. 171:67-78.

Walsh, M.T., Ewing, R.Y., Odell, D. K., and Bossart, G.D., 2001. Mass Strandings of Cetaceans. in Marine Mammal Medicine. Eds.by L. A. Dierauf, and F. M. D. Gulland (CRC Press, Boca Raton), pp. 83-96.

Walker, W.A. 1981. Geographical variation in morphology and biology of bottlenose dolphins (*Tursiops*) in the eastern North Pacific. Southwest Fisheries Science Center Administrative Report LJ-81-03C. La Jolla, California: National Marine Fisheries Service.

Walker, R.J., E.O. Keith, A.E. Yankovsky and D.K. Odell. 2005. Environmental correlates of cetacean mass stranding in sites in Florida. Marine Mammal Science. 21:327-335.

Walker, W.A., J.G. Mead, and R.L. Brownell. 2002. Diets of Baird's beaked whales *Berardius bairdii*, in the southern Sea of Okhotsk and off the Pacific Coast of Honshu, Japan. Marine Mammal Science. 18:902-919.

Walsh, W.A. and D.R. Kobayashi. 2004. A description of the relationships between marine mammals and the Hawaii-based longline fishery from 1994 to 2003. Report prepared by the University of Hawaii and Pacific Islands Fisheries Science Center.

Wang, M.-.C., W.A. Walker, K.T. Shao, and L.S. Chou. 2002. Comparative analysis of the diets of pygmy sperm whales and dwarf sperm whales in Taiwanese waters. Acta Zoologica Taiwanica. 13:53-62.

Ward, W.D. 1960. Recovery from high values of temporary threshold shift. Journal of the Acoustical Society of America. 32:497–500.

Ward, W.D. 1997. Effects of high-intensity sound. In Encyclopedia of Acoustics, ed. M.J. Crocker, 1497-1507. New York: Wiley.

Ward, W.D., A. Glorig, and DL. Sklar. 1958. Dependence of temporary threshold shift at 4 kc on intensity and time. Journal of the Acoustical Society of America. 30:944–954.

Ward, W.D., A. Glorig, and D.L. Sklar. 1959. Temporary threshold shift from octave-band noise: Applications to damage-risk criteria. Journal of the Acoustical Society of America. 31:522–528.

Waring, G. T. and J. T. Finn. 1995. Cetacean trophic interactions off the northeast USA inferred from spatial and temporal co-distribution patterns. Unpublished meeting document. ICES C.M, 1995/N:7:1-44. International Council for the Exploration of the Sea: Copenhagen, Denmark.

Waring, G.T., T. Hamazaki, D. Sheehan, G. Wood, and S. Baker. 2001. Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) summer habitat in shelf-edge and deeper waters off the northeast U. S. Marine Mammal Science. 17:703-717.

Wartzok, D. and D.R. Ketten. 1999. Marine Mammal Sensory Systems. Biology of Marine Mammals (ed. J.E. Reynolds III and S.A. Rommel), pp 324-422.

Waring, G.T., J.M. Quintal, and C.P. Fairfield, eds, 2002. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments – 2002. NOAA Technical Memorandum NMFS-NE-169:1-318.

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. 37:6-15.

Watkins, W.A. and W.E. Schevill. 1977. Sperm whale codas. Journal of the Acoustical Society of America. 62:1485-1490.

Watkins, W.A., K.E. Moore, and P. Tyack. 1985. Sperm whale acoustic behaviors in the southeast Caribbean. Cetology. 49:1-15.

Watkins, W.A., P. Tyack, K.E. Moore, and J.E. Bird. 1987. The 20-Hz signals of finback whales (*Balaenoptera physalus*). Journal of the Acoustical Society of America. 82:1901-1912.

Watkins, W.A., M.A. Daher, A. Samuels, and D.P. Gannon. 1997. Observations of *Peponocephala electra*, the melon-headed whale, in the southeastern Caribbean. Caribbean Journal of Science. 33:34-40.

Watkins, W.A., M.A. Daher, K.M. Fristrup, and T.J. Howald. 1993. Sperm whales tagged with transponders and tracked underwater by sonar. Marine Mammal Science. 9:55-67.

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. 18:55-68.

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.

Weilgart, L. and H. Whitehead. 1997. Group-specific dialects and geographical variation in coda repertoire in South Pacific sperm whales. Behavioral Ecology and Sociobiology. 40:277-285.

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.

Welch, B.L. and A.S. Welch (eds.). 1970. Physiological effects of noise. Plenum Press, New York, NY.

Weller, D.W., B. Würsig, H. Whitehead, J.C. Norris, S.K. Lynn, R.W. Davis, N. Clauss, and P. Brown. 1996. Observations of an interaction between sperm whales and short-finned pilot whales in the Gulf of Mexico. Marine Mammal Science. 12:588-594.

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.

Westlake, R.L. and W.G. Gilmartin. 1990. Hawaiian monk seal pupping locations in the Northwestern Hawaiian Islands. Pacific Science. 44:366-383.

Weston, D.E. 1960. Underwater Explosions as Acoustic Sources. Proceedings of the Physics Society. 76: 233.

Whitehead, H. 2003. Sperm whales: Social evolution in the ocean. Chicago: University of Chicago Press.

Whitehead, H. and L. Weilgart. 1991. Patterns of visually observable behaviour and vocalizations in groups of female sperm whales. Behaviour. 118:276-296.

Whitehead, H, S. Brennan and D. Grover. 1992. Distribution and behaviour of male sperm whales on the Scotian Shelf, Canada. Canadian Journal of Zoology. 70:912-918.

Wiggins, S.M., M.A. McDonald, L.M. Munger, S.E. Moore, and J.A. Hildebrand. 2004. Waveguide propagation allows range estimates for North Pacific right whales in the Bering Sea. Canadian Acoustics. 32:146-154.

Wilkinson, D.M. 1991. Report to the Assistant Administrator for Fisheries, in Program Review of the Marine Mammal Stranding Network. U.S. Department of Commerce, National Oceanographic and Atmospheric Administrations, National Marine Fisheries Service, Silver Springs, MD. 171 pp.

Willis, P.M. and R.W. Baird. 1998. Status of the dwarf sperm whale, *Kogia simus*, with special reference to Canada. Canadian Field-Naturalist. 112:114-125.

Winn, H.E. and P.J. Perkins. 1976. Distribution and sounds of the minke whale, with a review of mysticete sounds. Cetology. 19:1-12.

Winn, H.E., J.D. Goodyear, R.D. Kenney, and R.O. Petricig. 1995. Dive patterns of tagged right whales in the Great South Channel. Continental Shelf Research. 15:593-611.

Witteveen, B.H., J.M. Straley, O. Von Ziegesar, D. Steel, and C.S. Baker. 2004. Abundance and mtDNA differentiation of humpback whales (*Megaptera novaeangliae*) in the Shumagin Islands, Alaska. Canadian Journal of Zoology. 82:1352-1359.

Wolanski, E., R.H. Richmond, G. Davis, E. Deleersnijder, and R.R. Leben. 2003. Eddies around Guam, an island in the Mariana Islands group. Continental Shelf Research. 23:991-1003.

Woods Hole Oceanographic Institution. 2005. Beaked Whale Necropsy Findings for Strandings in the Bahamas, Puerto Rico, and Madiera, 1999 – 2002. Technical Report, WHOI-2005-09.

Woodward, B.L. and J.P. Winn. 2006. Apparent lateralized behavior in gray whales feeding off the central British Columbia coast. Marine Mammal Science. 22:64-73.

Würsig, B., S.K. Lynn, T.A. Jefferson, and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. Aquatic Mammals. 24:41-50.

Wursig, B., and W.J. Richardson. 2002. Effects of Noise, Pages 794-802 in W. F. Perrin, B. Wursig, and J. G. M. Thewissen, eds. Encyclopedia of Marine Mammals. San Diego.

Yelverton, J.T. 1981, Underwater Explosion Damage Risk Criteria for Fish, Birds, and Mammals, Manuscript, presented at 102nd Meeting of the Acoustical Society of America, Miami Beach, FL, December, 1982. 32pp.

Yochem, P.K. and S. Leatherwood. 1985. Blue whale-*Balaenoptera musculus*. Pages 193-240 in S.H. Ridgway and R. Harrison, eds. Handbook of Marine Mammals. Volume 3: The sirenians and baleen whales. San Diego: Academic Press.

Yost, W.A. 1994. Fundamentals of Hearing: An Introduction. San Diego: Academic Press.

Yost, W.A. 2000. Fundamentals of Hearing: An Introduction (4th. Ed.) , Academic Press, New York.

Yu, H-Y., H-K. Mok, R-C. Wei, and L-S., Chou. 2003. Vocalizations of a rehabilitated rough-toothed dolphin, *Steno bredanensis*. Page 183 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December 2003. Greensboro, North Carolina.

Yuen, M.E., P.E Nachtigall, and A.Ya Supin. 2005. Behavioral and AEP Audiograms of a false killer whale (*Pseudorca crassidens*). Journal of the Acoustical Society of America. 118: 2688-2695.

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.

Zeeberg, 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.

Zimmer, W.M.Z., P.L. Tyack, M.P. Johnson, and P.T. Madsen. 2005. Three-dimensional beam pattern of regular sperm whale clicks confirms bent-horn hypothesis. Journal of the Acoustical Society of America. 117:1473-1485.

Zimmer, W.M. X., and P.L. Tyack. 2007. Repetitive shallow dives pose decompression risk in deep-diving beaked whales. Marine Mammal Science. 23:888-925.

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. Marine Mammal Strandings in the United States, Miami, FL, NMFS.

# APPENDICES

This page intentionally left blank.

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

# APPENDIX A: MARINE MAMMAL MODELING

This page intentionally left blank**.**

# A MARINE MAMMAL MODELING

## A.1 Background and Overview

All marine mammals are protected under the Marine Mammal Protection Act (MMPA). The MMPA prohibits, with certain exceptions, the take of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States.

The Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of their ecosystems. A species is considered endangered if it is in danger of extinction throughout all or a significant portion of its range. A species is considered threatened if it is likely to become an endangered species within the foreseeable future. There are marine mammals, already protected under MMPA, listed as either endangered or threatened under ESA, and afforded special protections. Actions involving sound in the water include the potential to harass marine animals in the surrounding waters. Demonstration of compliance with MMPA and the ESA, using best available science, has been assessed using criteria and thresholds accepted or negotiated, and described here.

Sections of the MMPA (16 United States Code [U.S.C.] 1361 et seq.) direct the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity, other than commercial fishing, within a specified geographical region. Through a specific process, if certain findings are made and regulations are issued, or if the taking is limited to harassment, notice of a proposed authorization is provided to the public for review.

Authorization for incidental takings may be granted if the National Marine Fisheries Service (NMFS) finds that the taking will have no more than a negligible impact on the species or stock(s), will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses, and that the permissible methods of taking, and requirements pertaining to the mitigation, monitoring, and reporting of such taking are set forth.

NMFS has defined negligible impact in 50 Code of Federal Regulations (CFR) 216.103 as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

Subsection 101(a)(5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. The National Defense Authorization Act of 2004 (NDAA) (Public Law 108-136) removed the small numbers limitation and amended the definition of “harassment” as it applies to a military readiness activity to read as follows:

> *(i) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or*
>
> *(ii) 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 [Level B Harassment].*

The primary potential impact on marine mammals from underwater acoustics is Level B harassment from noise. For explosions, in the absence of any mitigation or monitoring measures, there is a very small chance that a marine mammal could be injured or killed when exposed to the energy generated from an explosive force on the sea floor. Analysis of noise impacts on cetaceans is based on criteria and thresholds initially presented in Navy Environmental Impact Statements for ship shock trials of the Seawolf submarine and the Winston Churchill (DDG 81; U.S. Department of the Navy [DoN], 2001) and the Incidental Harassment Authorization (National Marine Fisheries Service, 2005) and the Letter of Authorization (NMFS, 2006) for Eglin Air Force Base.

Non-lethal injurious impacts (Level A Harassment) are defined in those documents as tympanic membrane (TM) rupture and the onset of slight lung injury. The threshold for Level A Harassment corresponds to a 50% rate of TM rupture, which can be stated in terms of an energy flux density (EFD) value of 205 decibels (dB) re 1 micropascal squared–second ($\mu Pa^2$-s). TM rupture is well-correlated with permanent hearing impairment. Ketten (1998) indicates a 30% incidence of permanent threshold shift (PTS) at the same threshold.

The criteria for onset of slight lung injury were established using partial impulse because the impulse of an underwater blast wave was the parameter that governed damage during a study using mammals, not peak pressure or energy (Yelverton, 1981). Goertner (1982) determined a way to calculate impulse values for injury at greater depths, known as the Goertner "modified" positive impulse. Those values are valid only near the surface because as hydrostatic pressure increases with depth, organs like the lung, filled with air, compress. Therefore, the "modified" positive impulse thresholds vary from the shallow depth starting point as a function of depth.

The shallow depth starting points for calculation of the "modified" positive impulses are mass-dependent values derived from empirical data for underwater blast injury (Yelverton, 1981). During the calculations, the lowest impulse and body mass for which slight, and then extensive, lung injury found during a previous study (Yelverton et al., 1973) were used to determine the positive impulse that may cause lung injury. The Goertner model is sensitive to mammal weight; such that smaller masses have lower thresholds for positive impulse so injury and harassment will be predicted at greater distances from the source for them. Impulse thresholds of 13.0 and 31.0 pounds per square inch-millisecond (psi-ms), found to cause slight and extensive injury in a dolphin calf, were used as thresholds in the analysis contained in this document.

### A 1.1 Metrics for Physiological Effect Thresholds

Effect thresholds used for acoustic impact modeling in this document are expressed in terms of Energy Flux Density (EFD) / Sound Exposure Level (SEL), which is total energy received over time in an area, or in terms of Sound Pressure Level (SPL), which is the level (root mean square) without reference to any time component for the exposure at that level. Marine and terrestrial mammal data show that, for continuous-type sounds of interest, Temporary Threshold Shift (TTS) and PTS are more closely related to the energy in the sound exposure than to the exposure SPL.

The Energy Level (EL) for each individual ping is calculated from the following equation:

$$EL = SPL + 10\log10\ (duration)$$

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 Threshold Shift (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 (given that generally applicable recovery times have not been experimentally established) and as a result, intermittent exposures from sonar are modeled as if they were 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.
- A single ping with SPL = 192 dB re 1 µPa and duration = 2 seconds.
- Two pings with SPL = 192 dB re 1 µPa and duration = 1 second.
- Two pings with SPL = 189 dB re 1 µPa and duration = 2 seconds.

### A 1.2 Derivation of an Effects Threshold for Marine Mammals Based on EFD

As described in detail in Section 3.7 of the draft MIRC EIS/OEIS, SEL (EFD level) exposure threshold established for onset-TTS is 195 dB re 1 $\mu Pa^2$-s. This result is corroborated by the short-duration tone data of Finneran et al. (2000, 2003) and the long-duration sound data from Nachtigall et al. (2003a, b). Together, these data demonstrate that TTS in small odontocetes 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 $\mu Pa^2$-s. Absent any additional data for other species and being that it is likely that small odontocetes are more sensitive to the mid-frequency active/high-frequency active (MFA/HFA) frequency levels of concern, this threshold is used for analysis for all cetacea.

A similar process has been used to establish a TTS threshold for the Hawaiian monk seal based on research by Kastak et al. (1999; 2005). Of the three pinniped groups studied by Kastak et al., elephant seals are the most closely related to the Hawaiian monk seal (the family *Monachinae*). The onset-TTS number, provided by Kastak et al. for elephant seals and used to analyze TTS impacts on monk seals in this document, is 204 dB re 1$\mu Pa^2$-s.

The PTS thresholds established for use in this analysis are 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). Using this estimation method (20 dB up from onset-TTS) for the Mariana Islands Range Complex (MIRC) analysis, the PTS threshold for cetacea is 215 dB re 1µPa$^2$-s and for monk seals it is 224 dB re 1µPa$^2$-s.

Level B (non-injurious) Harassment also includes a TTS threshold consisting of 182 dB re 1 µPa$^2$-s maximum EFD level in any 1/3-octave band above 100 hertz (Hz) for toothed whales (e.g., dolphins). A second criterion, 23 psi, has recently been established by NMFS to provide a more conservative range for TTS when the explosive or animal approaches the sea surface, in which case explosive energy is reduced, but the peak pressure of 1 µPa$^2$-s is not (Table A-1). NMFS applies the more conservative of these two.

For Multiple Successive Explosions (MSEs), the acoustic criterion for sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. The sub-TTS threshold is derived following the approach of the Churchill Final Environmental Impact Statement (FEIS) for the energy-based TTS threshold. The research on pure-tone exposures reported in Schlundt et al. (2000) and Finneran and Schlundt (2004) provided a threshold of 192 dB re 1 µPa$^2$-s as the lowest TTS value. This value for pure-tone exposures is modified for explosives by (a) interpreting it as an energy metric, (b) reducing it by 10 dB to account for the time constant of the mammal ear, and (c) measuring the energy in 1/3 octave bands, the natural filter band of the ear. The resulting TTS threshold for explosives is 182 dB re 1 µPa$^2$-s in any 1/3 octave band. As reported by Schlundt et al. (2000) and Finneran and Schlundt (2004), instances of altered behavior in the pure-tone research generally began five dB lower than those causing TTS. The sub-TTS threshold is therefore derived by subtracting 5 dB from the 182 dB re 1 µPa$^2$-s in any 1/3 octave band threshold, resulting in a 177 dB re 1 µPa$^2$-s (EL) sub-TTS behavioral disturbance threshold for MSE.

**Table A-1: Level A and B Harassment Threshold–Explosives**

| Threshold Type (Explosives) | Threshold Level |
|---|---|
| Level A – 50% Eardrum rupture | 205 dB |
| Temporary Threshold Shift (TTS) (peak one-third octave energy) | 182 dB |
| Sub-TTS Threshold for Multiple Successive Explosions (peak one-third octave energy) | 177 dB |
| Temporary Threshold Shift (TTS) (peak pressure) | 23 psi |
| Level A – Slight lung injury (positive impulse) | 13 psi-ms |
| Mortality – 1% Mortal lung injury (positive impulse) | 31 psi-ms |

### A 1.3 Derivation of a Behavioral Effect Threshold for Marine Mammals Based on SPL

Over the past several years, the Navy and NMFS have worked on developing alternative criteria to replace and/or to supplement the acoustic thresholds used in the past to estimate the probability of marine mammals being behaviorally harassed by received levels of MFA and HFA sonar. Following publication of the Hawaii Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) the Navy continued working with the NMFS to refine a mathematically representative curve for assessment of behavioral effects modeling associated with the use of MFA/HFA sonar. As detailed in Section 4.1.2, the NMFS Office of Protected Resources made the decision to use a risk function and applicable input parameters to estimate 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/HFA sonar. This decision was based on the recommendation of the two NMFS scientists, consideration of the independent reviews from six scientists, and NMFS MMPA regulations affecting the Navy's use of Surveillance Towed Array Sensor System Low-Frequency Active (SURTASS LFA) sonar (DoN, 2002; National Oceanic and Atmospheric Administration [NOAA], 2007).

The particular acoustic risk function developed by the Navy and NMFS is derived from a solution in Feller (1968) with input parameters modified by NMFS for MFA/HFA sonar for mysticetes, odontocetes, and pinnipeds. In order to represent a probability of risk in developing this function, the function would 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 DoN 2001, the mathematical function below is adapted from a solution in Feller (1968).

$$R = \frac{1-\left(\frac{L-B}{K}\right)^{-A}}{1-\left(\frac{L-B}{K}\right)^{-2A}}$$

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% risk

A = risk transition sharpness parameter (10 for odontocetes and 8 for mysticetes)

It is important to note that the probabilities associated with acoustic modeling do not represent an individual's probability of responding; they identify the proportion of an exposed population (as represented by an evenly distributed density of marine mammals per unit area) that is likely to respond to an exposure. In addition, modeling does not take into account reductions from any of the Navy's standard protective mitigation measures which should significantly reduce or eliminate actual exposures that may have otherwise occurred during training.

## A.2 Acoustic Sources

The MIRC 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). In general, the narrowband sources in this exercise are ASW 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 ASW 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. Propagation loss is sufficiently sensitive to frequency as to require model estimates at several frequencies over such a wide band.

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 2.1 Sonars

The majority of training and research, development, testing, and evaluation activities in the MIRC involve five types of narrowband sonars. Exposure estimates are calculated for each sonar according to the manner in which it operates. For example, the AN/SQS 53 and AN/SQS 56 are hull-mounted, MFA surface ship sonars that operate for many hours at a time (although sound is output—the "active" portion—only a small fraction of that time), so it is most useful to calculate and report surface ship sonar exposures per hour of operation. The BQQ-10 submarine sonar is also reported per hour of operation. However, the submarine sonar is modeled as pinging only twice per hour. The AN/AQS-22 is a helicopter-deployed sonar, which is lowered into the water, pings several times, and then moves to a new location; this sonar is used for localization and tracking a suspected contact as opposed to searching for contacts. For the AN/AQS-22, it is most helpful to calculate and report exposures per dip. The AN/SSQ-62 is a sonobuoy that is dropped into the water from an aircraft or helicopter and pings about 10 to 30 times in an hour. For the AN/SSQ-62 and AN/SSQ 125 (AEER), it is most helpful to calculate and report exposures per sonobuoy. For the MK-48 torpedo, the sonar is modeled for a typical training event and the MK-48 reporting metric is the number of torpedo runs. Table A-2 presents the deployment platform, frequency class, the metric for reporting exposures, and the units for each sonar.

**Table A-2: Active Sonars Modeled in the MIRC**

| Sonar | Description | Frequency Class | Exposures Reported | Units per hour |
|---|---|---|---|---|
| MK-48 | Torpedo sonar | High-frequency | Per torpedo | One torpedo run |
| AN/SQS-53 | Surface ship sonar | Mid-frequency | Per hour | 120 sonar pings |
| AN/SQS-56 | Surface ship sonar | Mid-frequency | Per hour | 120 sonar pings |
| AN/SSQ-62 | Sonobuoy sonar | Mid-frequency | Per sonobuoy | 8 sonobuoys |
| AN/SSQ-125 AEER | Sonobuoy sonar | Mid frequency | Per sonobuoy | 8 sonobuoys |
| AN/AQS-22 | Helicopter-dipping sonar | Mid-frequency | Per dip | 2 dips |
| BQQ-10[1] | Submarine sonar | Mid-frequency | Per hour | 2 sonar pings |

Note:
[1] BQQ-10 is modeled as representative of all MFA submarine sonar (BQQ-10, BQQ-5, and BSY-1)

Note that MK-48 source described here is the high-frequency active (HFA) sonar on the torpedo; the explosive source of the detonating torpedo is described in the next subsection.

The acoustic modeling that is necessary to support the take 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 – This is the level relative to 1 µPa2-s of the integral over frequency and time of the square of the pressure and is given by the total energy level across the band of the source, scaled by the pulse length (10 log10 [pulse length]).
- 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 assumed to have constant level across the width of the beam with flat, 20-dB down sidelobes at all other angles.

Similarly, two parameters define the vertical beam pattern:

- Vertical beam width – Width of the source beam (degrees) in the vertical plane measured at the 3-dB down point. (assumed constant for all vertical steer directions).
- 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 $\theta$ is

$$\text{Power} = \max \{ \sin^2 [ n(\theta_s - \theta) ] / [ n \sin (\theta_s - \theta) ]^2,\ 0.01 \},$$

Where $\theta_s$ is the vertical beam steer direction, and

$$n = 2*L/\lambda \text{ (L = array length, } \lambda \text{ = wavelength),}$$

The beamwidth of a line source is determined by n (the length of the array in half-wavelengths) as $\theta_w = 180^o/n$.

- 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, 3 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.

Many of the actual parameters and capabilities of these sonars are classified. Parameters used for modeling were derived to be as representative as possible taking into account the manner with which the sonar would be used in various training scenarios. However, when there was a wide range of potential modeling input values, the default was to model using a nominal parameter likely to result in the most impact, so that the model would err towards the maximum potential exposures.

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 2.2 Explosives

Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. The acoustic energy of an explosive is, generally, much greater than that of a sonar, so careful treatment of them is important, since they have the potential to injure. 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 (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. 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). Since most MIRC explosive sources are munitions that detonate essentially upon impact, the effective source depths are quite shallow, and therefore the surface-image interference effect can be pronounced. In order to limit the cancellation effect (and thereby provide exposure estimates that tend toward the worst case), relatively deep detonation depths are used. Consistent with earlier Virtual At Sea Training System/Integrated Maritime Portable Acoustic Scoring and Simulator Buoy System (VAST/IMPASS) modeling, a source depth of 1 foot is used for gunnery rounds. For the missile and bombs, a source depth of 2 meters (m) is used. For Extended Echo Ranging/Improved Extended Echo Ranging (EER/IEER) a nominal depth of 20 m is used to ensure that the source is located within any significant surface duct, resulting in maximum potential exposures. Table A-3 gives the ordnances of interest in the MIRC, their NEWs, and their expected detonation depths.

**Table A-3: Explosive Sources Modeled in MIRC**

| Ordnance | Net Explosive Weight for Modeling | Detonation Depth for Modeling |
|---|---|---|
| 5" Naval gunfire | 9.54 lbs | 1 ft |
| 76 mm Rounds | 1.6 lbs | 1 ft |
| Maverick | 78.5 lbs | 2 m |
| Harpoon | 448 lbs | 2 m |
| MK-82 | 238 lbs | 2 m |
| MK-83 | 574 lbs | 2 m |
| MK-48 | 851 lbs | 50 ft |
| Demolition Charges | 10 lbs | Bottom |
| EER/IEER | 5 lbs | 20 m |

The exposures expected to result from these ordnances are generally 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 harassed by each ordnance detonation. There may be rare occasions when MSEs are part of a static location event. For these events, the Churchill FEIS approach was extended to cover MSE events occurring at the same location. For MSE exposures, accumulated energy over the entire training time is the natural extension for energy thresholds since energy accumulates with each subsequent shot; this is consistent with the treatment of multiple arrivals in Churchill. For positive impulse, it is consistent with the Churchill FEIS to use the maximum value over all impulses received.

For MSEs, the acoustic criterion for sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. For MSE events potential behavioral disturbances were estimated by extrapolation from the acoustic modeling results for the explosives TTS threshold (182 dB re 1 µPa2-s in any 1/3 octave band). To account for the 5 dB lower sub-TTS threshold, a factor of 3.17 was applied to the TTS modeled numbers in order to extrapolate the number of sub-TTS exposures estimated for MSE events. This multiplication factor is used to calculate the increased area represented by the difference between the 177 dB sub-TTS threshold and the modeled 182 dB threshold. The factor is based on the increased range 5 dB would propagate (assuming spherical spreading), where the range increases by approximately 1.78 times, resulting in a circular area increase of approximately 3.17 times that of the modeled results at 182 dB.

A special case in which simple addition of the exposure estimates may not be appropriate is addressed by the modeling of a "representative" Sink Exercise (SINKEX). In a SINKEX, a decommissioned surface ship is towed to a specified deep-water location and there used as a target for a variety of weapons. Although no two SINKEXs are ever the same, a representative case derived from past exercises is described in the Programmatic SINKEX Overseas Environmental Assessment (March 2006) for the Western North Atlantic.

In a SINKEX, weapons are typically fired in order of decreasing range from the source with weapons fired until the target is sunk. A torpedo is used after all munitions have been expended if the target is still afloat. Since the target may sink at any time during the exercise, the actual number of weapons used can vary widely. In the representative case, however, all of the ordnances are assumed expended; this represents the worst case with maximum exposure.

The sequence of weapons firing for the representative SINKEX is described in Table A-4. Guided weapons are nearly 100% accurate and are modeled as hitting the target (that is, no underwater acoustic effect) in all but two cases: (1) the Maverick is modeled as a miss to represent the occasional miss, and (2) the MK-48 torpedo intentionally detonates in the water column immediately below the hull of the target. Unguided weapons are more frequently off-target and are modeled according to the statistical hit/miss ratios. Note that these hit/miss ratios are artificially low in order to demonstrate a worst-case scenario; they should not be taken as indicative of weapon or platform reliability.

**Table A-4: Representative SINKEX Weapons Firing Sequence**

| Time (Local) | Event Description |
|---|---|
| 0900 | Range Control Officer receives reports that the exercise area is clear of non-participant ship traffic, marine mammals, and sea turtles. |
| 0909 | Hellfire missile fired, hits target. |
| 0915 | 2 HARM missiles fired, both hit target (5 minutes apart). |
| 0930 | 1 Penguin missile fired, hits target. |
| 0940 | 3 Maverick missiles fired, 2 hit target, 1 misses (5 minutes apart). |
| 1145 | 1 SM-1 fired, hits target. |
| 1147 | 1 SM-2 fired, hits target. |
| 1205 | 5 Harpoon missiles fired, all hit target (1 minute apart). |
| 1300-1335 | 7 live and 3 inert MK 82 bombs dropped – 7 hit target, 2 live and 1 inert miss target (4 minutes apart). |
| 1355-1410 | 4 MK 83 bombs dropped – 3 hit target, 1 misses target (5 minutes apart). |
| 1500 | Surface gunfire commences – 400 5-inch rounds fired (one every 6 seconds), 280 hit target, 120 miss target. |
| 1700 | MK 48 Torpedo fired, hits, and sinks target. |

## A.3 Environmental Provinces

Propagation loss ultimately determines the extent of the Zone of Influence (ZOI) 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
- Surface roughness, as determined by wind speed

Due to the importance that propagation loss plays in 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, which are accepted as standards for 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 – 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 MIRC.

### A 3.1 Impact of Environmental Parameters

Within a typical operating area, the environmental parameter that tends to vary the most is bathymetry. It is not unusual for water depths to vary by an order of magnitude or more, resulting in significant impacts upon the ZOI calculations. Bottom loss can also vary considerably over typical operating areas, but its impact on ZOI 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 ZOI 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 larger role.

The spatial variability of the sound speed field is generally small over operating areas 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.

### A 3.2 Environmental Provincing Methodology

The underwater acoustic environment can be quite variable over ranges in excess of 10 kilometers. For ASW 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 operating area, 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 the process of selecting environmental provinces. Only the broadband sources produce acoustic energy at the frequencies of interest for low-frequency bottom loss (typically less than 1 kHz); even for those sources the low-frequency acoustic energy is secondary to the energy above 1 kHz. 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. For this analysis “octave-spaced” intervals (10, 20, 50, 100, 200, 500, 1,000, 2,000, and 5,000 m) provide an adequate sampling of water depth dependence.

ZOI volumes are then computed using propagation loss estimates derived for the representative environments. Finally, a weighted average of the ZOI 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 operating area of interest.

As discussed in the previous subsection, ZOI 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 meters), 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 ZOI 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 operating area, the number of environmental provinces tends to range from 5 to 20.

### A 3.3 Description of Environmental Provinces

The MIRC encompasses a large area about the Mariana Islands. For this analysis, the general operating area is bounded to the north and south by latitude lines of 7oN and 19oN and to the east and west by meridians of 138oE and 150oE. Within this large region are two sub-areas as described below in which SINKEX may be performed.

- SINKEX East: An area east of Guam; bounded in latitude by 14o N and 16o N, and in longitude by 146o 30’E and 149o 12’E.
- SINKEX South: All of Warning Area 517 that is more than 50 n.m. offshore. W-517 is an irregularly-shaped region with the following vertices:

13°-10’N 144°-30’E
13°-10’N 144°-42’E
12°-50’N 144°-45’E
11°-00’N 144°-45’E
11°-00’N 143°-00’E
11°-45’N 143°-00’E

11°-50'N 144°-30'E

The acoustic sonars described in subsection H.2 are deployed throughout the general operating area. The explosive sources, other than demolition charges, are limited to the two SINKEX subareas. The use of demolition charges is limited to Agat Bay and Outer Apra Harbor inshore areas.

This subsection describes the representative environmental provinces selected for the MIRC. For all of these provinces, the average wind speed, winter and summer, is 11 knots.

The general operating area of the MIRC contains a total of 163 distinct environmental provinces. These represent various combinations of five bathymetry provinces, nine Sound Velocity Profile (SVP) provinces, and five HFBL classes.

The bathymetry provinces represent depths ranging from 200 meters to typical deep-water depths (more than 5,000 meters). Nearly all of the MIRC is characterized as deep-water (depths of 2,000 meters or more). The remaining water depths (1,000 meters and less) provide only small contributions to the analysis. The distribution of the bathymetry provinces over the MIRC is provided in Table A-5.

**Table A-5: Distribution of Bathymetry Provinces in MIRC**

| Province Depth (m) | Frequency of Occurrence |
|---|---|
| 200 | 0.04 % |
| 500 | 0.32 % |
| 1,000 | 1.31 % |
| 2,000 | 10.74 % |
| 5,000 | 87.59 % |

Nine SVP provinces describe the sound speed field in the MIRC; however, the variability among the nine provinces is relatively small as demonstrated by the summer profiles presented in Figure A-1. The dominant difference among the profiles is the steepness of the thermocline.

The seasonal variation is likewise of limited dynamic range, as might be expect given that the range is located in temperate waters. The surface sound speed of the winter profile is only a few m/s slower than the summer profile as depicted in Figure A-2. Both seasons exhibit a well-formed surface duct with average mixed layers of approximately 50 meters and 75 meters in the summer and winter, respectively.

The distribution of the nine SVP provinces across the MIRC is provided in Table A-6.

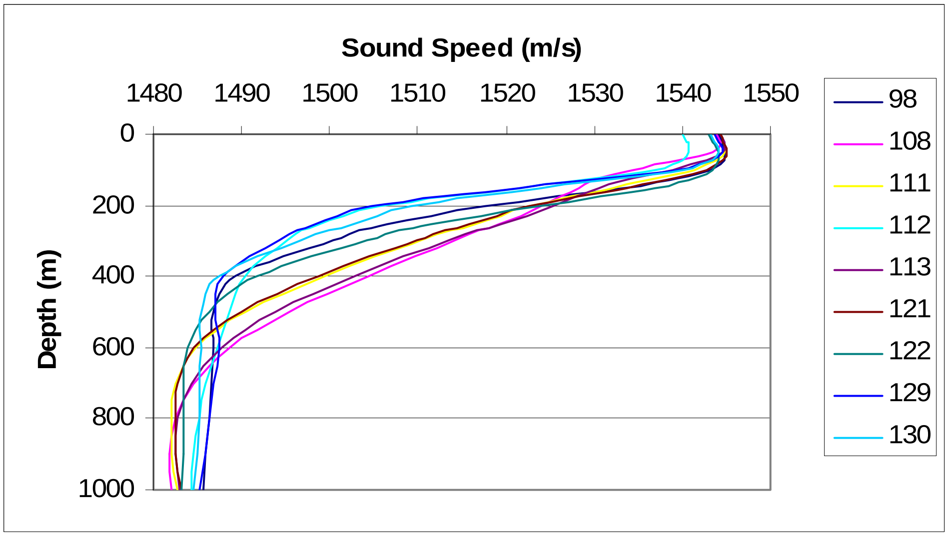


**Figure A-1: Summer SVPs in MIRC**

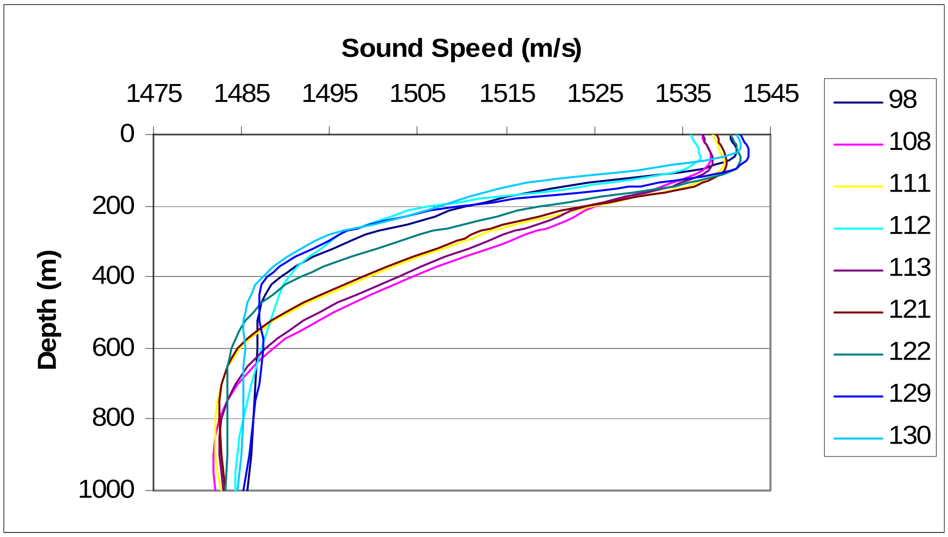


**Figure A-2: Winter SVPs in MIRC.**

**Table A-6: Distribution of SVP Provinces in MIRC**

| SVP Province | Frequency of Occurrence |
|---|---|
| 98 | 29.40 % |
| 108 | 0.31 % |
| 111 | 18.65 % |
| 112 | 1.15 % |
| 113 | 12.41 % |
| 121 | 5.53 % |
| 122 | 24.43 % |
| 129 | 2.14 % |
| 130 | 5.99% |

The five HFBL classes represented in the MIRC range from moderate-loss bottoms (class 4, 5 and 6) to high-loss bottoms (classes 7 or 8). The distribution of HFBL classes summarized in Table A-7 indicates that approximately 60% of the MIRC is high-loss bottom with the remaining 40% moderate-loss bottom.

**Table A-7: Distribution of High-Frequency Bottom Loss Classes in MIRC**

| HFBL Class | Frequency of Occurrence |
|---|---|
| 4 | 11.31 % |
| 5 | 23.34 % |
| 6 | 4.79 % |
| 7 | 14.96 % |
| 8 | 45.60 % |

The logic for consolidating the environmental provinces focuses upon water depth, using the sound speed profile (in deep water) and the HFBL class (in shallow water) as secondary differentiating factors. The first consideration was to ensure that all five bathymetry provinces are represented. Then within each bathymetry province further partitioning of provinces proceeded as follows:

- The three shallowest bathymetry provinces are each represented by one environmental province. In each case, the bathymetry province is dominated by a single, high-loss bottom, so that the secondary differentiating environmental parameter is of no consequence.
- The 2,000-meter bathymetry province consists of two environmental provinces. The vast majority of this bathymetry province consists of high-loss bottoms making the SVP provinces making the more important secondary differentiating environmental parameter. The variance in the sound speed field, which is generally quite small, is represented by two SVP provinces.
- The 5,000-meter bathymetry province is far and away the most prevalent water depth in the MIRC. Although the environmental variability across this bathymetry province is relatively small, its sheer size relative to the other water depths warrants some partitioning to capture some of this variability. This is accomplished by subdividing this

bathymetry province into four environmental provinces, one for each of the four most prevalent SVP provinces.

The resulting nine environmental provinces used in the MIRC acoustic modeling are described in Table A-8.

**Table A-8: Distribution of Environmental Provinces in the MIRC Study Area**

| Environmental Province | Water Depth | SVP Province | HFBL Class | LFBL Province | Sediment Thickness | Frequency of Occurrence |
|---|---|---|---|---|---|---|
| 1 | 200 m | 122 | 8 | – 98* | 0.22 secs | 0.06 % |
| 2 | 500 m | 122 | 8 | – 98* | 0.16 secs | 0.32 % |
| 3 | 1,000 m | 122 | 8 | 62 | 0.2 secs | 1.31 % |
| 4 | 2,000 m | 122 | 8 | 62 | 0.19 secs | 2.52 % |
| 5 | 2,000 m | 111 | 8 | 62 | 0.19 secs | 10.97 % |
| 6 | 5,000 m | 98 | 5 | 13 | 0.18 secs | 35.74 % |
| 7 | 5,000 m | 122 | 8 | 13 | 0.1 secs | 21.27 % |
| 8 | 5,000 m | 111 | 4 | 43 | 0.39 secs | 16.15 % |
| 9 | 5,000 m | 113 | 4 | 43 | 0.32 secs | 11.66 % |

* Negative province numbers indicate shallow water provinces

The percentages given in Table A-8 indicate the frequency of occurrence of each environmental province across the MIRC Study Area. The distributions of the environments within each of the SINKEX areas are, by definition, limited to the two deepest bathymetry provinces as indicated in Table A-9.

**Table A-9: Distribution of Environmental Provinces within SINKEX Sub-Areas**

| Environmental Province | SINKEX East | SINKEX South |
|---|---|---|
| 4 | 1.62% | 0.00% |
| 5 | 0.00% | 0.11% |
| 6 | 15.32% | 99.89% |
| 7 | 83.06% | 0.00% |

## A.4 Impact Volumes and Impact Ranges

Many 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, defines 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 activities 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 may be injured or otherwise harassed 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 takes is estimated as the "product" (scalar or vector, depending on 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 takes is discussed in subsection H.5.

## A 4.1 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.

### A.4.1.1 Transmission Loss Calculations

TL data are pre-computed for each of two seasons in each of the environmental provinces described in the previous subsection using the GRAB propagation loss model (Keenan, 2000). The TL output consists of a parametric description of each significant eigenray (or propagation path) from source to animal. The description of each eigenray includes 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 TL suffered along the eigenray path.

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-10. Note that some of the low-power sources do not require TL data to large maximum ranges.

**Table A-10: TL Depth and Range Sampling Parameters by Sonar Type**

| Sonar | Range Step | Maximum Range | Depth Sampling |
|---|---|---|---|
| MK-48 | 10 m | 10 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |
| AN/SQS-53C | 10 m | 200 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |
| AN/AQS-22 | 10 m | 10 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |
| AN/ASQ-62 | 5 m | 5 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |
| AN/SQS-56 | 10 m | 50 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |
| BQQ-10 | 20 m | 150 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |
| AN/SQS-53C Kingfisher Mode | 10 m | 200 km | 0 – 1 km in 5 m steps<br>1 km – Bottom in 10 m steps |

In a few cases, most notably the AN/SQS-53C for thresholds below approximately 180 dB, TL data may be required by the energy summation algorithm at ranges greater than covered by the pre-computed GRAB data. In these cases, TL is extrapolated to the required range using a simple cylindrical spreading loss law in addition to the appropriate absorption loss. This extrapolation leads to a conservative (or under) estimate of TL at the greater ranges.

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.

#### A.4.1.2 Energy Summation

The summation of EFD over multiple pings in a range-independent environment is a trivial 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 EFD at that grid point. After each grid point has been updated, the accumulated energy at grid points in each depth layer is compared to the specified threshold. If the accumulated 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 omni 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 (RMAX) for a single ping. The impact range in this case is the maximum range at which the effective energy source level reduced by the TL is greater than the threshold. Next, the source is moved along a straight-line track and EFD is accumulated at a point that has a CPA range of RMAX at the mid-point of the source track. That total EFD summed over all pings is then compared to the prescribed threshold. If it is greater than the threshold (which, for the first RMAX, it must be) then RMAX is increased by 10%, the accumulation process is repeated, and the total energy is again compared to the threshold. This continues until RMAX grows large enough to ensure that the accumulated EFD at that lateral range is less than the threshold. The lateral range dimension of the volumetric grid is then set at twice RMAX, with the grid centered along the source track. In the direction of advance for the source, the volumetric grid extends of the interval from [–RMAX, 3 RMAX] 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 RMAX]. Once the source reaches 2 RMAX 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-3.

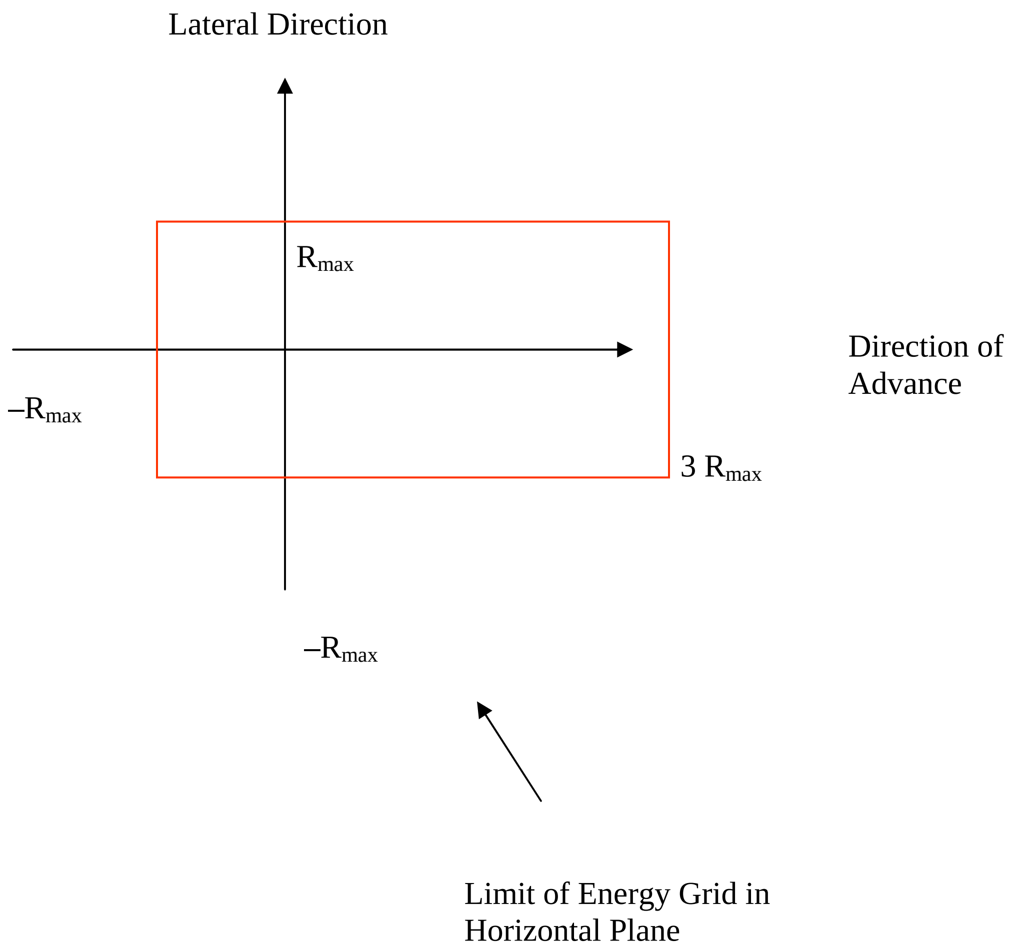


**Figure A-3: Horizontal Plane of Volumetric Grid for Omni Directional Source**

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-4.

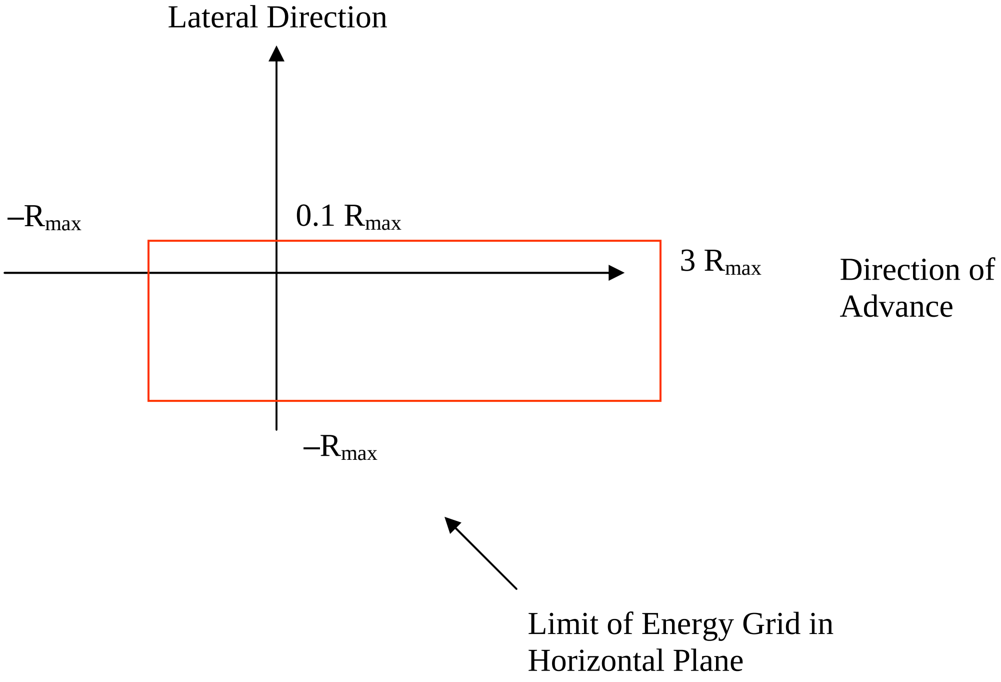


**Figure A-4: Horizontal Plane of Volumetric Grid for Starboard Beam Source**

Once the extent of the grid is established, the grid sampling can be defined. In both dimensions of the horizontal plane the sampling rate is approximately RMAX/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 RMAX with a partitioning rate of RMAX/100 (approximately 1%). 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 than 10 meters to ensure that significant TL variability over depth is captured.

#### A.4.1.3 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 Figure A-5.

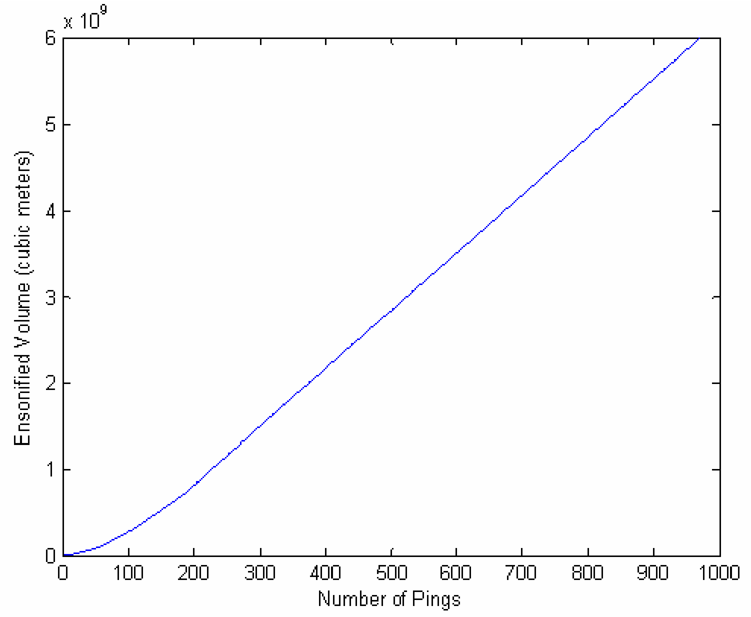


**Figure A-5: 53C Impact Volume by Ping**

The slope of the asymptotic limit of the impact volume in 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-6 provides an example of an hourly impact volume vector for a particular environment.

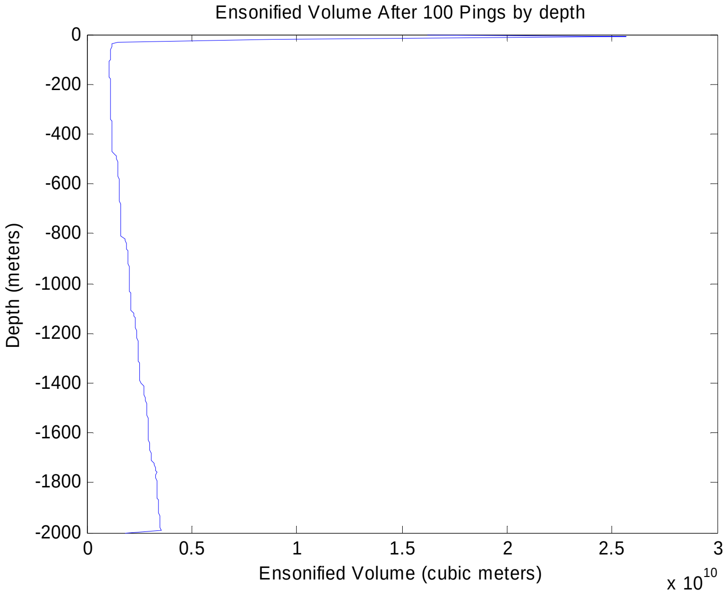


**Figure A-6: Example of an Impact Volume Vector**

## A 4.2 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 the subsections of A.4.2.3.

### A.4.2.1 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 and the EER source are broadband, contributing significant energy from tens of hertz to tens of kilohertz. 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.

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

$$\sin^2 [\, 4\pi\, f\, z_s\, z_a / (c^2\, t)\, ]$$

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

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

### A.4.2.2 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 subsection H.2.2.

The effective energy source level, which is treated as a de facto input for the other sonars, is instead modeled directly for EER and munitions. For both, 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)). The energy source level over a one-third octave band with a center frequency of f for a source with a net explosive weight of w pounds is given by:

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

where the peak pressure for the shock wave at 1 meter is defined as

$$\mathbf{p_{max} = 21600\ (w^{1/3} / 3.28\ )^{1.13}\ \ psi} \tag{A-1}$$

and the time constant is define as:

$$\mathbf{\theta = [(0.058)\ (w^{1/3})\ (3.28 / w^{1/3})^{\ 0.22}\ ] / 1{,}000\ msec} \tag{A-2}$$

In contrast to munitions that are modeled as omnidirectional sources, the EER source is a continuous line array that produces a directed source. The EER array consists of two explosive strips that are fired simultaneously from the center of the array. Each strip generates a beam pattern with the steer direction of the main lobe determined by the burn rate. The resulting response of the entire array is a bifurcated beam for frequencies above 200 Hz, while at lower frequencies the two beams tend to merge into one.

Since very short ranges are under consideration, the loss of directivity of the array needs to be accounted for in the near field of the array. This is accomplished by modeling the sound pressure level across the field as the coherent sum of contributions of infinitesimal sources along the array that are delayed according to the burn rate. For example, for frequency f the complex pressure contribution at a depth z and horizontal range x from an infinitesimal source located at a distance z' above the center of the array is

$$p(r,z) = e^{\,i\phi}$$

where

$$\phi = kr' + \alpha z', \text{ and}$$

$$\alpha = 2\pi f / c_b$$

with k the acoustic wave number, cb the burn rate of the explosive ribbon, and r' the slant range from the infinitesimal source to the field point (x,z).

Beam patterns as function of vertical angle are then sampled at various ranges out to a maximum range that is approximately L2 / .. where L is the array length and is the wavelength. This maximum range is a rule-of-thumb estimate for the end of the near field (Bartberger, 1965). Finally, commensurate with the resolution of the TL samples, these beam patterns are averaged over octave bands.

A couple of sample beam patterns are provided in Figure A-7 and Figure A-8. In both cases, the beam response is sampled at various ranges from the source array to demonstrate the variability across the near field. The 80-Hz family of beam patterns presented in Figure A-7 shows the rise of a single main lobe as range increases.

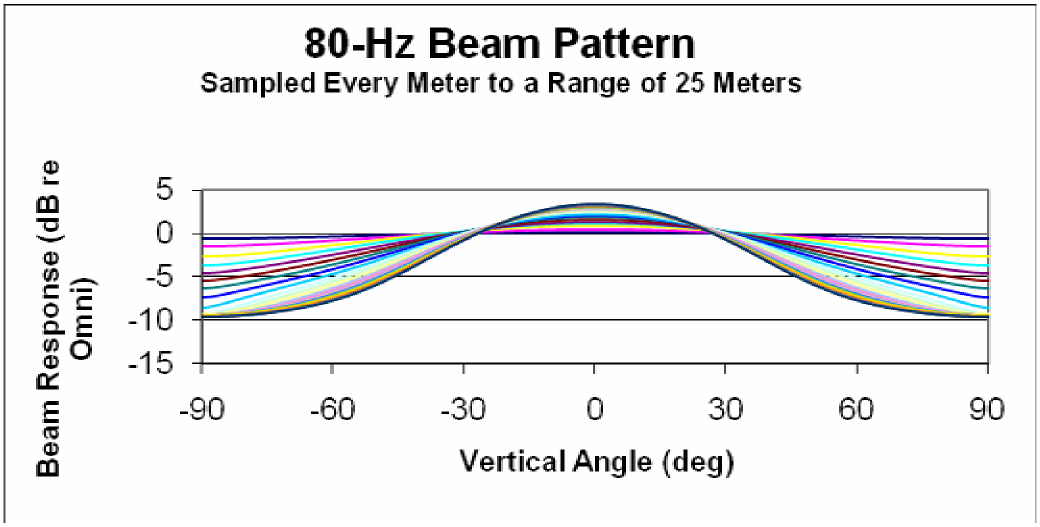


**Figure A-7: 80-Hz Beam Patterns across Near Field of EER Source**

On the other hand, the 1,250-Hz family of beam patterns depicted in Figure A-8 demonstrates the typical high-frequency bifurcated beam.

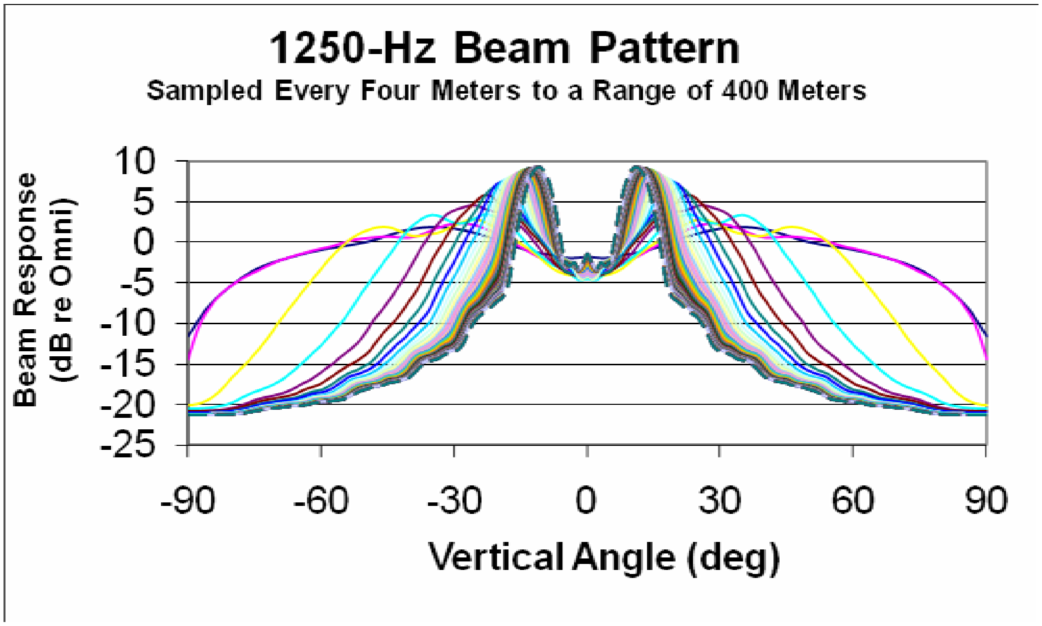


**Figure A-8: 1,250-Hz Beam Patterns across Near Field of EER Source**

### A.4.2.3 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.

#### A.4.2.3.1 *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 EFD is sampled at several frequencies in one-third-octave bands and only the peak one-third-octave level is accumulated over time.

#### A.4.2.3.2 *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 the vertical beam pattern, is averaged across frequency on an eigenray-by-eigenray basis. This averaged transmission ratio (normalized by the total broadband source level) is then compared across all eigenrays with the maximum designated as the peak arrival. Peak pressure at that range/animal depth combination is then simply the product of:

- The square root of the averaged transmission ratio of the peak arrival,
- The peak pressure at a range of one meter (given by equation A-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.

#### A.4.2.3.3 *"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 1 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).

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

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

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

#### A.4.2.4 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 be easily 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.

### A 4.3 Impact Volume by Region

The MIRC is described by 11 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 thirteen environmental provinces within the range. Unique hourly impact volume vectors for winter and summer are calculated for each type of source and each metric/threshold combination.

## A.5 Risk Function: Theoretical and Practical Implementation

This section discusses the recent addition of a risk function "threshold" to 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. What these two parts mean, how they affect exposure calculations, and how they are implemented are the objects of discussion.

### Thresholds and Metrics

The term "thresholds" is broadly used to refer to both thresholds and metrics. The difference, and the distinct roles of each in effects analyses, will be the foundation for understanding the risk function approach, putting it in perspective, and showing that, conceptually, it is similar to past approaches.

Sound is a pressure wave, so at a certain point in space, sound is simply rapidly changing pressure. Pressure at a point is a function of time. Define p(t) as pressure (in micropascals) at a given point at time t (in seconds); this function is called a "time series." Figure A-9 gives the time series of the first "hallelujah" in Handel's Hallelujah Chorus.

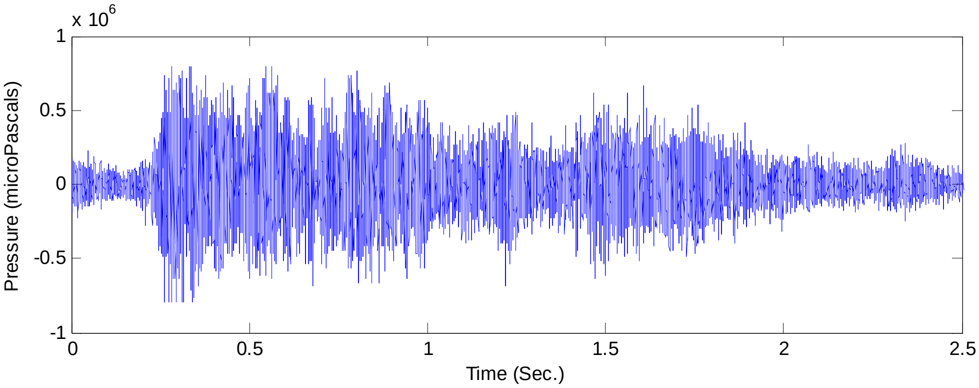


**Figure A-9: Time Series**

The time-series of a source can be different at different places. Therefore, sound, or pressure, is not only a function of time, but also of location. Let the function p(t), then be expanded to p(t;x,y,z) and denote the time series at point (x,y,z) in space. Thus, the series in Figure A-9 p(t) is for a given point (x,y,z). At a different point in space, it would be different.

Assume that the location of the source is (0,0,0) and this series is recorded at (0,10,-4). The time series above would be p(t;0,10,-4) for 0<t<2.5.

As in Figure A-9, pressure can be positive or negative, but acoustic power, which is proportional to the square of the pressure, is always positive, this makes integration meaningful. Figure A-10 is $p^2(t;0,10,-4)$.

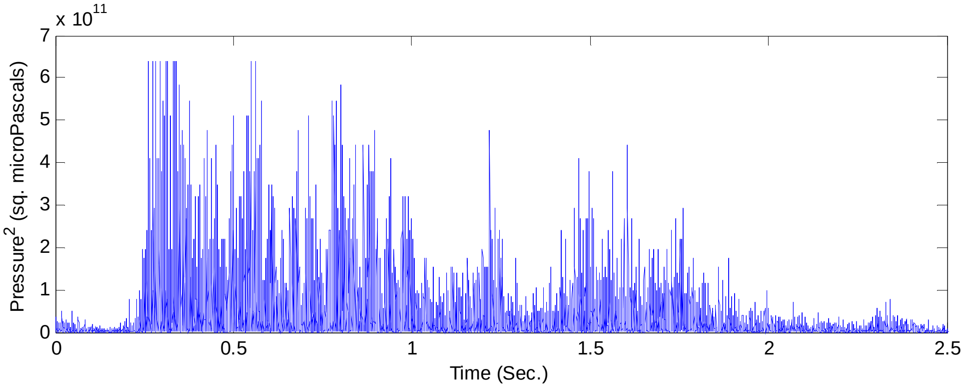


**Figure A-10: Time Series Squared**

The metric chosen to evaluate the sound field at the end of this first "hallelujah" determines how the time series is summarized from thousands of points, as in Figure A-9, to a single value for each point (x,y,z) in the space. The metric essentially "boils down" the four dimensional p(t,x,y,z) into a three dimensional function m(x,y,z) by dealing with time. There is more than one way to summarize the time component, so there is more than one metric.

**Max Sound Pressure Level (SPL)**

Because of the large dynamic range of the acoustic power, it is generally represented on a logarithmic scale using SPLs. SPL is actually the ratio of acoustic power density (power/unit area = $\frac{p^2}{Z}$ where Z = ρc is the acoustic impedance). This ratio is presented on a logarithmic scale relative to a reference pressure level, and is defined as:

$$SPL = 10\log_{10}(\frac{p^2}{p_{ref}^2}) = 20\log_{10}(abs\left(\frac{p}{p_{ref}}\right))$$

(Note that SPL is defined in dB re a reference pressure, even though it comes from a ratio of powers)

One way to characterize the power of the time series $p(t; x, y, z)$ with a single number over the 2.5 seconds is to only report the maximum SPL value of the function over time or,

$$SPL_{\max} = \max\left\{10\log_{10}\left(p^2(t,x,y,z)\right)\right\} \text{ (relative to a reference pressure of 1) for } 0<t<2.5$$

The $SPL_{\max}$ for this snippet of the Hallelujah Chorus is:

$$10\log_{10}\left(6.4\times10^{11}\,\mu Pa^2 / 1\mu Pa^2\right) = 118dB \text{ Re } 1\mu\text{Pa}$$

and occurs at 0.2606 seconds, as shown in Figure A-11.

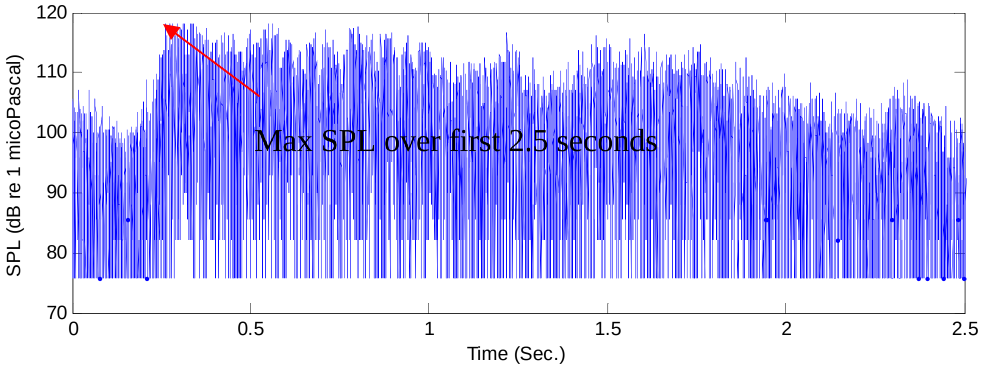


**Figure A-11: Max SPL of Time Series Squared**

**Integration**

$SPL_{\max}$ is not necessarily influenced by the duration of the sound (2.5 seconds in this case). Integrating the function over time gives the energy flux density, which does take this duration into account. A simple integration of $p^2(t;x,y,z)$ over t is common and is proportional to the energy flux density at (x,y,z). Because we will again be dealing in levels (logarithms of ratios), we neglect the impedance and simply measure the square of the pressure:

$$Energy = \int_0^T p^2(t,x,y,z)dt$$ , where T is the maximum time of interest in this case 2.5.

The energy for this snippet of the Hallelujah Chorus is $8.47 \times 10^{10}\ \mu Pa^2 \cdot s$. This would more commonly be reported as an EL:

$$EL = 10\log_{10}\left(\frac{\int_0^T p^2(t,x,y,z)dt}{1.0\mu Pa^2 s}\right) = \text{ 109.3 dB Re } 1\mu\text{Pa}^2\text{s}$$

Energy is sometimes called "equal energy" because if p(t) is a constant function and the duration is doubled, the effect is the same as doubling the signal amplitude (y value). Thus, the duration and the signal have an "equal" influence on the energy metric.

Mathematically,

$$\int_0^{2T} p(t)^2\,dt = 2\int_0^T p(t)^2\,dt = \int_0^T 2p(t)^2\,dt$$

or a doubling in duration equals a doubling in energy equals a doubling in signal.

Sometimes, the integration metrics are referred to as having a "3 dB exchange rate" because if the duration is doubled, this integral increases by a factor of two, or 10log10(2)=3.01 dB. Thus, equal energy has "a 3 dB exchange rate."

After p(t) is determined (i.e., when the stimulus is over), propagation models can be used to determine p(t;x,y,z) for every point in the vicinity and for a given metric. Define

$$m_a(x, y, z, T) = \text{value of metric "a" at point (x,y,z) after time T}$$

So,

$$m_{energy}(x, y, z; T) = \int_0^T p(t)^2\, dt$$

$$m_{\max\, SPL}(x, y, z; T) = \max(10 \log_{10}\left(p^2(t)\right))\ over\ \left[0, T\right]$$

Since modeling is concerned with the effects of an entire event, T is usually implicitly defined: a number that captures the duration of the event. This means that $m_a(x, y, z)$ is assumed to be measured over the duration of the received signal.

**Three Dimensions versus Two Dimensions**

To further reduce the calculation burden, it is possible to reduce the domain of $m_a(x, y, z)$ to two dimensions by defining $m_a(x, y) = \max\{m_a(x, y, z)\}$ over all z. This reduction is not used for this analysis, which is exclusively three-dimensional.

**Threshold**

For a given metric, a threshold is a function that gives the probability of exposure at every value of $m_a$. This threshold function will be defined as

$$D(m_a(x, y, z)) = \Pr(effect\ at\ m_a(x, y, z))$$

The domain of D is the range of $m_a(x, y, z)$, and its range is the number of thresholds.

An example of threshold functions is the Heavyside (or unit step) function, currently used to determine PTS and TTS in cetaceans. For PTS, the metric is $m_{energy}(x, y, z)$, defined above, and the threshold function is a Heavyside function with a discontinuity at 215 dB, shown in Figure A-12.

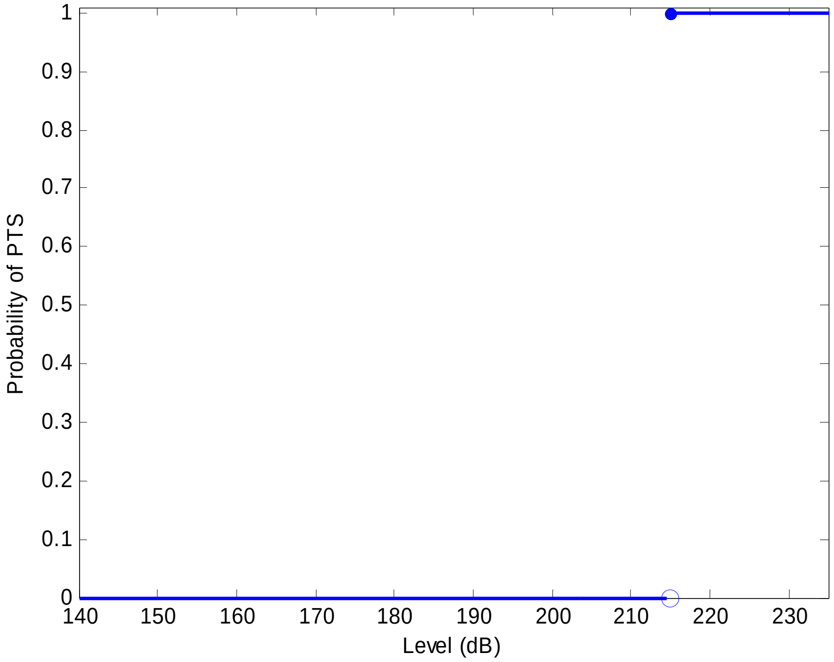


**Figure A-12: PTS Heavyside Threshold Function**

Mathematically, this D is defined as:

$$D(m_{energy}) = \begin{cases} 0 \;\; for\ m_{energy} < 215 \\ 1 \;\; for\ m_{energy} \geq 215 \end{cases}$$

Any function can be used for D, as long as its range is in [0,1]. The risk functions use normal Feller risk functions (defined below) instead of heavyside functions, and use the max SPL metric instead of the energy metric. While a heavyside function is specified by a single parameter, the discontinuity, a Feller function requires three parameters: the basement cutoff value, the level above the basement for 50% effect, and a steepness parameter. Mathematically, these Feller, "risk" functions, D, are defined as

$$D(m_{\max SPL}) = \begin{cases} \dfrac{1}{1+\left(\dfrac{K}{m_{\max SPL} - B}\right)^{A}} \;\; for\ m_{\max SPL} \geq B \\ 0 \;\; for\ m_{\max SPL} < B \end{cases}$$

where B=cutoff (or basement), K=the difference in level (dB) between the basement and the median (50% effect) harassment level, and A = the steepness factor. The risk function for odontocetes and pinnipeds uses the parameters:

B = 120 dB,

K = 45 dB, and

A = 10.

The risk function for mysticetes uses:

B = 120 dB,

K = 45 dB, and

A = 8.

Harbor porpoises are a special case. Though the metric for their behavioral harassment is also SPL, their risk function is a heavyside step function with a harassment threshold discontinuity (0 % to 100 %) at 120 dB. All other species use the continuous Feller CDF function for evaluating expected harassment.

**Multiple Metrics and Thresholds**

It is possible to have more than one metric, and more than one threshold in a given metric. For example, in this document, humpback whales have two metrics (energy and max SPL), and three thresholds (two for energy, one for max SPL). The energy thresholds are heavyside functions, as described above, with discontinuities at 215 and 195 for PTS and TTS respectively. The max SPL effect is calculated from the Feller risk function for odontocetes defined in the previous section.

**Calculation of Expected Exposures**

Determining the number of expected exposures for disturbance is the object of this analysis.

$$\text{Expected exposures in volume V} = \int_V \rho(V) D(m_a(V))dV$$

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

$$\int_{-\infty}^{0} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$$

**Numeric Implementation**

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 non-negative 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 section presents a brief outline of 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, so a balance between accuracy and time is determined in the decision of step size. For this analysis, z is sampled in 5-meter steps to 1,000 meters in depth and 10-meter steps to 2,000 meters, which is the limit of animal depth in this analysis. The step size for x is 5 meters, and y is sampled with an interval that increases as the distance from the source increases. Mathematically,

$$\begin{aligned} &z \in Z = \{0, 5, ...1000, 1010, ..., 2000\} \\ &x \in X = \{0, \pm 5, ..., \pm 5k\} \\ &y \in Y = \left\{0, \pm 5 * (1.005)^0, \pm 5 * \left[(1.005)^0 + (1.005)^1\right], ..., \pm 5 * \left[\sum_{i=0}^{j} (1.005)^i\right]\right\} \end{aligned}$$

for integers k, j, which depend on the propagation distance for the source. For this analysis, k = 20,000 and j = 600.

With 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, $\int_{-\infty}^{0} \rho(z) f(z)dz$ 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 x 200 km (40,000 sq km), 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 meters.

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 0.5 dB wide bins; 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:

$$\sum_{\ell \in L_1} D(\ell) V_{z_0}(\ell) \approx \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} D(m_{\max SPL}(x, y, z_0)) dxdy$$

So, 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.

For the interested reader, the following section includes an in-depth discussion of the method, software, and other details of the f(z) calculation.

**Software Detail**

The risk function metric uses the cumulative normal probability distribution to determine the probability that an animal is affected by a given SPL. The probability distribution is defined by a low-level cutoff level (below which the species is not affected), a 50% effect level, and a steepness factor. The acoustic quantity of interest is the maximum SPL 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 SPL of the source and the TL curve, the received SPL is calculated on a volumetric grid. For a given depth, volume associated with each SPL interval is calculated. Then, this volume is multiplied by the probability that an animal will be affected by that SPL. This gives the impact volume for that depth, that 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 SPL 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 SPL at each x/y plane grid point is calculated using the SPL 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-13 shows a volume histogram for a low-power sonar. Level bins are 0.5 dB in width and the depth is 50 meters in an environment with water depth of 100 meters. 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 function probability function at that level. Total expected impact volume for a given depth is the sum of these "expected" volumes. Figure A-14 is an example of the impact volume as a function of depth at a water depth of 100 meters.

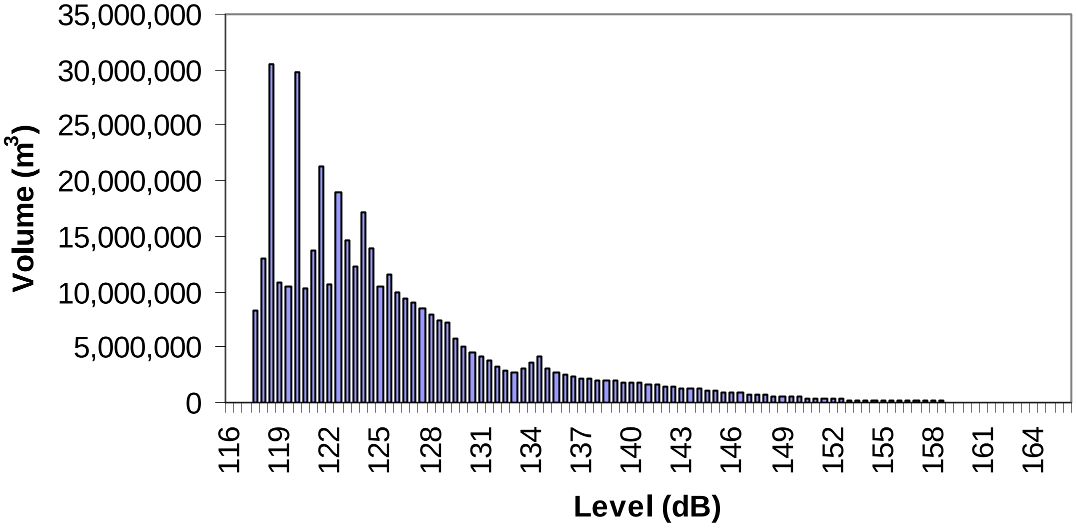


**Figure A-13: Example of a Volume Histogram**

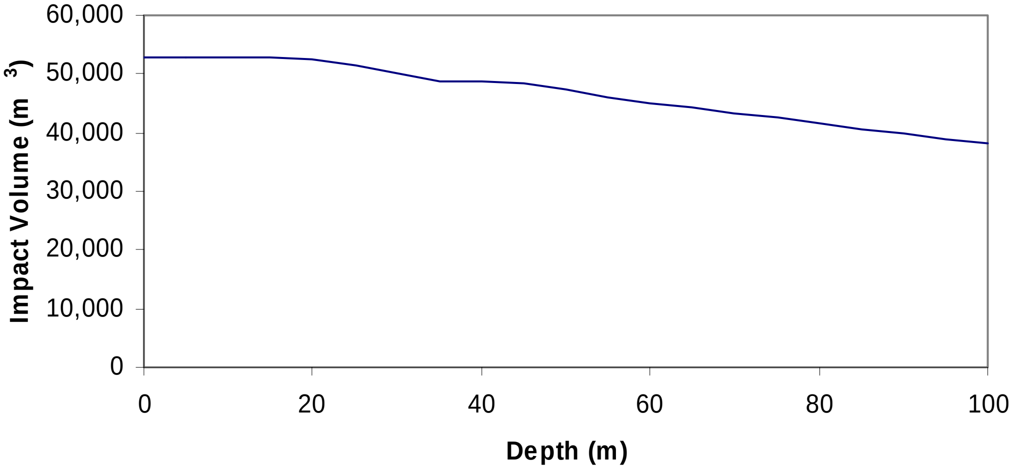


**Figure A-14: Example of the Dependence of Impact Volume on Depth**

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 meters in the x-coordinate and a slowly expanding spacing in the y-coordinate that starts with 5 meters 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 nth grid size is related to the first grid size by multiplying by (1+Ry)(n-1). For an initial grid size of 5 meters and a growth factor of 0.005, the 100th grid increment is 8.19 meters. 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 –Rmax to +Rmax, where Rmax is the maximum range used in the TL calculations. The z direction uses a uniform spacing of 5 meters down to 1,000 meters and 10 meters from 1,000 to 2,000 meters. This is the same depth mesh used for the effective energy metric as described above. The depth mesh does not extend below 2,000 meters, on the assumption that animals of interest are not found below this depth.

The next three figures 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-15 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 5m and the y-axis growth factor is 0, i.e., uniform spacing. The impact volume for a 5 meters grid size is the reference. For grid sizes between 2.5 and 7.5 meters, the change is less than 0.1%. A grid size of 5 meters for the x-axis is used in the calculations. Figure A-16 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 meters and the y-axis growth factor is 0. The impact volume for a 5-meter 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 meters, the change is less than 0.1%. A grid size of 5 meters is used for the y-axis in our calculations. Figure A-17 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 meters and the initial y-axis grid size is 5 meters. 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%. A growth factor of 0.005 is used in the calculations.

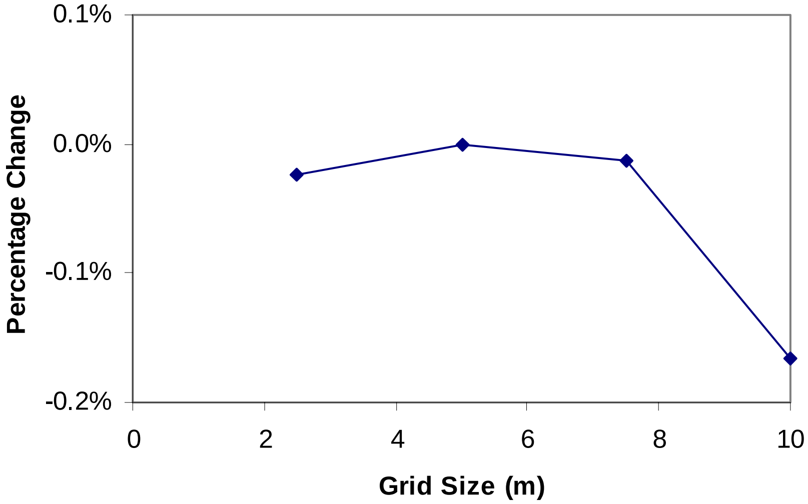


**Figure A-15: Change of Impact Volume as a Function of X-Axis Grid Size.**

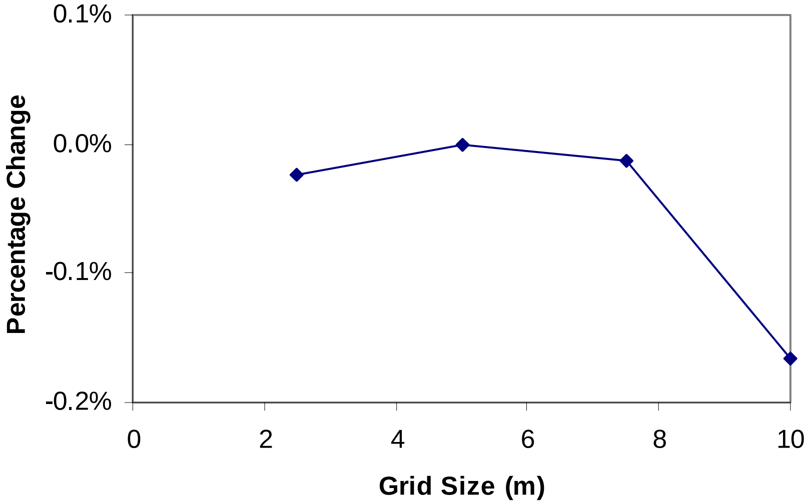


**Figure A-16: Change of Impact Volume as a Function of Y-Axis Grid Size**

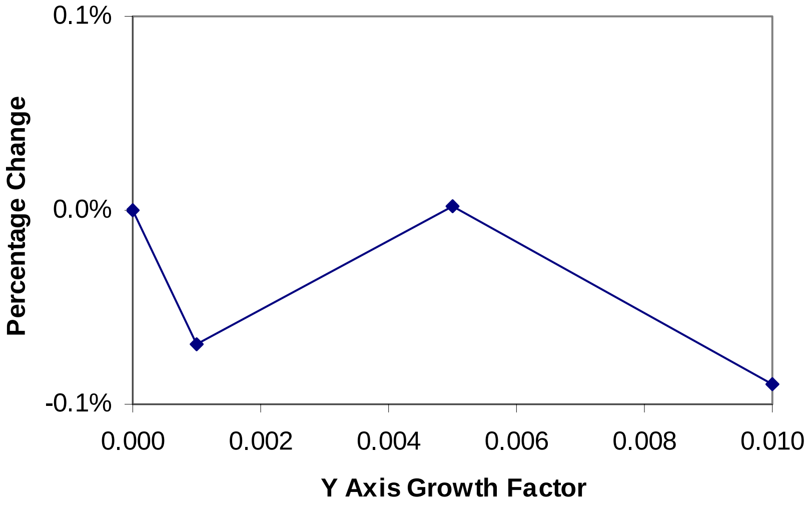


**Figure A-17: Change of Impact Volume as a Function of Y-Axis Growth Factor**

Another factor influencing the accuracy of the calculation of impact volumes is the size of the bins used for SPL. The SPL bins extend from 100 dB (far lower than required) up to 300 dB (much higher than that expected for any sonar system). Figure A-18 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 meters the initial y-axis grid size is 5 meters, 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%. A bin width of 0.5 is used in our calculations.

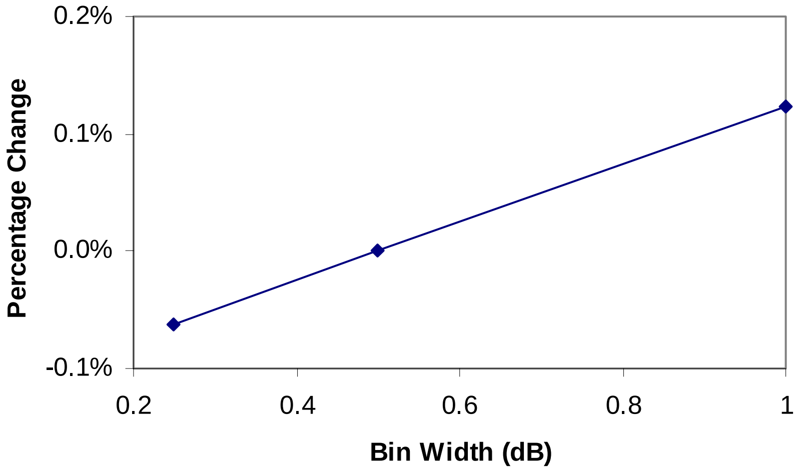


**Figure A-18: Change of Impact Volume as a Function of Bin Width**

Two other issues for discussion are the maximum range (Rmax) 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 Rmax needs some discussion since it is not clear that the same value can be used for both metrics. Rmax was set so that the TL at Rmax 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 log10(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 SPL 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 has 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 beamformed eigenrays on the range mesh used for the TL calculation, the vertically beamformed 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 grid points with distances less than Rmax are used. To obtain the SPL at a grid point, the SPL of the source is reduced by that TL. For the first ping, the volumetric grid is populated by the calculated SPL 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 SPL for each grid point is again calculated for the new source location. Since the risk function metric uses the maximum of the SPLs at each grid point, the newly calculated SPL at each grid point is compared to the SPL 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 SPL.

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-13. Multiplying by the risk function 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-14, 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-19 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-20 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.

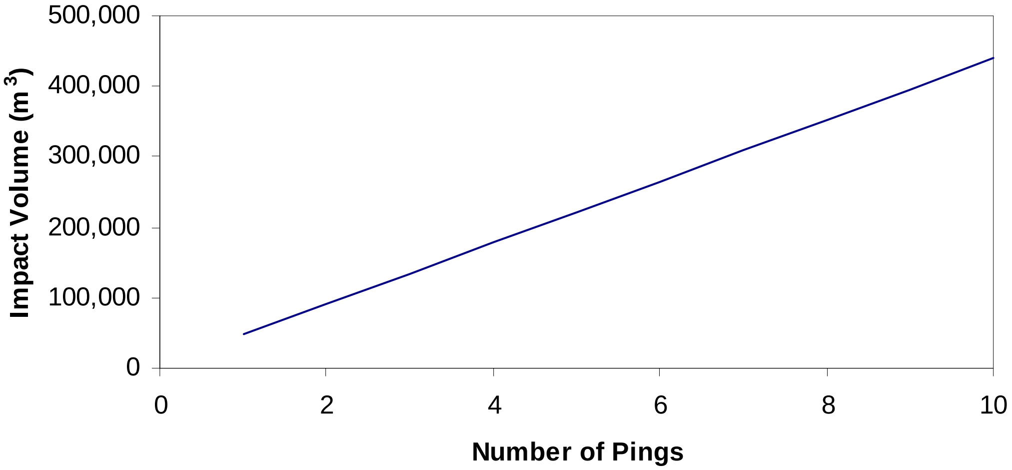


**Figure A-19: Dependence of Impact Volume on the Number of Pings**

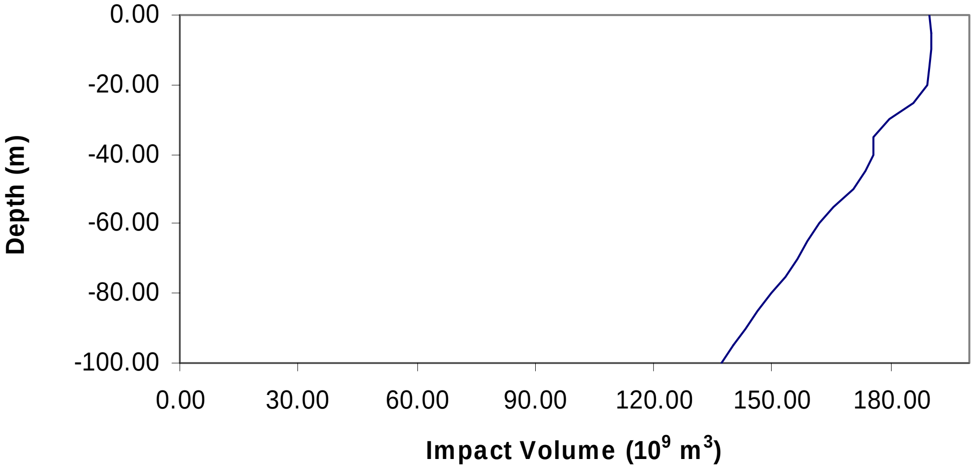


**Figure A-20: Example of an Hourly Impact Volume Vector**

## A 5.1 Exposure Estimates

The following sperm whale example demonstrates the methodology used to create a three-dimensional density by merging the area densities with the depth distributions. The sperm whale surface density is 0.0028 whales per square kilometer. From the depth distribution report, "depth distribution for sperm whales based on information in the Amano paper is: 19% in 0-2 m, 10% in 2-200 m, 11% in 201-400 m, 11% in 401-600 m, 11% in 601-800 m and 38% in >800 m." So the sperm whale density at 0-2 m is 0.0028*0.19/0.002 = 0.266 per cubic km, at 2-200 m is 0.0028*0.10/0.198 = 0.001414 per cubic km, and so forth.

In general, the impact volume vector samples depth in finer detail than given by the depth distribution data. When this is the case, the densities are apportioned uniformly over the appropriate intervals. For example, suppose the impact volume vector provides volumes for the intervals 0-2 meters, 2-10 meters, and 10-50 meters. Then for the depth-distributed densities discussed in the preceding paragraph,

- 0.266 whales per cubic km is used for 0-2 meters,
- 0.001414 whales per cubic km is used for the 2-10 meters, and
- 0.001414 whales per square km is used for the 10-50 meters.

Once depth-varying, three-dimensional densities are specified for each species type, with the same depth intervals and the ensonified volume vector, the density calculations are finished. The expected number of ensonified animals within each depth interval is the ensonified volume at that interval multiplied by the volume density at that interval and this can be obtained as the dot product of the ensonified volume and animal density vectors.

Since the ensonified volume vector is the ensonified volume per unit operation (i.e., per hour, per sonobuoy, etc), the final take count for each animal is the unit operation take count multiplied by the number of units (hours, sonobuoys, etc). The tables below are organized by threshold level; each table represents the expected exposures at different threshold levels for a different source types. For sonar sources, exposures are reported at 195 dB, and 215 dB. For explosive sources, exposures are reported by level A (corresponding to 182 dB one-third-octave energy) and level B (corresponding to 205 dB one-third-octave energy and 13 psi-ms). These thresholds are explained in section F.1.

The number of total exposures at different threshold levels for each alternative are presented in Section 3.7 in Volume 1 of the draft MIRC EIS/OEIS.

## A.6 Post Acoustic Modeling Analysis

The acoustic modeling results include additional analysis to account for land mass, multiple ships, and number of animals that could be exposed. Specifically, post modeling analysis is designed to consider:

- Acoustic footprints for sonar sources must account for land masses.
- Acoustic footprints for sonar sources should not be added independently, which would result in overlap with other sonar systems used during the same active sonar activity. As a consequence, the area of the total acoustic footprint would be larger than the actual acoustic footprint when multiple ships are operating together.
- Acoustic modeling should account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

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 ship path, proximity of shoreline, high-resolution density estimates, and other details of the scenario. However, in the MIRC, there are sound-producing events for which the source locations, number of projectors, 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 decibel (dB) SPL when the ship passes at closest point of approach (CPA) on Tuesday morning, how do we know it doesn't receive a higher level on Tuesday evening?" This question cannot be answered without knowing the path of the ship (and several other facts). Because the path of the ship 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-11 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.

The following sections discuss three topics that require action details, and describes how the modeling calculations used the general knowledge and assumptions to overcome the future-action uncertainty considering re-exposure of animals, land shadow, and the effect of multiple-ship training events.

**Table A-11: Unknowns and Assumptions**

| Unknowns | Relevance | Assumption |
|---|---|---|
| Path of ship (esp. with respect to animals) | Ambiguity of multiple exposures,<br>Local population: upper bound of harassments | Most conservative case: ships are everywhere within Sonar Operating Area |
| Ship(s) 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 |
| Number of ships | Effect of multiple ships | Average number of ships per training event |
| Distance between ships | Effect of multiple ships | Average distance between ships |

**Multiple Exposures in General Modeling Scenario**

Consider the following hypothetical scenario. A box shaped area is designated on the surface of a well-studied ocean environment with well-known sound propagation characteristics. A sonar-equipped ship and 44,000 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 effects.

For the first period of time, the ship 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 ship travels in a straight line, this calculation is valid. However, after an undetermined amount of time, the ship will change course to a new and unknown heading.

If the ship changes direction 180 degrees and travels back through the same swath of ocean, all the animals the ship passes at 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 ship (though most have received sound from it), so the population is completely "fresh." Most ship headings lead to a population of a mixed "freshness," varying by course direction. Since the route and position of the ship over time are unknown, the freshness of the population at CPA with the ship is unknown. This ambiguity continues through the remainder of the training event.

What is known? The source and, in general, the animals remain in the Sonar Operating Area (SOA). Thus, if the farthest range to a possible effect from the ship is X kilometers (km), no animals farther than X km outside of the SOA 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 SOA 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 training event means that multiple exposures cannot be calculated for any individual animal. It must be dealt with generally at the local 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 during the training event. 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% chance of harassment, its contribution increases to 0.7. If two animals receive a level that indicates 50% 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 training event 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 ship 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 2 animals per square kilometer (km2) produces 100 expected harassments, then action A in an area with 1 animal per km2 would produce 50 expected harassments. The modeling produces the number of expected harassments per ping starting with 100% 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% of which are initially unharassed. After the first ping, 99 animals are unharassed, so the number of animals harassed during the second ping are

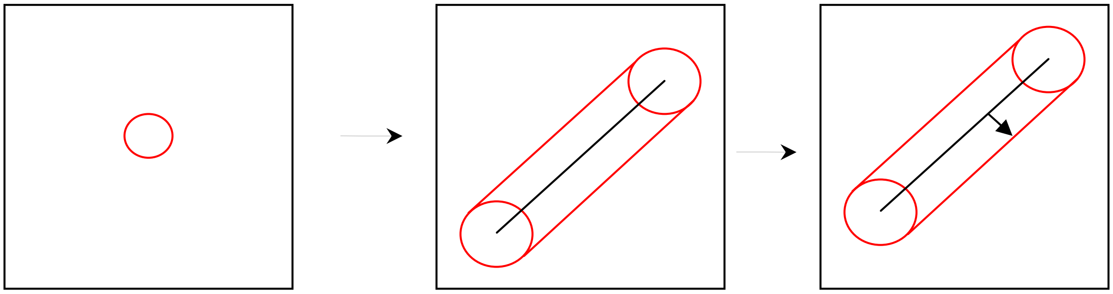
$$10\left(\frac{99}{100}\right) = 1(.99) = 0.99 \text{ animals}$$

and so on for the subsequent pings.

### Mathematics

A closed form function for this process can be derived as follows.

Define $H =$ number of animals harassed per ping with 100% unharassed population. H is calculated by determining the expected takes for a source moving in a straight line for the duration of the exercise and dividing by the number of pings in the exercise (Figure A-21).



$$\text{H} = \int\int\int \rho(z) D(L(x,y,z))\,dxdydz\ /\text{N\_pings}$$

**Figure A-21: Process of Calculating H**

The total unharassed population is then calculated by iteration. Each ping affects the unharassed population left after all previous pings:

Define $P_n =$ unharassed population after ping n

$P_0 =$ local population

$$P_1 = P_0 - H$$

$$P_2 = P_1 - H\left(\frac{P_1}{P_0}\right)$$

$$\ldots$$

$$P_n = P_{n-1} - H\left(\frac{P_{n-1}}{P_0}\right)$$

Therefore,

$$P_n = P_{n-1}\left(1-\left(\frac{H}{P_0}\right)\right) = P_{n-2}\left(1-\left(\frac{H}{P_0}\right)\right)^2 = \ldots = P_0\left(1-\left(\frac{H}{P_0}\right)\right)^n$$

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 periods of sonar use to training 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 training 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 every animal which enters the training area at any time in the exercise (and also many outside) is “harassable” and creates an upper bound on the number of harassments for the exercise. Since this is equivalent to assuming that there are sonars transmitting simultaneously from each point in the confined area throughout the action length, this greatly overestimates the take from an exercise.

NMFS has defined a 24-hour "refresh rate," or amount of time in which an individual can be harassed no more than once. The Navy has determined that, in a 24-hour period, all sonar activities in the MIRC transmit for a subset of that time (Table A-12).

**Table A-12: Duration of 53C Use During 24-hour Period**

| Exercise | Longest continuous interval of 53C use in 24-hour period |
|---|---|
| Multi-Strike Group | 12 hours |
| TRACKEX-TORPEX | 12 hours |

The most conservative assumption for a single ping is that it harasses the entire population within the range (a gross over-estimate). However, the total harassable population for multiple pings will be even greater, since animal motion over the period in the Table A-12 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 MIRC modeling areas uses a straight-line animal motion assumption. This is a conservative assumption.

For a circular area, the straight-line motion in any direction produces the same increase in harassable population. However, since the ranges are non-circular polygons, choosing the initial fixed direction as perpendicular to the longest diagonal produces greater results than any other 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 range modeling areas due to animal motion. The MIRC expansions use this estimate as an absolute upper bound on animal-motion expansion.

Figure A-22 illustrates an example that illustrates the overestimation, which occurs during the second arrow:

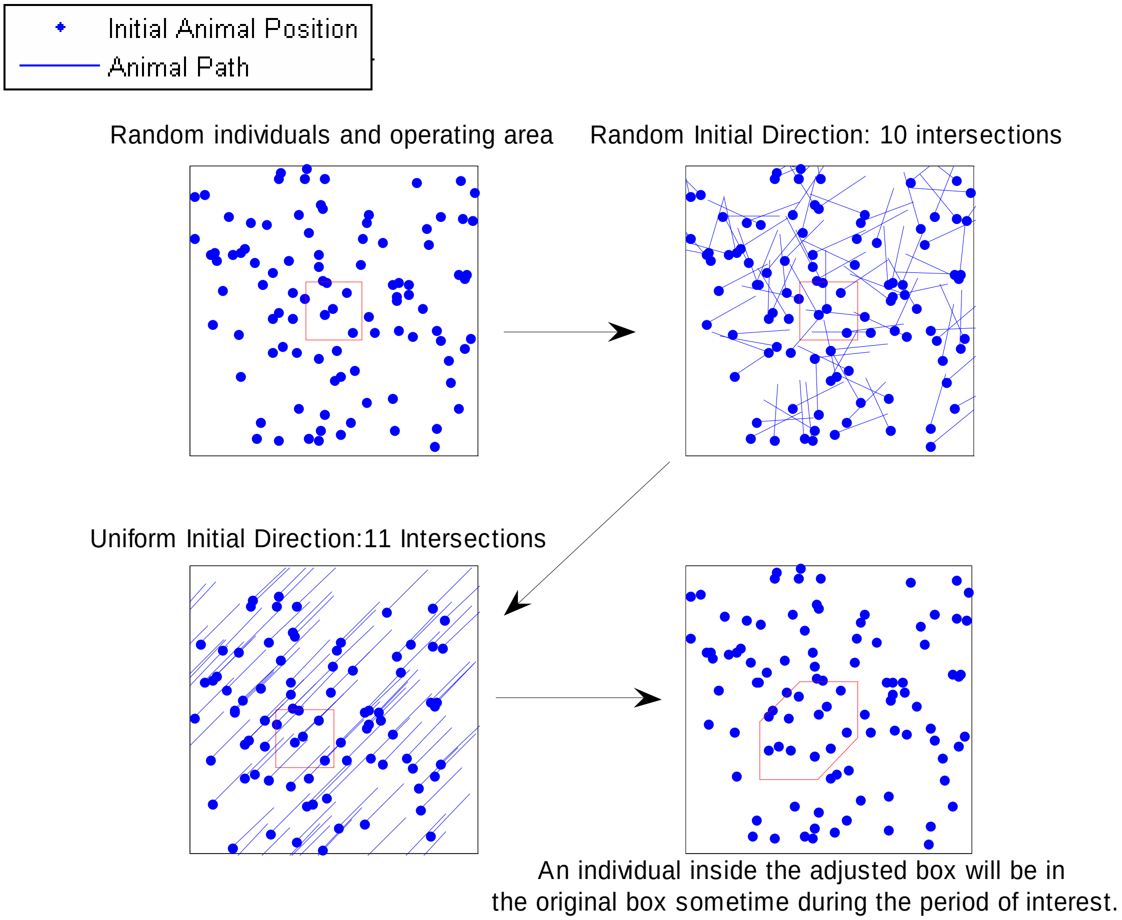


**Figure A-22: Process of Setting an Upper Bound on Individuals Present in Area**

It is important to recognize that the area used to calculate the harassable population, shown in Figure A-22 will, in general, be much larger than the area that will be within the ZOI of a ship for the duration of its broadcasts. For a ship moving faster than the speed of the marine animals, a better (and much smaller) estimate of the harassable population would be that within the straight line ZOI cylinder shown in Figure A-22. Using this smaller population would lead to a greater dilution of the unharassed population per ping and would greatly reduce the estimated takes.

### Risk Function Expansion

The expanded area contains the number of animals that will enter the range 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 assume pinging at every point on the range border throughout the exercise and would include all area with levels from a source on the closest border point greater than the risk function basement. In the case of MIRC, this would include all area within approximately 150 km from the edge of the adjusted box. This basic method would give a crude and exaggerated upper bound, since only a tiny fraction of this out-of-range area can be ensonified above threshold for a given ping. 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, which would give all animals inside the area a 100% probability of harassment, and those outside the area a varying probability, based on the risk function.

$$\int_{0}^{L^{-1}(120\,dB)} D(L(r))dr \,,$$

Where L is the SPL function with domain in range and range in level,

r is the range from the sonar operating area,

L-1(120 dB) is the range at which the received level drops to 120 dB, and

D is the risk function (probability of harassment vs. level).

At the corners of the polygon, additional area can be expressed as

$$\frac{[\pi - \theta] \displaystyle\int_{0}^{L^{-1}(120\,dB)} D(L(r))rdr}{2\pi}$$

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 MIRC, this method adds an area equivalent by 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, is the harassable population and an absolute upper bound on possible harassments for that operation.

Figure A-23 illustrates 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 initially unharassed population which could be affected by training activities.

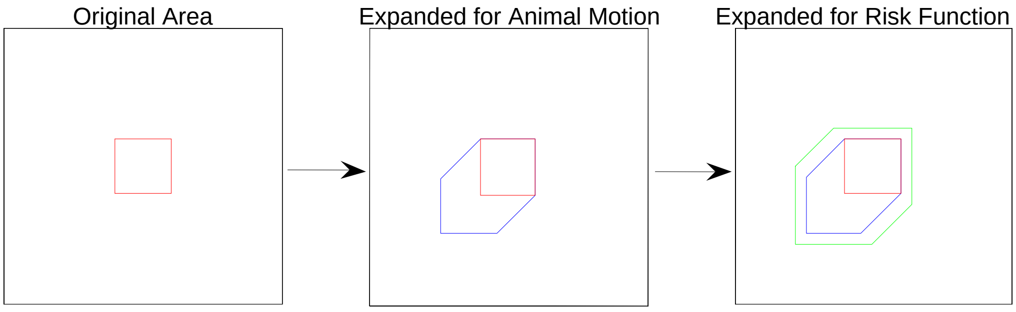


**Figure A-23: Process of Expanding Area to Create Upper Bound of Harassments**

**Example Case**

Consider a sample case from the MIRC. For the most powerful source, the 53C, the expected winter rate of harassment for pantropical spotted dolphins is approximately 0.132 harassments per ping. The exercise will transmit sonar pings for 12 hours in a 24-hour period, as given in the action table above, with 120 pings per minute, a total of 120*12=1,440 pings in a 24-hour period.

The Quinault range with Kalaloch extension has an area of approximately 1,677,264 square kilometers and a diagonal of 1857 km. Adjusting this with straight-line (upper bound) animal motion of 5.5 kilometers per hour for 12 hours, animal motion adds 1857*5.5*12= 122,562 square kilometers to the area. Using the risk function to calculate the expected range outside the SOA adds another 20,728 square kilometers, bringing the total upper-bound of the affected area to 1,820,554 square km.

For this analysis, pantropical spotted dolphins have an average density of 0.0226 animals per square kilometer, so the upper bound number of pantropical spotted dolphins that can be affected by 53C activity in the MIRC during a 24-hour period is 1,820,554 *0.0226=41,145 dolphins.

In the first ping, 0.132 whitesided dolphins will be harassed. With the second ping, $0.132\left(\frac{41145-.132}{41145}\right)=0.1319995765$ pantropical spotted dolphins will be harassed. Using the formula derived above, after 12 hours of continuous operation, the remaining unharassed population is

$$P_{1440}=P_0\left(1-\left(\frac{h}{P_0}\right)\right)^{1440}=41145\left(1-\left(\frac{0.132}{41145}\right)\right)^{1440}\approx 40955.3$$

So the harassed population will be 41145-40955.3 = 189.7 animals.

Contrast this with linear accumulation of harassments without consideration of the local population and the dilution of the unharassed population:

Harassments = 0.132 *1440=190.1 animals

The difference in harassments is very small, as a percentage of total harassments, because the size of the MIRC implies a large “harassable” population relative to the harassment per ping of the 53C. In cases where the harassable population is not as large, with respect to the per ping harassments, the difference in harassments between linear accumulation and density dilution is more pronounced.

## 2) Land Shadow

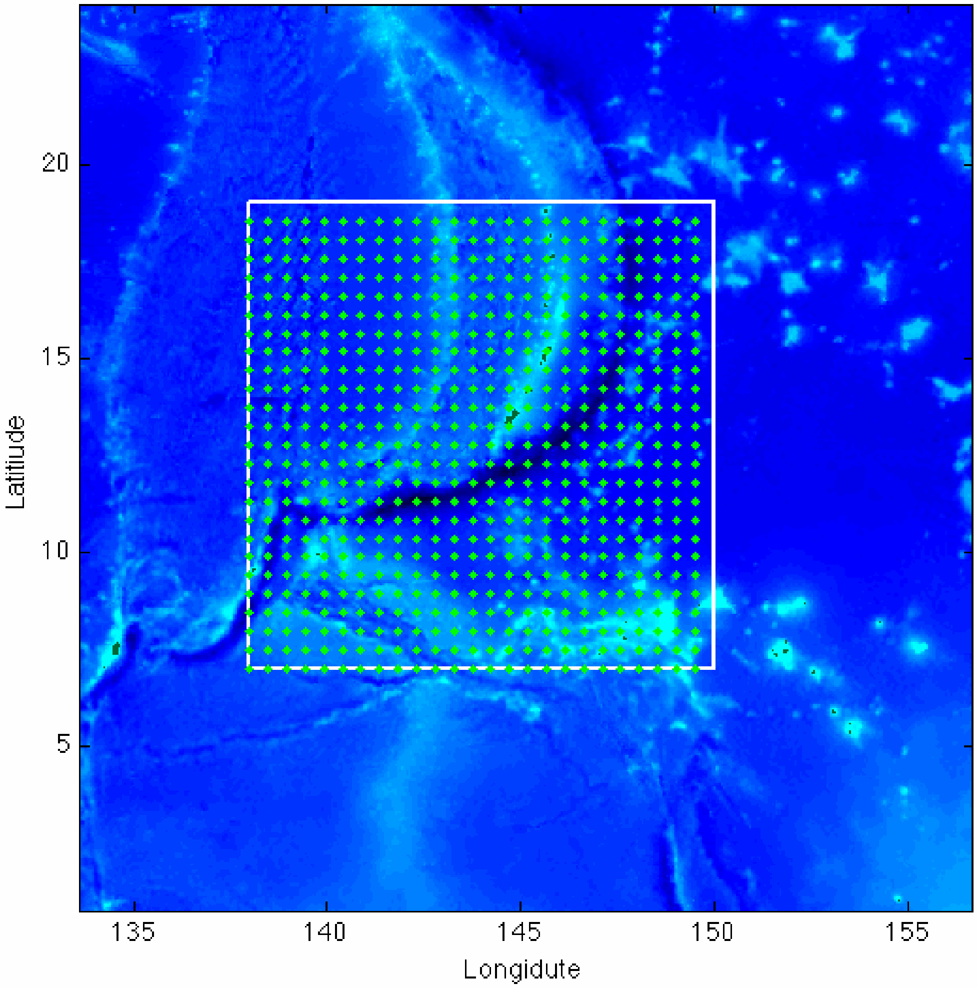
The risk function considers harassment possible if an animal receives 120 dB SPL, or above. In the open ocean of the MIRC, this can occur as far away as 150 km, so over a large "effect" area, sonar sound could, but does not necessarily, harass an animal. The harassment calculations for a general modeling case must assume that this effect area covers only water fully populated with animals, but in some portions of the MIRC, 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 range.

For the ranges, in each alternative, the land shadow is computed over a dense grid in each operations area. Figure A-24 shows the grid for the MIRC.

For each of the coastal points that are within 150 km of the grid, the azimuth and distance is computed. In the computation, only the minimum range at each azimuth is computed. Figure A-25 shows the minimum range compared with azimuth for the sample point.

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.



1 **Figure A-24: Illustrative Grid for MIRC Study Area. Each green point represents approximately 100**
2 **points on the actual grid used for land shadow calculation, which samples every km.**

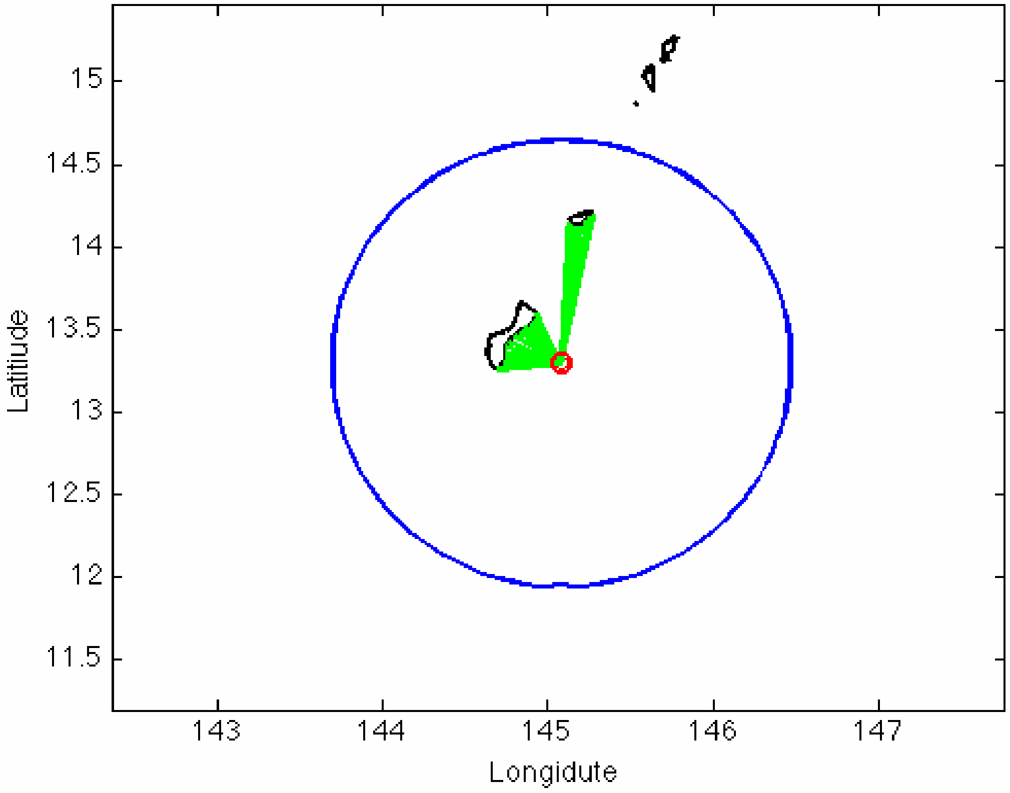


**Figure A-25: The nearest point at each azimuth (with 1° spacing) to a sample grid point (red circle) is shown by the green lines.**

### 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-13 gives a mathematical extrapolation of the distances and levels at which harassments occur, with average propagation in the MIRC.

**Table A-13: Behavioral Harassments at each Received Level Band from 53C**

| Received Level (dB SPL) | Distance at which Levels Occur in MIRC | Percent of Behavioral Harassments Occurring at Given Levels |
|---|---|---|
| Below 150 | 15 km – 150 km | < 2% |
| 150>Level>160 | 6 km – 15 km | 18% |
| 160>Level>170 | 2 km – 6 km | 41% |
| 170>Level>180 | 0.5 km – 2 km | 27% |
| 180>Level>190 | 170 m – 500 m | 10% |
| Above 190 dB | 0 m – 170 m | <3% |

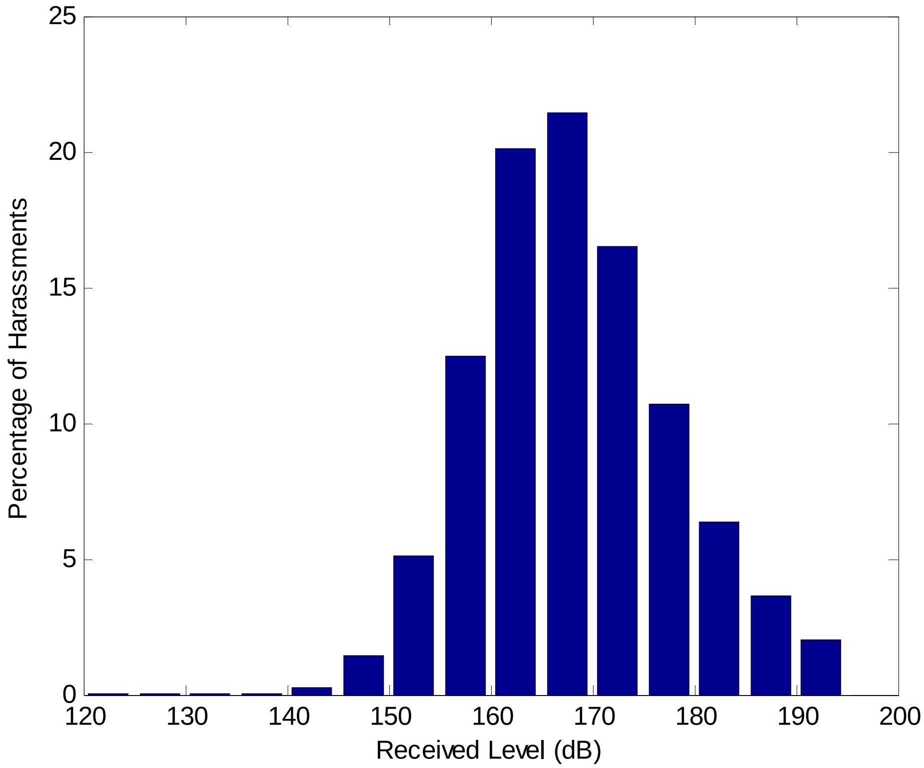


**Figure A-26: The approximate percentage of behavioral harassments for every 5 band of received level from the 53C**

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 the 53C, since approximately 94% of harassments occur within 10 kilometers of the source, a sound path blocked by land at 10 kilometers will, on average, cause approximately 94% the effect of an unblocked path.

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 $\theta_n$ = 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 $A(rn)\theta n/(2\pi)$. For illustration, the following plots give the land shadow reduction factor at each point in each range area for the 53C. The white portions of the plot indicate the areas outside the range and the blue lines indicate the coastline. The color plots inside the ranges give the land shadow factor at each point. The average land shadow factor for the 53C in the MIRC is 0.9997, or the reduction in effect is 0.03%. For the other, lower-power sources, this reduction is lower. The effect of land shadow in the MIRC is also negligible.

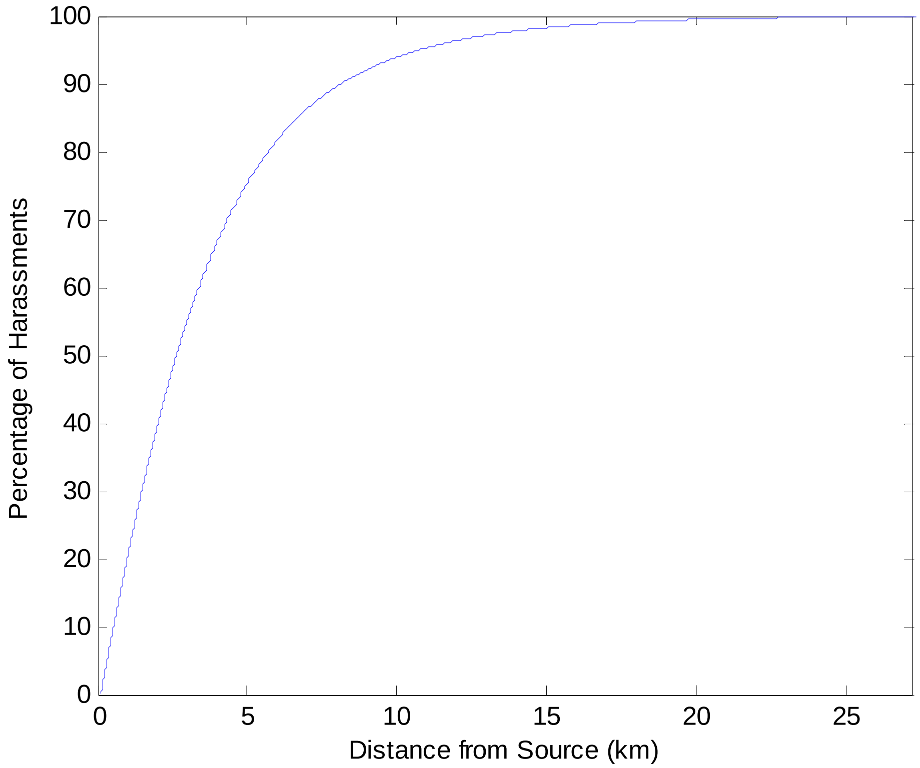


**Figure A-27: Average Percentage of Harassments Occurring Within a Given Distance**

### 3) The Effect of Multiple Ships

Behavioral harassment, under risk function, uses maximum SPL over a 24-hour period as the metric for determining the probability of harassment. An animal that receives sound from two sonars, operating simultaneously, receives its maximum SPL from one of the ships. Thus, the effects of the louder, or closer, sonar determine the probability of harassment, and the more distant sonar does not. If the distant sonar operated by itself, it would create a lesser effect on the animal, but in the presence of a more dominating sound, its effects are cancelled. When two sources are sufficiently close together, their sound fields within the cutoff range will partially overlap and the larger of the two sound fields at each point in that overlap cancel the weaker. If the distance between sources is twice as large as the range to cutoff, there will be no overlap.

Computation of the overlap between sound fields requires the precise locations and number of the source ships. The general modeling scenarios of the MIRC do not have these parameters, so the effect was modeled using an average ship distance, 20 km, and an average number of ships per exercise. The number of ships per exercise varied based on the type of exercise, as given in Table A-14.

**Table A-14: Average Number of 53C-Transmitting Ships in the MIRC Exercise Types**

| Action | Average Number of SQS-53C-Transmitting Ships |
|---|---|
| Multi-Strike Group | 4 |
| TRACKEX-TORPEX | 1.5 |

The formation of ships in any of the above exercise has been determined by Navy planners. The ships are located in a straight line, perpendicular to the direction traveled. Figures A-28 and A-29 show examples with four ships, and their ship tracks.

The sound field created by these ships, which transmit sonar continually as they travel will be uniform in the direction of travel (or the "x" direction), and vary by distance from the ship track in the direction perpendicular to the direction of travel (or the "y" direction) (Figure A-30).

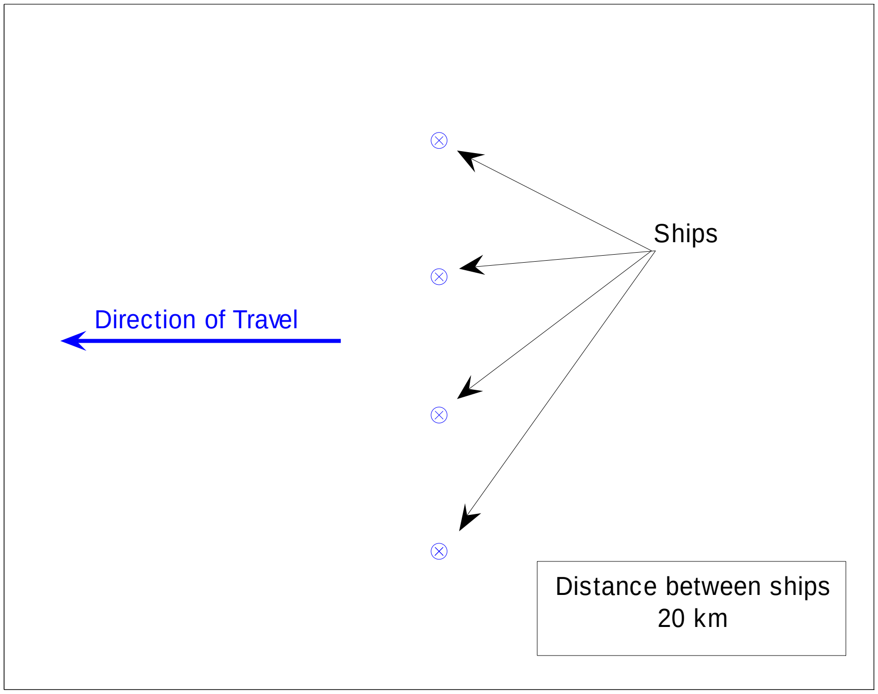


Figure A-28: Formation and Bearing of Ships in Four-Ship Example

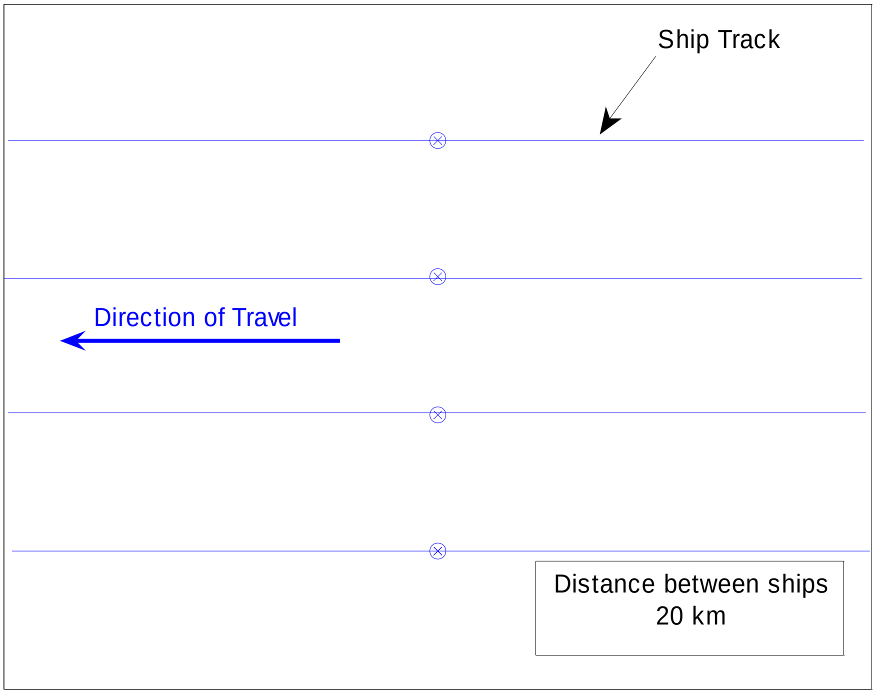


**Figure A-29: Ship Tracks of Ships in 4-Ship Example**

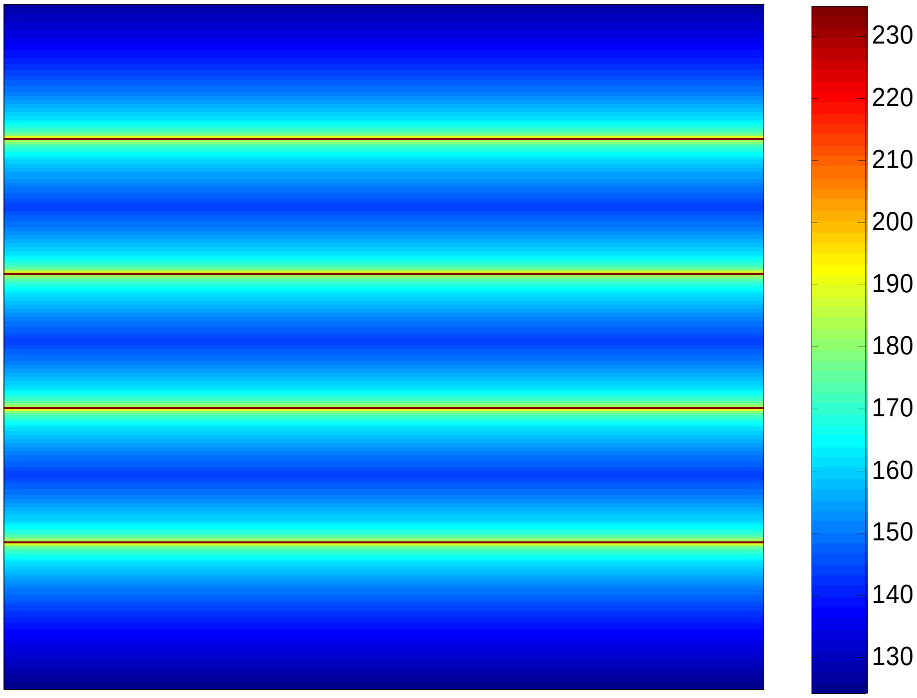


**Figure A-30: Sound Field Produced by Multiple Ships**

This sound field of the four ships operating together ensonifies less area than four ships operating individually. However, because at the time of modeling, even the average number of ships and mean distances between them were unknown, a post-calculation correction should be applied.

Referring to the above picture of the sound field around the ship tracks, the portion above the upper-most ship track, and the portion below the lower-most ship track sum to produce exactly the sound field as an individual ship.

Therefore, the remaining portion of the sound field, between the uppermost ship track and the lowermost ship track, is the contribution of the three additional ships (Figure A-31).

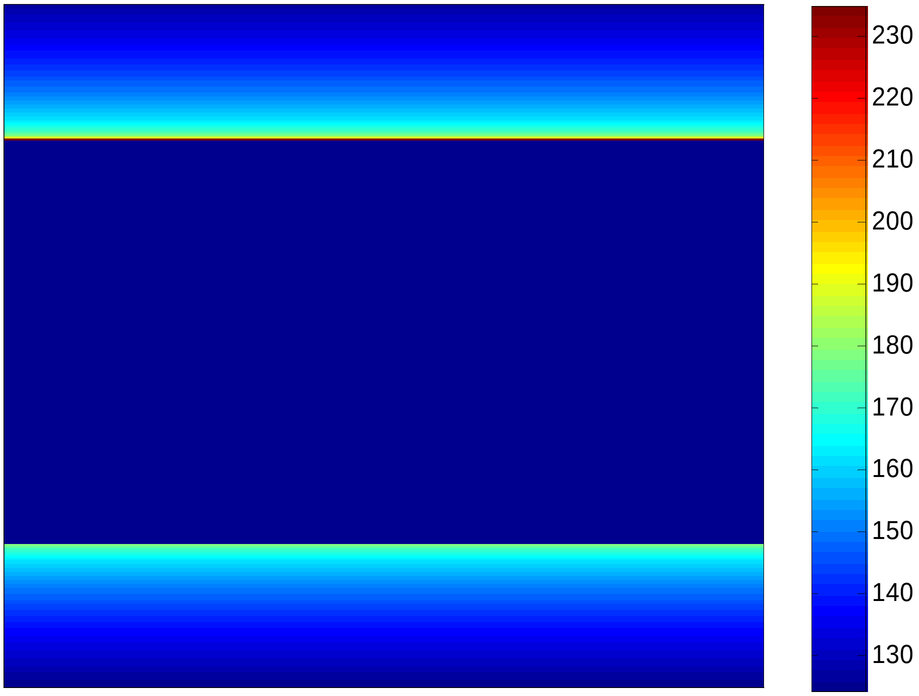


**Figure A-31: Upper and Lower Portion of Sound Field**

This remaining sound field is made up of three bands (Figure A-32). Each of the three additional ships contributes one band to the sound field. Each band is somewhat less than the contribution of the individual ship because its sound is overcome by the nearer source at the center of the band. Since each ship maintains 20 kilometer distance between it and the next, the height of these bands is 20 km, and the sound from each side projects 10 kilometers before it is overcome by the source on the other side of the band. Thus, the contribution to a sound field for an additional ship is identical to that produced by an individual ship whose sound path is obstructed at 10 kilometers. The work in the previous discussion on land shadow provides a calculation of effect reduction for obstructed sound at each range. An AQS-53C-transmitting ship with obstructed signal at 10 kilometers causes 94% of the number of harassments as a ship with an unobstructed signal. Therefore, each additional ship causes 0.94 times the harassments of the individual ship. Applying this factor to the four exercise types from the above table, an adjustment from the results for a single ship can be applied to predict the effects of multiple ships (Table A-15).

**Table A-15: Adjustment Factors for Multiple Ships in MIRC Exercise Types**

| Action | Average Number of SQS-53C-Transmitting Ships | Adjustment Factor from Individual Ship for Formation and Distance |
|---|---|---|
| Multi-Strike Group | 4 | 3.82 |
| TRACKEX-TORPEX | 1.5 | 1.475 |

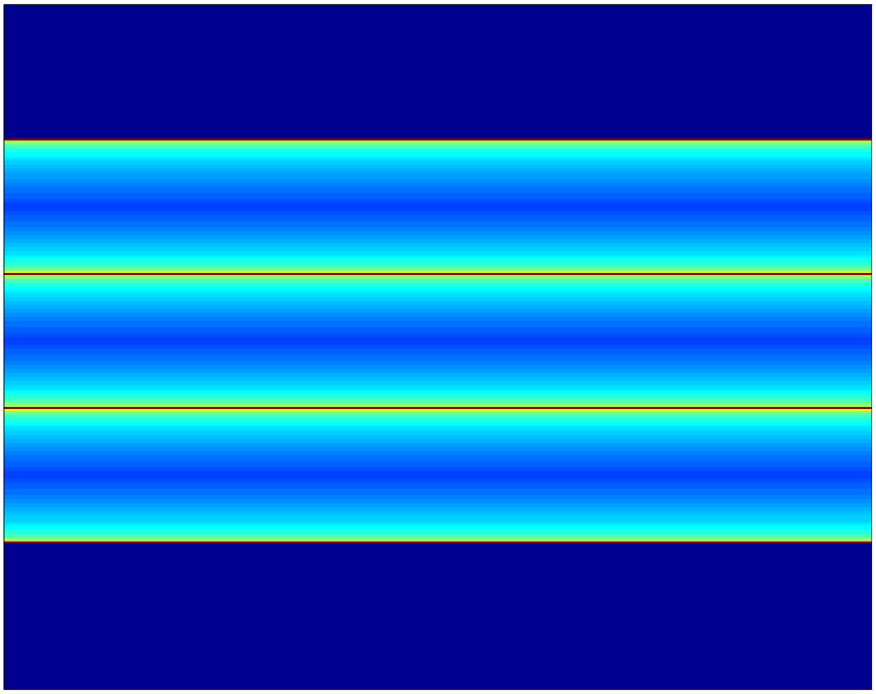


**Figure A-32: Central Portion of Sound Field**

## A.7 References

Arons, A.B. (1954). “Underwater Explosion Shock Wave Parameters at Large Distances from the Charge,” J. Acoust. Soc. Am. 26, 343.

Bartberger, C.L. (1965). “Lecture Notes on Underwater Acoustics,” NADC Report NADC=WR-6509, Naval Air Development Center Technical Report, Johnsville, PA, 17 May (AD 468 869) (UNCLASSIFIED).

Christian, E.A. and J.B. Gaspin, (1974). Swimmer Safe Standoffs from Underwater Explosions,” NSAP Project PHP-11-73, Naval Ordnance Laboratory, Report NOLX-89, 1 July (UNCLASSIFIED).

Department of the Navy (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.

Department of the Navy (2001), “Final Environmental Impact Statement, Shock Trial of the WINSTON S. CHURCHILL (DDG 81),” U.S. Department of the Navy, NAVSEA, 597 p.

Goertner, J.F. (1982). “Prediction of Underwater Explosion Save Ranges for Sea Mammals,” Naval Surface Warfare Center (NSWC) Report NSCW TR 82-188, NSWC, Dahlgren, VA (UNCLASSIFIED).

Goertner, J.F. (1982), “Prediction of Underwater Explosion Safe Ranges for Sea Mammals,” NSWC TR 82-188, Naval Surface Weapons Center, Dahlgren, VA.

Keenan, R.E., Denise Brown, Emily McCarthy, Henry Weinberg, and Frank Aidala (2000). “Software Design Description for the Comprehensive Acoustic System Simulation (CASS Version 3.0) with the Gaussian Ray Bundle Model (GRAB Version 2.0)”, NUWC-NPT Technical Document 11,231, Naval Undersea Warfare Center Division, Newport, RI, 1 June (UNCLASSIFIED).

McGrath, J.R. (1971). “Scaling Laws for Underwater Exploding Wires,” J. Acoust. Soc. Am. 50, 1030-1033 (UNCLASSIFIED).

Urick, R.J. (1983). Principles of Underwater Sound for Engineers, McGraw-Hill, NY (first edition: 1967, second edition: 1975) (UNCLASSIFIED).

Weston, D.E. (1960). “Underwater Explosions as Acoustic Sources,” Proc. Phys. Soc. 76, 233 (UNCLASSIFIED).

# APPENDIX B: MARINE MAMMAL DENSITY AND DEPTH DITRIBUTION FOR THE MARIANA ISLANDS RANGE COMPLEX

This page intentionally left blank**.**

Marine mammal species occurring in the western Pacific near the Marianas include baleen whales (mysticetes), toothed whales (odontocetes), seals (carnivores commonly referred to as pinniped) and the dugong (sirenian). Baleen and toothed whales, collectively known as cetaceans, spend their entire lives in the water and spend most of the time (>90% 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% of the time because their ears are nearly always below the water's surface. Seals and sea lions (pinnipeds) spend significant amounts of time out of the water during breeding, molting and hauling out periods. In the water, pinnipeds spend varying amounts of time underwater, as some species regularly undertake long, deep dives (e.g., elephant seals) and others are known to rest at the surface in large groups for long amounts of time (e.g., California sea lions). When not actively diving, pinnipeds at the surface often orient their bodies vertically in the water column and often hold their heads above the water surface. Consequently, pinnipeds may not be exposed to underwater sounds to the same extent as cetaceans. Dugongs 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% of the time.

For the purposes of this analysis, we have adopted a conservative approach to underwater noise and marine mammals:

- Cetaceans – assume 100% of time is spent underwater and therefore exposed to noise
- Pinnipeds – adjust densities to account for time periods spent at breeding areas, haulouts, etc.; but for those animals in the water, assume 100% of time is spent underwater and therefore exposed to noise
- Sirenians – assume 100% of time is spent underwater and therefore exposed to noise

This document is organized into taxonomic categories: mysticetes, odontocetes, carnivores (pinnipeds), and sirenian. Nomenclature was adopted from the Integrated Taxonomic Information System (www.itis.gov).

## B.1 DENSITY

The Mariana Islands have not been extensively surveyed for marine mammals. The Marine Resources Assessment for the Marianas Operating Area (DoN, 2005) listed 20 species of marine mammal as regularly occurring in the area, with 12 additional species considered "rare" or "extralimital" (see Table 3-1, DoN, 2005).

A vessel survey was conducted in January-April 2007 specifically to determine marine mammal abundance and densities in the Mariana archipelago (SRS-Parsons et al., 2007). Densities were derived for 16 species/species groups based on analysis of data collected during this survey (Table 3-5 in SRS-Parsons et al., 2007), and provided to SAIC as GFI. The authors of the report indicate that "abundance and density estimates for those species analyzed are underestimated" because there was no correction for animals below the water's surface and/or not detected. These densities have been included in this document exactly as provided in the report. Conditions during the surveys were marginal, with higher than desired sea states. Likely due to these conditions, cryptic species (beaked whales, Kogia sp) were not seen at all.

Densities for species known to occur regularly or whose distributions likely encompass the Marianas (those having regular or rare occurrence), and which were not seen during the 2007 survey effort, were extrapolated by SAIC from other Pacific Ocean geographic areas and referenced appropriately. Note that these extrapolated densities are likely not underestimates of density because correction factors were included in analysis (e.g., Ferguson and Barlow, 2003: Barlow, 2006).

Marine mammal densities and other pertinent information are presented in Table B-1 and are bolded in the text. The Mariana Survey area and the MIRC are depicted in Figure B-1.

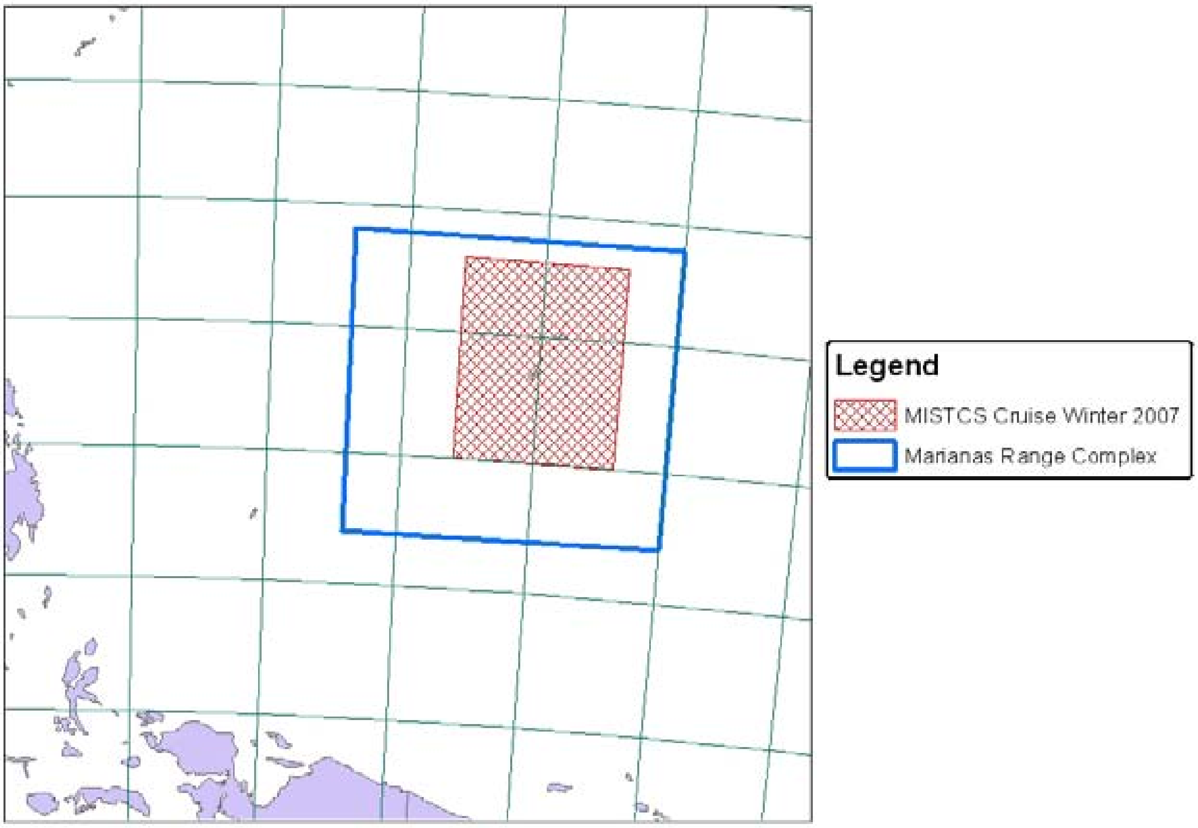


**Figure B-1. MIRC Study Area and the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) study area.**

## Table B-1. Summary of Marine Mammal Species in the MIRC

| Common Name | Scientific Name | Status | Density/km$^2$ | Source | Notes |
|---|---|---|---|---|---|
| **MYSTICETES** | | | | | |
| Blue whale | *Balaenoptera musculus* | E | 0.0001 | Ferguson and Barlow, 2003 | |
| Fin whale | *B. physalus* | E | 0.0003 | Ferguson and Barlow, 2003 | |
| Sei whale | *B. borealis* | E | 0.00029 | SRS-Parsons et al., 2007 | |
| Bryde's whale | *B. edeni* | | 0.00041 | SRS-Parsons et al., 2007 | |
| Sei/Bryde's whale | *B. borealis/edeni* | | 0.000056 | SRS-Parsons et al., 2007 | |
| Minke whale | *B. acutorostrata* | | 0.0004 | SRS-Parsons et al., 2007;<br>Ferguson and Barlow, 2003 | several acoustic detections in winter 2007; no visual observations; density from Ferguson and Barlow (2003) |
| Unidentified Balaenopterid | *Balaenoptera sp.* | | 0.00012 | SRS-Parsons et al., 2007 | |
| Humpback whale | *Megaptera novaeangliae* | E | 0.0069 | Ferguson and Barlow, 2003;<br>SRS-Parsons et al., 2007 | applicable for Oct-May only (not expected in Jun-Sep); Marianas may be within winter breeding range; one sighting and several acoustic detections in winter 2007 |
| **ODONTOCETES** | | | | | |
| Sperm whale | *Physeter catodon* | E | 0.00123 | SRS-Parsons et al., 2007 | |
| Pygmy and dwarf sperm whales | *Kogia sp.* | | 0.0078 | Barlow, 2006 | |
| Cuvier's beaked whale | *Ziphius cavirostris* | | 0.0052 | Barlow, 2006 | |
| Blainville's beaked whale | *Mesoplodon densirostris* | | 0.0009 | Barlow, 2006 | |
| Gingko-toothed beaked whale | *M. ginkgodens* | | 0.0005 | Ferguson and Barlow, 2003 | |
| Longman's beaked whale | *Indopacetus pacificus* | | 0.0003 | Barlow, 2006 | |
| Killer whale | *Orcinus orca* | | 0.0002 | Barlow, 2006 | |
| False killer whale | *Pseudorca crassidens* | | 0.00111 | SRS-Parsons et al., 2007 | |
| Pygmy killer whale | *Feresa attenuata* | | 0.00014 | SRS-Parsons et al., 2007 | |
| Short-finned pilot whale | *Globicephala macrorhynchus* | | 0.00159 | SRS-Parsons et al., 2007 | |
| Risso's dolphin | *Grampus griseus* | | 0.0106 | Miyashita, 1993 | |

**Table B-1. Summary of Marine Mammal Species in the MIRC (cont'd)**

| Common Name | Scientific Name | Status | Density/km$^2$ | Source | Notes |
|---|---|---|---|---|---|
| Melon-headed whale | *Peponocephala electra* | | 0.00428 | SRS-Parsons et al., 2007 | |
| Fraser's dolphin | *Lagenodelphis hosei* | | 0.0069 | Barlow, 2006 | |
| Bottlenose dolphin | *Tursiops truncatus* | | 0.00021 | SRS-Parsons et al., 2007 | |
| Rough-toothed dolphin | *Steno bredanensis* | | 0.00029 | SRS-Parsons et al., 2007 | |
| Bottlenose/Rough-toothed | *Tursiops/Steno* | | 0.00009 | SRS-Parsons et al., 2007 | |
| Short-beaked common dolphin | *Delphinus delphis* | | 0.0021 | Ferguson and Barlow, 2003 | |
| Striped dolphin | *Stenella coeruleoalba* | | 0.00616 | SRS-Parsons et al., 2007 | |
| Spinner dolphin | *S. longirostris* | | 0.00314 | SRS-Parsons et al., 2007 | |
| Pantropical spotted dolphin | *S. attenuata* | | 0.0226 | SRS-Parsons et al., 2007 | |
| Unidentified delphinid | | | 0.00107 | SRS-Parsons et al., 2007 | |

## B.2 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 and by using a tag that either must be implanted in the skin/blubber in some manner or adhere to the skin. There is slightly more data for some pinnipeds, as they can be tagged while on shore during breeding or molting seasons and the tags can be glued to the pelage rather than implanted. 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 or (for pinnipeds) when the animal returns to the beach. 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.

There are somewhat suitable depth distribution data for some marine mammal species. Sample sizes are usually extremely small, nearly always fewer than 10 animals total and often only 1 or 2 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.

Depth distribution information was researched by SAIC, and is included for those species for which a density is available for the Marianas region, either from the 2007 survey or extrapolated from elsewhere. Depth info is bolded in text. Detailed depth information compiled by SAIC for marine mammal species in the MIRC Study Area for which densities are available is also included in the tables at the end of this appendix.

## B.3 DENSITY AND DEPTH DISTRIBUTION COMBINED

Density is nearly always reported for an area, e.g., animals/square kilometer (m2). Analyses of survey results using Distance Sampling techniques usually include correction factors for animals at the surface but not seen as well as animals below the surface and not seen. Therefore, although the area (e.g., km2) 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, even though this is likely rarely true. Marine mammals are usually clumped in areas of greater importance, for example, areas of high productivity, lower predation, safe calving, etc. Density can occasionally be calculated for smaller areas that are used regularly by marine mammals, but more often than not there are insufficient data to calculate density for small areas. Therefore, assuming an even distribution within the prescribed area remains the norm.

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, with some species capable of regular deep dives (>800 meters [m]) and others diving to <200 m, regardless of the bottom depth. Assuming that all species are evenly distributed from surface to 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 three-dimensional density estimate is possible. These 3-D estimates allow more accurate modeling of potential marine mammal exposures from specific noise sources.

## B.4 MYSTICETES

### B.4.1 Blue whale, Balaenoptera musculus—Rare

Between two and five stocks of blue whales exist in the North Pacific, with the best known and studied population inhabiting the eastern North Pacific (Sears, 2002); far less information exists for the stock(s) in the western North Pacific. Blue whales are considered rare in the Marianas region (DoN, 2005), but their distribution range likely overlaps with the area. No blue whales were seen during the 2007 vessel survey (SRS-Parsons et al., 2007). Density for blue whales in the Eastern Tropical Pacific (ETP) ranged from 0.0001 to 0.0035/km2 (Ferguson and Barlow, 2003). Due to the rare status and complete lack of sightings in the Marianas, the lowest density (0.0001/km2) reported for the ETP will be used for this area and is applicable year round.

Blue whales feed on euphausiid crustaceans, including Euphausia sp and Thysanoessa sp (Sears, 2002). They have been documented feeding near the surface as well as at depths exceeding 140 m (Croll et al., 2001a). Data from southern California and Mexico showed that whales dived to >100 m for foraging; once at depth, vertical lunge-feeding often occurred (lunging after prey). Lunge-feeding at depth is energetically expensive and likely limits the deeper diving capability of blue whales. Foraging dives were deeper than traveling dives; traveling dives were generally to ~ 30 m. Typical dive shape was somewhat V-shaped, although the bottom of the V was wide to account for the vertical lunges at bottom of dive. Blue whales also have shallower foraging dives. Best info for % of time at depth is from Lagerquist et al (2000; Figure 2): 78% in 0-16 m, 9% in 17-32 m, 13% in >32 m; most dives were to <16 m and 96-152 m ranges, but only 1.2% of total time was spent in deeper range.

### B.4.2 Fin whale, Balaenoptera physalus—Rare

Fin whales occur in all oceans in temperate to polar latitudes, and many populations undergo seasonal migrations, from low latitude breeding areas to higher latitude feeding areas (Aguilar, 2002). Fin whales are considered rare in the Marianas region (DoN, 2005), but their distribution range likely overlaps with the area. No fin whales were seen during the 2007 vessel survey (SRS-Parsons et al., 2007). Density for fin whales in the ETP ranged from 0.0003 to 0.0054/km2 (Ferguson and Barlow, 2003). Due to the rare status and complete lack of sightings in the Marianas, the lowest density (0.0003/km2) reported for the ETP will be used for this area and is applicable year round.

Fin whales feed on planktonic crustaceans, including Thysanoessa sp and Calanus sp, as well as schooling fish including herring, capelin and mackerel (Aguilar, 2002). Depth distribution data from the Ligurian Sea in the Mediterranean are the most complete (Panigada et al., 2003), and showed differences between day and night diving; daytime dives were shallower (<100m) and night dives were deeper (>400m), likely taking advantage of nocturnal prey migrations into shallower depths; this data may be atypical of fin whales elsewhere in areas where they do not feed on vertically-migrating prey. Goldbogen et al. (2006) studied fin whales in southern California and found that 60% of total time was spent diving, with the other 40% near surface (<50m); dives were to >225 m and were characterized by rapid gliding ascent, foraging lunges near the bottom of dive, and rapid ascent with flukes. Dives were somewhat V-shaped although the bottom of the V was wide. Based on this information, percentage of time at depth levels is estimated as 40% at <50m, 20% at 50-225 m (covering the ascent and descent times) and 40% at >225 m.

### B.4.3 Sei whale, Balaenoptera borealis—Regular

Sei whales occur in all oceans from subtropical to sub-arctic waters, and can be found on the shelf as well as in oceanic waters (Reeves et al., 2002). Sei whales were considered extralimital in the Marianas area (DoN, 2005), however they were visually and acoustically located during the 2007 vessel survey (SRS-Parsons et al., 2007). Density was calculated as 0.00029/km2, which is applicable year round.

Sei whales feed on copepods, amphipods, euphausiids, shoaling fish, and squid (Horwood, 2002). Stomach content analysis indicated that they are likely skim feeders that take in swarms in low density. Pauly et al. (1998) used stomach contents and morphological and behavioral information to standardize diet compositions for several marine mammals; based on this analysis, sei whales rely on large invertebrates for 80% of their diet, with the remaining components being small squids, small pelagics, mesopelagics and miscellaneous fishes. There have been no depth distribution data collected on this somewhat elusive species. In lieu of depth data, minke whale depth distribution percentages will be extrapolated to sei whales: 53% at <20 m and 47% at 21-65 m.

### B.4.4 Bryde's whale, *Balaenoptera edeni*—Regular

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). Bryde's whales were the most frequently sighted mysticete during the 2007 vessel survey (SRS-Parsons et al., 2007). Density was calculated as 0.00041/km2, which is applicable year round.

Bryde's whales feed on pelagic schooling fish, small crustaceans including euphausiids and copepods and cephalopods (Kato, 2002). Diet composition analyzed by Pauly et al. (1998) indicated 40% of the diet was large zooplankton with 60% composed of small pelagics, mesopelagics and miscellaneous fishes. 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: 53% at <20 m and 47% at 21-65 m).

### B.4.5 Sei / Bryde's whale, Balaenoptera borealis / edeni—Regular

Bryde's and sei whales are difficult to differentiate at-sea, and many sightings cannot be definitively recorded as one or the other species during survey efforts. The density for this combined species group from the 2007 vessel survey effort was 0.000056/km2 (SRS-Parsons et al., 2007), which is applicable year round.

There are no depth data for either of these mysticete species, so minke whale depth distribution percentages will be extrapolated to this group: 53% at <20 m and 47% at 21-65 m.

### B.4.6 Minke whale, Balaenoptera acutorostrata—Regular

Minke whales are the smallest of all mysticete whales, and often exhibit cryptic behaviors in tropical waters making them difficult to see. They are widely distributed in the north Atlantic and Pacific (Perrin and Brownell, 2002). Minke whales can be found in near shore shallow waters and have been detected acoustically in offshore deep waters. Most minke whale populations inhabit colder waters in summer and migrate to warmer regions in winter. Minke whales were considered rare in the Marianas (DoN, 2005), and they were not sighted during the 2007 vessel survey (SRS-Parsons et al., 2007). However, they were the most frequent acoustically detected mysticete, with 29 localizations near the Marianas Trench. Density for minke whales in the ETP ranged from 0.0002 to 0.0004/km2 (Ferguson and Barlow, 2003). Due to the relatively high number of acoustic detections, the highest density (0.0004/ km2) reported for the ETP will be used for this area.

Minke whales feed on small schooling fish and krill, and are the smallest of all balaenopterid species which may affect their ability to dive. The only depth distribution data for this species were 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) was 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 % of time at depth are as follows: 53% at <20 m and 47% at 21-65 m.

### B.4.7 Unidentified Balaenopterid, *Balaenoptera* sp.

Balaenopterid whale sightings that could not be identified to individual species were analyzed as a species group, unidentified balaenopterids. The density for this combined species group from the 2007 vessel survey effort was 0.00012/km2 (SRS-Parsons et al., 2007), which is applicable year round.

The depth distribution for fin whales will be extrapolated to this species group. Therefore, 40% at <50m, 20% at 50-225 m and 40% at >225 m.

### B.4.8 Humpback whale, *Megaptera novaeangliae*—Regular

Humpback whales are found in all oceans, in both coastal and continental waters as well as near seamounts and deep water during migration (Reeves et al., 2002). Some populations have been extensively studied (e.g., Hawaii, Alaska, Caribbean), and details about migratory timing, feeding and breeding areas are fairly well known. Humpbacks are highly migratory, feeding in summer at mid and high latitudes and calving and breeding in winter in tropical or subtropical waters. Humpback whales are regular visitors to the Marianas region (DoN , 2005). Distribution and abundance of humpbacks in this area is still largely unknown, but they are not expected in the area from June-September. They were observed only once during the 2007 vessel survey, but were the second most frequent acoustically detected mysticete (SRS-Parsons et al., 2007). The acoustic data (singing males) may indicate that the area around Saipan is an active breeding site. Density for humpback whales in the ETP ranged from 0.0001-0.0069/km2 (Ferguson and Barlow, 2003) and 0.2186/km2 for Hawaii inshore waters (during peak breeding season; Mobley et al., 2001). The Hawaii breeding population is well studied regarding population size and timing, and there is no indication that the Marianas represent a similar size breeding area. Therefore, the highest density (0.0069/km2) reported for the ETP will be used for this area.

Humpback whales feed on pelagic schooling euphausiids and small fish including capelin, herring and mackerel (Clapham, 2002). Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (55%) was large zooplankton with 15% composed of small pelagics and 30% miscellaneous fishes. Like other large mysticetes, humpback whales are a “lunge feeder” taking advantage of dense prey patches and engulfing as much food as possible in a single gulp. They also blow nets, or curtains, of bubbles around or below prey patches to concentrate the prey in one area, then lunge with mouths open through the middle. Dives appear to be closely correlated with the depths of prey patches, which vary from location to location. In the north Pacific, most dives were of fairly short duration (<4 min) with the deepest dive to 148 m (southeast Alaska; Dolphin, 1987a), while whales observed feeding on Stellwagen Bank in the North Atlantic dove to <40 m (Hain et al., 1995). Depth distribution data collected at a feeding area in Greenland resulted in the following estimation of depth distribution: 37% of time at <4 m, 25% at 4-20 m, 7% at 21-35m, 4% at 36-50 m, 6% at 51-100 m, 7% at 101-150 m, 8% at 151-200 m, 6% at 201-300 m, and <1% at >300 m (Dietz et al., 2002). The area near the Marianas may be part of a humpback whale breeding area, however, so non-feeding depth distributions collected by Baird et al. (2000a) in Hawaii are likely more appropriate: 40% of time in 0-10 m, 27% in 11-20 m, 12% in 21-30 m, 4% in 31-40 m, 3% in 41-50 m, 2% in 51-60 m, 2% in 61-70 m, 2% in 71-80 m, 2% in 81-90 m, 2% in 91-100 m, 1% in 101-110 m, 1% in 111-120 m, 1% in 121-130 m, 1% in 131-140 m, and <1% in <140 m depth.

### B.4.9 North Pacific right whale, Eubalaena japonica—Rare

North Pacific right whales range across the northern Pacific, from the Bering Sea south to Japan in the west and California in the east. They occur mostly in coastal and shelf waters but have been sighted well offshore (Reeves et al., 2002). Despite international protection, the species has not recovered and remains one of the rarest of all cetaceans. Their distribution range may include the Marianas, but there is no information on population size nor is there any density applicable to the area.

## B.5 ODONTOCETES

### B.5.1 Sperm whale, *Physeter catodon*—Regular

Sperm whales are most often found in deep water, near submarine canyons, and along the edges of banks and over continental slopes (Reeves et al., 2002). Adult males range farther north than females and juvenile males which tend to inhabit waters >1,000 m deep and north to 50°N in the north Pacific. Sperm whales were the most frequently sighted mysticete during the 2007 vessel survey in the Marianas (SRS-Parsons et al., 2007). Density was calculated as 0.00123/km2, which is applicable year round.

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. Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (60%) were large squids with the remaining composition including benthic invertebrates, small squids, small pelagics, mesopelagics, and miscellaneous fishes. Some evidence suggests that sperm whales 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) of sperm whales in the Gulf of California overlapped with depth distributions (200-400 m) 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). 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 1,000-1,500m. Based on values in Table 1 (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) of 31%. Mean bottom time divided by total time (17.5/45.9) and adjusted to include the % of time at the surface between dives, yields a percentage of time at the bottom of the dive (in this case >800 m as the mean maximum depth was 840 m) of 34%. Total time in the water column descending or ascending equals duration of dive minus bottom time (37.4-17.5) or ~20 minutes. Assuming a fairly equal descent and ascent rate (as shown in the table) 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 = 2.5 minutes one direction (which correlates well with the descent/ascent rates provided) and therefore 5 minutes for both directions. Same for 201-400 m, 401-600 m and 601-800 m. Therefore, the depth distribution for sperm whales based on information in the Amano paper is: 31% in <10 m, 8% in 10-200 m, 9% in 201-400 m, 9% in 401-600 m, 9% in 601-800 m and 34% in >800 m. The percentages derived above from data in Amano and Yoshioka (2003) are in fairly close agreement with those derived from Table 1 in Watwood et al. (2006) for sperm whales in the Ligurian Sea, Atlantic Ocean and Gulf of Mexico.

### B.5.2 Pygmy (*Kogia breviceps)* and Dwarf *(K. sima)* sperm whales—Regular

Pygmy and dwarf sperm whales are very cryptic at-sea, and generally difficult to see even under the best survey conditions. No Kogia were seen during the 2007 vessel survey (SRS-Parsons et al., 2007), when survey conditions were far less than optimal. They are considered regular visitors to the area (DoN, 2005). The distribution of Kogia sp. is generally temperate to tropical and probably seaward of the continental shelf (Reeves et al., 2002). Density for dwarf and pygmy sperm whales in the ETP ranged from 0.0015-0.0269/km2 (Ferguson and Barlow, 2003) and 0.0078/km2 for Hawaii offshore (Barlow, 2006). The offshore Hawaii density (0.0078/km2) is likely more indicative for this species group in the Marianas than densities from the ETP, and will be used for this analysis.

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. Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (75-80%) were small and large squids with the remaining composition including benthic invertebrates, mesopelagics and miscellaneous fishes. There is some evidence that they 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 as 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 undertakes shallower non-foraging dives in-between deep foraging dives. Blainville’s beaked whale depth distribution data, taken from Tyack et al. (2006) and summarized in greater depth later in this document is: 26% at <2 m, 41% at 2-71 m, 2% at 72-200 m, 4% at 201-400 m, 4% at 401-600 m, 4% at 601-835 m and 19% at >838 m.

### B.5.3 Cuvier’s beaked whale, *Ziphius cavirostris*—Regular

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 therefore difficult to sight and identify. Cuvier’s were not seen during the 2007 vessel cruise (acoustic detections were not possible due to the limitations of the system at higher frequencies), but are considered regular visitors to the Marianas area based on habitat (DoN, 2005). Density for Cuvier’s beaked whales in the ETP ranged from 0.003-0.038/km2 (Ferguson and Barlow, 2003) and 0.0052/km2 for offshore Hawaii (Barlow, 2006). The offshore Hawaii density (0.0052/km2) is likely more indicative for this species in the Marianas than densities from the ETP, and will be used for this analysis.

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), deep (>1,000 m) and short-inter-ventilation (within 2-3 m 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 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 deep foraging dives (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 = 1070 m (range 689-1888 m)

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 (range 22-425 m)

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) 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 (# of 200 m depth categories between surface and 1070 m) which equals ~five min per 200 m. The five-minute value was applied to each 200 m depth category from 400-1070 m; for the 2-220 m 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% at <2 m, 29% at 2-220 m, 4% at 221-400 m, 4% at 401-600 m, 4% at 601-800 m, 5% at 801-1070 m and 27% in >1070 m.

### B.5.4 Blainville's beaked whale, *Mesoplodon densirostris*—Regular

Blainville's are distributed circumglobally in tropical and warm temperate waters (Pitman, 2002b). Very little is known about the behavior of this species, as they are cryptic and difficult to sight at-sea. Blainville's were not seen during the 2007 vessel cruise (acoustic detections were not possible due to the limitations of the system at higher frequencies), but are considered regular visitors to the Marianas area based on habitat (DoN, 2005). Density for Blainville's beaked whales in the ETP ranged from 0.0005-0.0013/km2 (Ferguson and Barlow, 2003) and 0.0009/km2 for offshore Hawaii (Barlow, 2006). The offshore Hawaii density (0.0009/km2) is likely more indicative for this species in the Marianas than densities from the ETP, and will be used for this analysis.

This species feeds primarily on mesopelagic squid and some fish, with most prey likely caught at >200 m (Pitman, 2002b). Like other beaked whales, they are believed to be suction feeders. Dive information has been collected on Blainville's beaked whales 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 deep foraging dives (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 (range 640-1251 m)

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 (range 20-240)

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) 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 depth categories between surface and 838 m), which equals 1.7 min per 70 m. The 1.7 min value was applied to each 70 m depth category from 72-838 m; for the 2-71 m 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% at <2 m, 41% in 2-71 m, 2% at 72-200 m, 4% at 201-400 m, 4% at 401-600 m, 4% at 601-835 m, and 19% at >835 m.

### B.5.5 Ginkgo-toothed beaked whale, *Mesoplodon ginkgodens*—Rare

Ginkgo-toothed beaked whales are distributed in warm temperate and tropical waters of the Pacific and Indian oceans (Pitman, 2002b). They were not seen during the 2007 vessel cruise (acoustic detections were not possible due to the limitations of the system at higher frequencies), but are considered rare visitors to the Marianas area based on habitat (DoN, 2005). Density for ginkgo-toothed beaked whales in the ETP ranged from 0.0005-0.0064/km2 (Ferguson and Barlow, 2003). Due to the rare status and complete lack of sightings in the Marianas, the lowest density (0.0005/ km2) reported for the ETP will be used for this area and is applicable year round.

There are no depth distribution data for this species. Like other Mesoplodon, they are believed to feed primarily on mesopelagic squid and some fish, with most prey likely caught at >200 m, and they are probably suction feeders. Depth distribution for Mesoplodon densirostris will be extrapolated to this species: 26% at <2 m, 41% in 2-71 m, 2% at 72-200 m, 4% at 201-400 m, 4% at 401-600 m, 4% at 601-835 m, and 19% at >835 m.

### B.5.6 Hubbs' beaked whale, *Mesoplodon carlhubbsi*—Extralimital

Hubb's beaked whales are known only from temperate waters of the North Pacific, mainly along the west coast of North America (Pitman, 2002b), and there are no known occurrences in the Marianas. Likely occurrence is considered extralimital (DoN, 2005) due to it known preference for colder water. There is no density.

### B.5.7 Longman's beaked whale, *Indopacetus pacificus*—Regular

Longmans's beaked whale is found in offshore deep waters of the continental slope (200-2,000 m) or deeper (Pitman, 2002a). Very little is known about the behavior of this species, as they are cryptic and difficult to sight at-sea. Longman's were not seen during the 2007 vessel cruise (acoustic detections were not possible due to the limitations of the system at higher frequencies), but are considered regular visitors to the Marianas area based on habitat (DoN, 2005). Density for Longman's beaked whales in the ETP ranged from 0.0002-0.003km2 (Ferguson and Barlow, 2003) and 0.0003/km2 for offshore Hawaii (Barlow, 2006). The offshore Hawaii density (0.0003/km2) is likely more indicative for this species in the Marianas than densities from the ETP, and will be used for this analysis.

Beaked whales feed primarily on mesopelagic squid and some fish, with most prey likely caught at >200 m (Pitman, 2002b). Most are believed to be suction feeders. There are no depth distribution data for Longman's beaked whales; therefore the depth distribution for Cuvier's beaked whales will be extrapolated to Longman's: 27% at <2 m, 29% at 2-220 m, 4% at 221-400 m, 4% at 401-600 m, 4% at 601-800 m, 5% at 801-1070 m and 27% in >1070 m.

### B.5.8 Killer whale, *Orcinus orca*—Regular

Killer whales are one of the most widely distributed mammal species in the world and are found in all oceans (Ford, 2002). There were no sightings during the 2007 vessel survey (SRS-Parsons et al., 2007), but they are considered a regular visitor to the Marianas region (DoN, 2005).

Density for killer whales in the ETP ranged from 0.0001-0.0004km2 (Ferguson and Barlow, 2003) and 0.000/km2 for offshore Hawaii (Barlow, 2006). The offshore Hawaii density (0.0002/km2) is likely more indicative for this species in the Marianas than densities from the ETP, and will be used for this analysis.

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, and males dove more frequently and more often to depths >100 m 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 ~4% of time at depths >30 m and 96% of time at depths 0-30 m.

### B.5.9 False killer whale, *Pseudorca crassidens*—Regular

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. False killer whales were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00111/km2 (SRS-Parsons et al., 2007), which is applicable year round.

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 in near-shore Hawaiian waters. In lieu of other information, the depth distribution for killer whales will be extrapolated to this species: 4% of time at depths >30 m and 96% of time at depths 0-30 m.

### B.5.10Pygmy killer whale, *Feresa attenuata*—Regular

Pygmy killer whales are known primarily from tropical to sub-tropical waters (Donahue and Perryman, 2002). They were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007) and density was calculated as 0.00014/km2 (SRS-Parsons et al., 2007), which is applicable year round.

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% of time at depths >30 m and 96% of time at depths 0-30 m.

### B.5.11 Short-finned pilot whale, *Globicephala macrorhynchus*—Regular

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). Short-finned pilot whales were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00159/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Short-finned pilot whales feed on squid and fish. Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (60%) was small and large squids with the remaining composition including small pelagics, mesopelagics and miscellaneous fishes. Stomach content analysis of pilot whales in the southern California Bight consisted entirely of cephalopod remains (Sinclair, 1992). The most common prey item identified by Sinclair (1992) was Loligo opalescens, which has been documented in spawning concentrations at depths of 20-55 m. Stomach content analysis from the closely related long-finned pilot whale (Globicephala melas) from the U.S mid-Atlantic coast demonstrated preference for cephalopods as well as a relatively high diversity of prey species taken (Gannon et al., 1997). Stomach content analysis from G. melas off New Zealand did not show the same diversity of prey (Beatson et al., 2007) which indicates that pilot whales may differ significantly in prey selection based on geographic location. The only study conducted on short-finned pilot whales in Hawaii has not been published in any detail (Baird et al., 2003b), but an abstract indicated that there were significant differences between day and night diving; dives of >100m were far more frequent at night, likely to take advantage of vertically-migrating prey; night dives regularly went to 300-500 m. Deepest dives were during the day, however, perhaps because prey was deeper. A diving study on G. melas also showed marked differences in daytime and nighttime diving in studies in the Ligurian Sea (Baird et al., 2002b), but there was no information on percentage of time at various depth categories. A study following two rehabilitated and released long-finned pilot whales provides a breakdown of percentage of time at depth distribution for two whales (Nawojchik et al., 2003), although this data may be skewed due to the unique situation. Heide-Jorgensen et al. (2002) studied diving behavior of long-finned pilot whales near the Faroe Islands in the north Atlantic. Most diving activity occurred at depth of less than 36 m and >90% of dives were within 12-17 m. Based on this information, the following are estimates of time at depth for both species of pilot whale: 60% at <7 m, 36% at 7-17 m and 4% at 18-828 m.

### B.5.12 Risso's dolphin, *Grampus griseus*—Regular

This species is known from tropical and warm temperate oceans, primarily in waters with surface temperatures between 50 and 82˚F (Reeves et al., 2002). They are mostly found in water depths from 400-1,000 m but are also known from the continental shelf. Risso's dolphin is considered a regular visitor to the Marianas region (DoN, 2005), although none were seen during the 2007 vessel survey (SRS-Parsons et al., 2007). Density for Risso's dolphins in the ETP ranged from 0.0005 to 0.3358/km2 (Ferguson and Barlow, 2003) and 0.0106 for the western Pacific (Miyashita, 1993). The western Pacific density (0.0106/km2) is likely more indicative for this species in the Marianas than densities from the ETP, and will be used for this analysis.

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 Gulf of Mexico 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 and 975 m 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.

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% at <50 m, 15% at 51-200 m, 15% at 201-400 m, 10% at 401-600 m and 10% at >600 m.

### B.5.13 Melon-headed whale, *Peponocephala electra*—Regular

Melon-headed whales are found worldwide in deep, offshore tropical and subtropical waters (Perrin, 2002c). They were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00428/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Melon-headed whales feed on squid, fish and occasionally crustaceans in the water column (Perrin, 2002c). Their prey is known to occur at depths to 1,500 m, although there is no direct evidence that the whales feed to that depth. Stomach content analysis suggests that they feed on prey similar to Fraser's dolphins (Jefferson and Barros, 1997). Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (70%) was small and large squids with the remaining composition including small pelagics, mesopelagics and miscellaneous fishes. There is not depth distribution data for this species; the depth distribution for Fraser's dolphins will be extrapolated to melon-headed whales: Daytime, 100% at 0-50 m; Nighttime, 100% at 0-700 m.

### B.5.14 Fraser's dolphin*, Lagenodelphis hosei*—Regular

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) in most areas. Fraser's dolphin is considered a regular visitor to the Marianas region (DoN, 2005), although none were seen during the 2007 vessel survey (SRS-Parsons et al., 2007). Density for Fraser's dolphins in the ETP ranged from 0.005 to 0.1525/km2 (Ferguson and Barlow, 2003) and 0.0069 for Hawaii offshore (Barlow, 2006). The offshore Hawaii density (0.0069/km2) is likely more indicative for this species in the Marianas than densities from the ETP, and will be used for this analysis.

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, 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% at 0-50 m; Nighttime, 100% at 0-700 m.

### B.5.15 Common bottlenose dolphin, *Tursiops truncatus*—Regular

Bottlenose dolphins are distributed in all oceans from temperate to tropical latitudes. Bottlenose dolphins were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00021/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Bottlenose dolphins feed on a large variety of fish and squid (Wells and Scott, 2002). Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (60%) was miscellaneous fishes with the remaining composition including small and large squids and small pelagics. 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) 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 of water surface; maximum dive depth was greater than 150 m and there was no apparent diurnal pattern. Stomach content analysis from Brazil indicated that small and medium-sized cephalopods were 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 depth, with deep dives (>100 m) occurring exclusively at night. Dives during the day were to shallower than at night, with 90% of all dives to within 50 m 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% at <50 m, 4% at >50 m; Nighttime: 51% at <50 m, 8% at 50-100 m, 19% at 101-250 m, 13% at 251-450 m and 9% at >450 m. Data on time spent at the surface were not published; therefore surface time was included in the least shallow depth category published.

### B.5.16 Indo-Pacific bottlenose dolphin, *Tursiops aduncus*—Extralimital

The Indo-Pacific bottlenose dolphin is distributed in coastal waters of the Indian Ocean and western Pacific Ocean, and is not generally associated with offshore islands (Wells and Scott, 2002). Their occurrence in the Marianas would be considered extralimital and there is no density.

### B.5.17 Rough-toothed dolphin, *Steno bredanensis*—Regular

Rough-toothed dolphins are distributed in warm temperate to tropical waters of all oceans. They were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00029/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Rough-toothed dolphins feed on fish and cephalopods, both oceanic and coastal species (Jefferson, 2002b). Diet composition analyzed by Pauly et al. (1998) indicated that the diet was variable including miscellaneous fishes, small pelagics, small and large squids, and benthic invertebrates. 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 (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% at 0-70 m.

### B.5.18 Bottlenose/rough-toothed dolphin, *Tursiops/Steno*—Regular

Sightings of dolphins during the 2007 vessel survey that could not be identified to species, but which were positively identified as either bottlenose or rough-toothed dolphins, were analyzed as this species group. Density was calculated as 0.00009/km2 (SRS-Parsons et al., 2007), which is applicable year round.

The depth distribution data for rough-toothed dolphins will be used for this species group as it represents a more conservative data set: 100% at 0-70 m.

### B.5.19 Short-beaked common dolphin, *Delphinus delphis*—Rare

Short-beaked common dolphins are found in continental shelf waters of the Atlantic and Pacific, as well as pelagic waters of the eastern tropical Pacific and Hawaii (Reeves et al., 2002; Perrin, 2002b). Common dolphins were not seen or detected acoustically during surveys in 2007 (SRS-Parsons et al., 2007). Density for common dolphins in the ETP ranged from 0.0021 to 1.9112/km2 (Ferguson and Barlow, 2003). Due to the rare status and complete lack of sightings in the Marianas, the lowest density (0.0021/ km2) reported for the ETP will be used for this area.

Common dolphins feed on small schooling fish as well as squid and crustaceans, and varies on habitat and location. They appear to take advantage of the deep scattering layer at dusk and during early night-time hours, when the layer migrates closer to the water surface, as several prey species identified from stomach contents are known to vertically migrate (e.g., Ohizumi et al., 1998; Pusineri et al., 2007). Perrin (2002b) reports foraging dives to 200 m, but there have been no detailed studies of diving behavior. Based on this limited information, depth distribution is estimated as: 100% at 0-200m.

### B.5.20 Striped dolphin, *Stenella coeruleoalba*—Regular

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). They were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00616/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Striped dolphins feed on pelagic fish and squid and may dive during feeding to depths exceeding 200 m (Archer, 2002). Diet composition analyzed by Pauly et al. (1998) indicated that the diet was variable including mesopelagics, miscellaneous fishes, small and large squids, small pelagics, and benthic invertebrates. However, studies are rare on this species. Stomach content remains from three dolphins in the Mediterranean 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 (Ozturk et al., 2007). They appear to be opportunistic feeders, as stomach samples from the Ligurian Sea included cephalopods, crustaceans and bony fishes (Wurtz and Marrale, 1993). 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. One study on pantropical spotted dolphins in Hawaii contains dive information (Baird et al., 2001a). The biggest differences recorded were in the increase in dive activity at night. During the day, 89% of time was spent within 0-10 m, most of the rest of the time was 10-50 m, and the deepest dive was to 122 m. At night, only 59% of time was spent from 0-10 m and the deepest dive was to 213 m; dives were especially pronounced at dusk. For activities conducted during daytime-only, the depth distribution would be 89% at 0-10 m and 11% at 11-50 m, with <1% at 51-122 m. For activities conducted over a 24-hour period, the depth distribution needs to be modified to reflect less time at surface and deeper depth dives; 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m.

### B.5.21 Spinner dolphin, *Stenella longirostris*—Regular

Spinner dolphins are found in tropical and subtropical waters of all oceans (Perrin, 2002d). They were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.00314/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Spinner dolphins feed on small mesopelagic fishes, and likely feed at night (Perrin, 2002d; Benoit-Bird and Au, 2003). Diet composition analyzed by Pauly et al. (1998) indicated a diet of mesopelagics, small and large squids and miscellaneous fishes. 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 ~250 m (Dolar et al., 2003). There was also evidence that they preyed on non-vertical migrating species found at ~400 m, and that they likely did not have the same foraging range as Fraser's dolphins in the same area (to 600 m). 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 fishes). Mean depth of spinner dolphins was always within 10 m 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) waters. Prey distribution during the day is estimated at 400-700 m. Based on these data, the following are very rough order estimates of time at depth: Daytime: 100% at 0-50 m; Nighttime: 100% at 0-400 m.

### B.5.22 Pantropical spotted dolphin – *Stenella attenuate*—Regular

Pantropical spotted dolphins are distributed worldwide in tropical and subtropical waters, with distribution extending from 40°N to 40°S (Perrin, 2002a). They were sighted during the 2007 vessel survey (SRS-Parsons et al., 2007), and detected acoustically. Density was calculated as 0.0226/km2 (SRS-Parsons et al., 2007), which is applicable year round.

Pantropical spotted dolphins feed on small epipelagic fishes, squids and crustaceans, and may vary their preferred prey seasonally (Perrin, 2002a; Wang et al., 2003). Diet composition analyzed by Pauly et al. (1998) indicated that most of diet (70%) was miscellaneous fishes and small squids with the remaining composition including large squids and small pelagics. Stomach contents of dolphins collected near Taiwan indicated that the distribution of primary prey was 0-200 m at night and >300 m 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., 2001a). The biggest differences recorded were in the increase in dive activity at night. During the day, 89% of time was spent within 0-10 m, most of the rest of the time was 10-50 m, and the deepest dive was to 122 m. At night, only 59% of time was spent from 0-10 m and the deepest dive was to 213 m; dives were especially pronounced at dusk. The following depth distributions are applicable: Daytime, 89% at 0-10 m and 11% at 11-50 m, with <1% at 51-122 m; Nighttime, 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m.

### B.5.23 Unidentified delphinid

Any dolphin sighted during the 2007 vessel survey that could not be identified to species was analyzed in the broad category of unidentified delphinid (SRS-Parsons et al., 2007). Density was calculated as 0.00107/km2 (SRS-Parsons et al., 2007), which is applicable year round.

The species with the highest density in the Marianas from the 2007 vessel surveys was the pantropical spotted dolphin so the depth distribution for that species was extrapolated to this species group: Daytime, 89% at 0-10 m and 11% at 11-50 m, with <1% at 51-122 m; Nighttime, 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m.

## B.6 CARNIVORES (Pinnipeds)

### B.6.1 Hawaiian monk seal, *Monachus schauinslandi*—Extralimital

Monk seals are distributed throughout the Hawaiian Island Archipelago and very occasionally south of the Archipelago at Wake Island, Johnston Atoll and Palmyra Atoll (Gilmartin and Forcada, 2002). Monk seals have never been seen in the Marianas region, and there is no density.

### B.6.2 Northern elephant seal, *Mirounga angustirostris*—Extralimital

Northern elephant seals are distributed in the northeast Pacific, and have been rarely sighted in Hawaii and Japan (Hindell, 2002). They have never been seen in the Marianas region, and there is no density.

## B.7 SIRENIAN

### B.7.1 Dugong, *Dugong dugong*—Extralimital

Dugongs are distributed in tropical and subtropical coastal and island waters of the Indian and Pacific Oceans (Marsh, 2002). There have been a few extralimital sightings near Guam (DoN, 2005) but Palau (>1,700 km distant) is the closest regular occurrence of this species. There is no density.

## B.8 References

Acevedo-Gutierrez, A, DA Croll and BR Tershy. 2002. High feeding costs limit dive time in the largest whales. *Journal of Experimental Biology* 205: 1747-1753.

Aguilar, A. 2002. Fin whale. Pp. 435-438 In: WF Perrin, B Wursig and JGM 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, FI. 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, FI and WF Perrin. 1999. *Stenella coeruleoalba*. Mammalian Species 603:1-9.

Baird, RW. 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, RW, DL Webster, DJ McSweeney, AD Ligon, GS Schorr and J. Barlow. 2006a. Diving behaviour of Cuvier’s (*Ziphius cavirostris*) and Blainville’s (*Mesoplodon densirostris*) beaked whales in Hawai’i. *Canadian Journal of Zoology* 84: 1120-1128.

Baird, RW, DJ McSweeney, C Bane, J Barlow, DR Salden, LK Antoine, R LeDuc and DL Webster. 2006b. Killer whales in Hawaiian waters: information on population identity and feeding habits. *Pacific Science* 60: 523-530.

Baird, RW, DL Webster, DJ McSweeney, AD Ligon, and GS Schorr. 2005a. Diving Behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's beaked whales (*Mesoplodon densirostris*) in Hawai`i. Report prepared by Cascadia Research Collective for the Southwest Fisheries Science Center. Available from www.cascadiaresearch.org.

Baird, RW, MB Hanson and LM 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, RW, MB Hanson, EE Ashe, MR Heithaus and GJ 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 the NMFS-NMML. Available from www.cascadiaresearch.org.

Baird, RW, DJ McSweeney, MR Heithaus and GJ Marshall. 2003b. Short-finned pilot whale diving behavior: deep feeders and day-time socialites. Abstract submitted to the 15th Biennial Conference on the Biology of Marine Mammals, Greensboro, NC, December 2003. Available from www.cascadiaresearch.org.

Baird, RW, JF Borsani, MB Hanson and PL Tyack. 2002b. Diving and night-time behavior of long-finned pilot whales in the Ligurian Sea. *Marine Ecology Progress Series* 237: 301-305.

Baird, RW, AD Ligon, SK Hooker and AM Gorgone. 2001a. Subsurface and nighttime behavior of pantropical spotted dolphins in Hawai'i. *Canadian Journal of Zoology* 79: 988-996.

Baird, RW, AD Ligon and SK Hooker. 2000a. Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: a Preliminary Report. Report under contract #40ABNC050729 from the Hawaiian Islands Humpback Whale National Marine Sanctuary, Kihei, HI to the Hawaii Wildlife Fund, Paia, HI. Available from www.cascadiaresearch.org.

Bannister, JL. 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.

Baraff, LS, PJ Clapham, DK Mattila and RS Bowman. 1991. Feeding behavior of a humpback whale in low-latitude waters. *Marine Mammal Science* 7(2): 197-202.

Barlow, J. 2006. Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. *Marine Mammal Science* 22(2): 446-464.

Baumgartner, MF. 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.

Bearzi, G, RR Reeves, G Notarbartolo Di Sciara, E Politi, A Canadas, A Frantzis and B Mussi. 2003. Ecology, status and conservation of short-beaked common dolphins *Delphinus delphis* in the Mediterranean Sea. *Mammal Review* 33(3): 224-252.

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.

Beatson, E, S O'Shea and M Ogle. 2007. First report on the stomach contents of long-finned pilot whales, *Globicephala melas*, stranded in New Zealand. *New Zealand Journal of Zoology* 34: 51-56.

Bello, G. 1992b. Stomach contents of a Risso's dolphin. Do dolphins compete with fishermen and swordfish? *European Research Cetaceans* 6: 199-202.

Benoit-Bird, KJ and WWL 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, PB. 1977. Two allopatric forms of Bryde's whale off South Africa. *Report to the International Whaling Commission* (Spec Iss 1): 10-38.

Blanco C and JA 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, MA Raduan and JA 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 JA 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, AS. and LP Folkow. 1995. Daily energy expenditure in free living minke whales. *Acta Physiologica Scandinavica* 153(1): 61-6.

Clapham, PJ. 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.

Clarke, M and R Young. 1998. Description and analysis of cephalopod beaks from stomachs of six species of odontocete cetaceans stranded on Hawaiian shores. *Journal Marine Biological Association UK* 78: 623-641.

Corkeron PJ and AR 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

Croll DA, A Acevedo-Gutierrez, BR Tershy and J Urban-Ramirez. 2001a. The diving behavior of blue and fin whales: is dive duration shorter than expected based on oxygen stores? ComparativeBiochemistry and Physiology a-Molecular and Integrative Physiology 129:797-809.

Davis, RW, N Jaquet, D Gendron, U Markaida, G Bazzino and W Gillly. 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.

DoN. 2005. Marine Resources Assessment for the Marianas Operating Area. Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii. Contract # N62470-02-D-9997, CTO 0027. Prepared by Geo-Marine Incorporated, Plano, TX. Available from: www.portal.navfac.navy.mil/portal/page?_pageid=181,3986942&_dad=portal&_schema=PORTAL.

Dietz, R, J Teilmann, MP Heide Jorgensen and MK Jensen. 2002. Satellite tracking of humpback whales in West Greenland. National Environmental Research Institute, Ministry of the Environment, Denmark. NERI Technical Report 411. Available from: http://www2.dmu.dk/1_viden/2_publikationer/3_fagrapporter/rapporter/FR411.pdf.

Dolar, MLL. 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, MLL, WA Walker, GL Kooyman and WF 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.

Dolphin, WF. 1988. Foraging dive patterns of humpback whales, *Megaptera novaeangliae*, in southeast Alaska: a cost-benefit analysis. *Canadian Journal of Zoology* 66: 2432-2441.

Dolphin, WF. 1987a. Dive behavior and estimated energy expenditures of foraging humpback whales in Southeast Alaska. *Canadian J. Zoology* 65: 354-362.

Donahue, MA and WA 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 JC Goold. 2004. Diving and feeding behaviour of sperm whales (*Physeter macrocephalus*) in the northwestern Mediterranean Sea. *Aquatic Mammals* 30(3): 419-426.

Estes, JA, MT Tinker, TM Williams and DF Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. *Science* 282: 473-476.

Ferguson, MC and J Barlow. 2003. Addendum: Spatial distribution and density of cetaceans in the eastern tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-96. Southwest Fisheries Science Center Administrative Report LJ-01-04 (Addendum). Available from http://swfsc.noaa.gov.

Ford, JKB. 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, JKB, GM Ellis, LG Barrett-Lennard, AB Morton, RS Palm and KC 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.

Gales, R, D Pemberton, M Clarke and CC 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.

Gannon, DP, AJ Read, JE Craddock and JG Mead. 1997. Stomach contents of long-finned pilot whales (*Globicephala melaena*) stranded on the US mid-Atlantic coast. *Marine Mammal Science* 13(3): 405-418.

Gilmartin, WG and J Forcada. 2002. Monk seals. Pp. 756-759 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Goldbogen, JA, J Calambokidis, RE Shadwick, EM Oleson, MA McDonald and JA Hildebrand. 2006. Kinematics of foraging dives and lunge-feeding in fin whales. *Journal of Experimental Biology* 209(7):1231-1244.

Hain, JHW, SL Ellis, RD Kenney, PJ Clapham, BK Gray, MT Weinrich and IG Babb. 1995. Apparent bottom feeding by humpback whales on Stellwagen Bank. *Marine Mammal Science* 11(4): 464-479.

Hamilton, PK, GS Stone and SM Martin. 1997. Note on a deep humpback whale *Megaptera novaeangliae* dive near Bermuda. *Bulletin of Marine Science* 61(2): 491-494.

Haug, T, U Lindstrom and KT Nilssen. 2002. Variations in minke whale diet and body condition in response to ecosystem changes in the Barents Sea. *Sarsia* 87: 409-422.

Haug, T, U Lindstrom, KT Nilssen, I Rottingen and HJ Skaug. 1996. Diet and food availability for northeast Atlantic minke whales. *Report of the International Whaling Commission* 46: 371-382.

Haug, T, H Gjosaeter, U Lindstrom and KT Nilssen. 1995. Diet and food availability for northeast Atlantic minke whales during summer 1992. *ICES Journal of Marine Science* 52: 77-86.

Heide-Jorgensen MP, D Bloch, E Stefansson, B Mikkelsen, LH Ofstad and R Dietz. 2002. Diving behaviour of long-finned pilot whales *Globicephala melas* around the Faroe Islands. *Wildlife Biology* 8:307-313.

Helweg, DA and LM Herman. 1994. Diurnal patterns of behaviour and group membership of humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters. *Ethology* 98: 298-311.

Heyning, JE. 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.

Hindell, MA. 2002. Elephant seals. Pp 370-373 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Hoelzel, AR, CW Potter and PB Best. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. *Proceedings of the Royal Society of London* 265: 1177-1183.

Hoelzel, A, EM Dorsey and J Stern. 1989. The foraging specializations of individual minke whales. *Animal Behavior* 38: 786-794.

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.

Jahoda, M, C Almirante, A Azzellino, S Panigada, M Zanardelli and S Canese, S. 1999. 3D-tracking as a tool for studying behavior in Mediterranean fin whales (*Balaenoptera physalus*), p. 89, 13th Biennial Conference on the Biology of Marine Mammals.

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, TA. 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, TA and NB Barros. 1997. *Peponocephala electra*. Mammalian Species 553:1-6.

Jefferson, TA, S Leatherwood and MA 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.

Johnson, M, PT Madsen, WMX Zimmer, N Aguilar de Soto, and PL Tyack. 2004. Beaked whales echolocate on prey. *Proceedings of the Royal Society, London B* (Suppl.) 271: S383-S386.

Johnston, DW, LH Thorne and AJ Read. 2005. Fin whales and minke whales exploit a tidally driven island wake ecosystem in the Bay of Fundy. *Marine Ecological Progress Series*305: 287-295.

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. *Scientific Reports of the Whales Research Institute* 32: 1-23.

Klatsky, LJ, RS Wells and JC Sweeney. 2007. Offshore bottlenose dolphins (*Tursiops truncatu*s): Movement and dive behavior near the Bermuda Pedestal. *Journal of Mammalogy* 88(1):59-66.

Koen Alonso, M, SN Pedraza, ACM Schiavini, RNP Goodall and EA 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.

Laerm, J, F Wenzel, JE Craddock, D Weinand, J McGurk, MJ Harris, GA Early, JG Mead, CW Potter and NB Barros. 1997. New prey species for northwester Atlantic humpback whales. *Marine Mammal Science* 13(4): 705-711.

Lagerquist, BA, KM Stafford and BR Mate. 2000. Dive characteristics of satellite-monitored blue whales (*Balaenoptera musculus*) off the central California coast. *Marine Mammal Science* 16(2): 375-391.

Ligon, AD and RW 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.

Lindstrom, U and T Haug. 2001. Feeding strategy and prey selection in minke whales foraging in the southern Barents Sea during early summer. *J. Cetacean Research and Management* 3: 239-249.

London, JM. 2006. Harbor seals in Hood Canal: Predators and Prey. PhD Dissertation, University of Washington.

Madsen, PT, M Johns, N Aguilar de Soto, WMX Zimmer and P Tyack. 2005. Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*). *The Journal of Experimental Biology* 208: 181-194.

Marsh, H. 2002. Dugong. Pp. 344-347 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

McAlpine, DF. 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, DF, LD Murison and EP 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.

Miyashita, T. 1993. Distribution and abundance of some dolphins taken in the north Pacific driftnet fisheries. *Bulletin of the International North Pacific Fisheries Commission* 53(III): 435-449.

Miyazaki N and WF 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 Pres, London.

Mobley, JR, SS Spitz, RA Grotefendt, PH Forestell, AS Frankel and GB Bauer. 2001b. Abundance of Humpback Whales in Hawaiian Waters: Results of 1993-2000 Aerial Surveys. Report to the Hawaiian Islands Humpback Whale National Marine Sanctuary. Available from: http://hawaiihumpbackwhale.noaa.gov/research/HIHWNMS_Research_Mobley.pdf.

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.

Nawojchik, R, DJ St. Aubin and A Johnson. 2003. Movements and dive behavior of two stranded, rehabilitated long-finned pilot whales (*Globecephala melas*) in the Northwest Atlantic. *Marine Mammal Science* 19(1): 232-239.

Nemoto, T and A Kawamura. 1977. Characteristics of food habits and distribution on baleen whales with special reference to the abundance of north Pacific sei and Bryde's whales. *Report to the International Whaling Commission* (Special Issue 1): 80-87.

Notarbartolo-di-Sciara, G, M Zanardelli, M Jahoda, S Panigada and S Airoldi. 2003. The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. *Mammal Review* 33(2): 105-150.

Ohizumi, H, M Yoshioka, K Mori and N Miyazaki. 1998. Stomach contents of common dolphins (*Delphinus delphis*) in the pelagic western North Pacific. *Marine Mammal Science* 14(4): 835-844.

Olson, PA and SB Reilly. 2002. Pilot whales. Pp. 898-903 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Ozturk, B, A Salman, AA 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.

Panigada, S, G Pesante, M Zanardelli and S Oehen. 2003. Day and night-time behaviour of fin whales in the western Ligurian Sea. Oceans 2003, Proceedings 1: 466-471.

Panigada, S, G Notarbartolo di Sciara and MZ Panigada. 2006. Fin whales summering in the Pelagos Sanctuary (Mediterranean Sea): Overview of studies on habitat use and diving behaviour. *Chemistry and Ecology* 22(Supp.1):S255-S263.

Panigada, S, M Zanardelli, S Canese and M Jahoda. 1999. How deep can baleen whales dive? *Marine Ecology Progress Series* 187: 309-311.

Papastavrou V, SC 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.

Pauly, D, AW Trites, E Capuli and V Chrisensen. 1998. Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Science* 55: 467-481.

Perrin, WF. 2002a. Pantropical spotted dolphin. Pp. 865-867 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin. WF. 2002b. Common dolphins. Pp. 245-248 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin, WF. 2002c. Melon-headed whales. Pp. 733-735 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin, WF. 2002d. Spinner dolphin. Pp. 1174-1178 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin, WF and RL 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.

Pitman, RL. 2002a. Indo-pacific beaked whale. Pp. 615-617 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Pitman, RL. 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.

Pusineri, C, V Magnin, L Meynier, J Spitz, S Hassani and V Ridoux. 2007. Food and feeding ecology of the common dolphin (*Delphinus delphis*) in the oceanic northeast Atlantic and comparison with its diet in neritic areas. *Marine Mammal Science* 23(1): 30-47.

Reeves, RR, BS Stewart, PJ Clapham, and JA Powell. 2002. *National Audubon Society Guide to Marine Mammals of the World*. Alfred A Knopf: New York.

Richard, KR and MA Barbeau. 1994. Observations of spotted dolphins feeding nocturnally on flying fish. *Marine Mammal Science* 10(4): 473-477.

Roberts, SM. 2003. Examination of the stomach contents from a Mediterranean sperm whale found south of Crete, Greece. *Journal of the Marine Biological Association UK* 83: 667-670.

Robertson, KM and SJ Chivers. 1997. Prey occurrence in pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. *Fishery Bulletin* 95(2): 334-348.

Robison, BH and JE Craddock. 1983. Mesopelagic fishes eaten by Fraser's dolphin, *Lagenodelphis hosei*. *Fishery Bulletin* 81(2): 283-289.

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, RA 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, MB, GJ Pierce, J Herman, A Lopez, A Guerra, E Mente and MR 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 MD, AA Hohn, AJ Westgate, JR Nicolas, BR Whitaker and WB 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.

Sears, R. 2002. Blue whale. Pp. 112-116 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Shane, SH, RS Wells and B Wursig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. *Marine Mammal Science* 2(1): 34-63.

Sinclair, EHS. 1992. Stomach contents of four short-finned pilot whales (*Globicephala melas*) from the southern California Bight. *Marine Mammal Science* 8(1): 76-81.

Smith, SC 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, NA, M Johnson, PT Madsen, PL Tyack, A Bocconcelli and JF Borsani. 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? *Marine Mammal Science* 22(3): 690-699.

SRS-Parsons, Geo-Marine, Inc. and Bio-Waves, Inc. 2007. Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of the Northern Mariana Islands. Final Report Contract No. N68711-02-D-8043; Task Order No 0036. Prepared for Naval Facilities Engineering Command Pacific. Provided as GFE from SRS-Parsons.

Tiemann, CO, AM Thode, J Straley, V O'Connell and K Folkert. 2006. Three-dimensional localization of sperm whales using a single hydrophone. *J. Acoustical Society of America* 120(4):2355-2365.

Tyack, PL, M Johnson, N Aguilar Soto, A Sturlese and PT 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, MC, WA Walker, KT Shao and LS Chou. 2003. Feeding habits of the pantropical spotted dolphin, *Stenella attenuata*, off the eastern coast of Taiwan. *Zoological Studies* 42(2): 368-378.

Watkins, WA, MA Daher, NA DiMarzio, A Samuels, D Wartzok, KM Fristrup, PW Howey and RR Maiefski. 2002. Sperm whale dives tracked by radio tag telemetry. *Marine Mammal Science* 18(1): 55-68.

Watkins, WA, MA 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, WA, MA Daher, KM Fristrup, TJ Howald and G Notarbartolo di Sciara. 1993. Sperm whales tagged with transponders and tracked underwater by sonar. *Marine Mammal Science* 9: 55-67.

Watwood, SL, PJO Miller, M Johnson, PT Madsen and PL Tyack. 2006. Deep-diving foraging behaviour of sperm whales (Physeter macrocephalus). Journal of Ecology 75: 814-825.

Wells, RS and MD 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.

Wurtz, M and D Marrale. 1993. Food of striped dolphin, *Stenella coeruleoalba*, in the Ligurian Sea. *Journal Marine Biological Association UK* 73: 571-578.

Wurtz, M, R Poggi and MR Clarke. 1992. Cephalopods from the stomach of a Risso's dolphin (*Grampus griseus*) from the Mediterranean. *Journal of the Marine Biological Association UK* 72: 861-867.

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC.

| GENERAL INFORMATION | | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Food Preference** | **Depth or Oceanic Preference** | **References** | | **Behavioral State** | **Geographic Region** | **Depth Information** | **Depth Distribution** | **Sample Size/ Time of Year/Method** | **References** |
| **MYSTICETES - Baleen whales** | | | | | | | | | | |
| **Blue whale** | Euphausiid crustaceans, including *Euphasia* sp and *Thysanoessa* sp | Coastal as well as offshore | Sears (2002); Croll et al. (2001a); Acevado et al. (2002); Bannister (2002) | | Feeding at depth | Northeast Pacific (Mexico, California) | Mean depth 140 +- 46 m; mean dive time 7.8 +- 1.9 min | | Seven whales/ May-August/Time-depth-recorder | Croll et al. (2001a) |
| **Blue whale** | | | | | Feeding near surface; surface intervals between deeper dives | Northeast Pacific (central California) | Mean depth 105 +- 13 m; mean dive time 5.8 +- 1.5 min | 78% in 0-16 m; 9% in 17-32; 13% in >32 m; most dives to <16 m and 96-152 m ranges, but only 1.2% of total time was spent in deeper range | One whale/ August-September/ Satellite depth-sensor-tag | Lagerquist et al. (2000) |
| **Blue whale** | | | | | Non-feeding | Northeast Pacific (Mexico, California) | Mean depth 68 +- 51 m; mean dive time 4.9 +- 2.5 min; most dives to ~30 m with occasional deeper V-shaped dives to >100m | | Seven whales/ May-August/Time-depth-recorder | Croll et al. (2001a) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fin whale** | Planktonic crustaceans, including *Thyanoessa* sp and *Calanus* sp, as well as schooling fishes such as capelin (*Mallotus* ), herring (*Clupea*) and mackerel (*Scomber*) | Pelagic with some occurrence over continental shelf areas, including in island wake areas of Bay of Fundy | Aguilar (2002); Croll et al. (2001a); Acevado et al. (2002): Notarbartolo-di-Sciara et al. (2003); Bannister (2002); Johnston et al. (2005) | | Feeding at depth | Northeast Pacific (Mexico, California) | Mean depth 98 +- 33 m; mean dive time 6.3+- 1.5 min | | Fifteen whales/ April-October/Time-depth-recorder | Croll et al. (2001a) |
| **Fin whale** | | | | | Non-feeding | Northeast Pacific (Mexico, California) | Mean depth 59 +-30 m; mean dive time 4.2 +- 1.7 min; most dives to ~ 30 m with occasional deeper V-shaped dives to >90 m | | Fifteen whales/ April-October/Time-depth-recorder | Croll et al. (2001a) |
| **Fin whale** | | | | | Feeding | Mediterranean (Ligurian Sea) | shallow dives (mean 26-33 m, with all <100m) until late afternoon; then dives in excess of 400 m (perhaps to 540 m); in one case a whale showed deep diving in midday; deeper dives probably were to feed on specific prey (*Meganyctiphanes norvegica*) that undergo diel vertical migration | | Three whales/ Summer/ Velocity-time-depth-recorder | Panigada et al. (1999);<br>Panigada et al. (2003);<br>Panigada et al. (2006) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fin whale** | | | | | Traveling | Mediterranean (Ligurian Sea) | shallow dives (mean 9.8 +- 5.3 m, with max 20 m) , shorter dive times and slower swimming speed indicate travel mode; deep dives (mean 181.3 +-195.4 m, max 474 m), longer dive times and faster swimming speeds indicate feeding mode | | One whale/ Summer/ Velocity-time-depth-recorder | Jahoda et al. (1999) |
| **Fin whale** | | | | | Feeding | Northeast Pacific (Southern California Bight) | mean dive depth 248+-18 m; total dive duration mean 7.0+-1.0 min with mean descent of 1.7+-0.4 min and mean ascent of 1.4+-0.3 min; 60% (i.e., 7.0 min) of total time spent diving with 40% (i.e., 4.7 min) total time spent near sea surface (<50m) | 44% in 0-49m (includes surface time plus descent and ascent to 49 m); 23% in 50-225 m (includes descent and ascent times taken from Table 1 minus time spent descending and ascending through 0-49 m); 33% at >225 m (total dive duration minus surface, descent and ascent times) | Seven whales/ August/ Bioacoustic probe | Goldbogen et al. (2006) |
| **Fin whale** | | | | | Feeding | Northeast Pacific (Southern California Bight) | Distribution of foraging dives mirrored distribution of krill in water column, with peaks at 75 and 200-250 m. | | Two whales/ September-October/ Time-depth-recorder | Croll et al. (2001a) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| GENERAL INFORMATION | | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sei whale** | Copepods, amphipods, euphausiids, shoaling fish and squid | More open ocean than coastal | Horwood (2002); Jefferson et al. (1993); Nemoto and Kawamura (1977); Bannister (2002) | | Feeding | Northwest Pacific - coastal | skim feeder that takes swarms in low density | | Several/ Year-round/ Stomach content analysis | Nemoto and Kawamura (1977) |
| **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) |
| **Minke whale** | Regionally dependent; can include euphausiids, copepods, small fish: Japanese anchovy preferred in western North Pacific, capelin and krill in the Barents Sea | Coastal, inshore and offshore; known to concentrate in areas of highest prey density, including during flood tides | Perrin and Brownell (2002); Jefferson et al. (1993); Murase et al. (2007); Bannister (2002); Lindstrom and Haug (2001); Johnston et al. (2005); Hoelzel et al. (1989); Haug et al. (2002); Haug et al. (1995); Haug et al. (1996) | | Feeding, Searching | North Atlantic (Norway) | Searching for capelin at less than 20 m, then lunge-feeding at depths from 15 to 55 m, then searching again at shallower depths | Based on time series in Figure 2, 47% of time was spent foraging from 21-55 m; 53% of time was spent searching for food from 0-20 m | One whale/ August/ Dive-depth-transmitters | Blix and Folkow (1995) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| GENERAL INFORMATION | | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Minke whale** | | | | | Feeding | North Pacific (San Juan Islands) | 80% of feeding occurred over depths of 20-100m; two types of feeding observed both near surface - lunge feeding and bird association | | 23 whales/ June-September/ behavioral observations | Hoelzel et al. (1989) |
| **Humpback whale** | Pelagic schooling euphausiids and small fish including capelin, herring, mackerel, croaker, spot, and weakfish | Coastal, inshore, near islands and reefs, migration through pelagic waters | Clapham (2002); Hain et al. (1995); Laerm et al. (1997); Bannister (2002) | | Feeding | North Atlantic (Stellwagen Bank) | Depths <40 m | | Several whales/ August/ Visual Observations | Hain et al. (1995) |
| **Humpback whale** | | | | | Feeding (possible) | Tropical Atlantic (Bermuda) | Dives to 240 m | | One whale/ April/ VHF tag | Hamilton et al. (1997) |
| **Humpback whale** | | | | | Feeding (in breeding area) | Tropical Atlantic (Samana Bay - winter breeding area) | Not provided; lunge feeding with bubblenet | | One whale/ January/ Visual observations | Baraff et al. (1991) |
| **Humpback whale** | | | | | Breeding | North Pacific (Hawaii) | Depths in excess of 170 m recorded; some depths to bottom, others to mid- or surface waters; dive duration was not necessarily related to dive depth; whales resting in morning with peak in aerial displays at noon | 40% in 0-10 m, 27% in 11-20 m, 12% in 21-30 m, 4% in 31-40 m, 3% in 41-50 m, 2% in 51-60 m, 2% in 61-70 m, 2% in 71-80 m, 2% in 81-90 m, 2% in 91-100 m, 3% in >100 m (from Table 3 | Ten Males/ February-April/ Time-depth-recorder | Baird et al. (2000a); Helweg and Herman (1994) |

**Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| **GENERAL INFORMATION** | | | | | **DEPTH SPECIFIC INFORMATION** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Humpback whale** | | | | | Feeding | Northeast Atlantic (Greenland) | Dive data was catalogued for time spent in upper 8 m as well as maximum dive depth; diving did not extend to the bottom (~1,000 m) with most time in upper 4 m of depth with few dives in excess of 400 m | 37% of time in <4 m, 25% of time in 4-20 m, 7% of time in 21-35m, 4% of time in 36-50 m, 6% of time in 51-100 m, 7% of time in 101-150 m, 8% of time in 151-200 m, 6% of time in 201-300 m, and <1% in >300 m (from Figure 3.10) | Four whales/ June-July/ Satellite transmitters | Dietz et al. (2002) |
| **Humpback whale** | | | | | Feeding | North Pacific (Southeast Alaska) | Dives were short (<4 min) and shallow (<60 m); deepest dive to 148m; percent of time at surface increased with increased dive depth and with dives exceeding 60 m; dives related to position of prey patches | | Several whales/ July-September/ Passive sonar | Dolphin (1987a);<br>Dolphin (1988) |

1 **Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| GENERAL INFORMATION | | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **ODONTOCETES - Toothed whales** | | | | | | | | | | |
| **Sperm whale** | Squids 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% of time) at the surface between dives; no measurement of depth of dive | | 16 whales/ July-August/ visual observations and click recordings | Drouot et al. (2004) |
| **Sperm whale** | | | | | Feeding | South Pacific (Kaikoura, New Zealand) | 83% 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) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | **GENERAL INFORMATION** | | | | **DEPTH SPECIFIC INFORMATION** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sperm whale** | | | | | Feeding | Equatorial Pacific (Galapagos) | Dives were not to ocean floor (2,000-4,000 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% of all dives; average depth 418 +- 216 m; most (91%) deep dives were to 100-500 m; deepest dives were 1,250-1,500m; 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 | 74% in <100 m; 24% in 100-500 m; 2% in >500m | Five whales/ October-November/ Satellite-linked dive recorder | Davis et al. (2007) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sperm whale** | | | | | Resting/ socializing | North Pacific (Baja California) | Most dives (74%) shallow (8-100 m) and short duration; likely resting and/or socializing | | Five whales/ October-November/ Satellite-linked dive recorder | Davis et al. (2007) |
| **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% of time at surface; deepest dive of 1186 m while deepest depths in area were 1,500-3,000 m so foraging was mid-water column; surface interval averaged 7.1 min | | Nine Whales/ July 2003/ DTAG | Palka and Johnson (2007) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sperm whale** | | | | | Feeding | Northwest Atlantic (Georges Bank) | 37% of total time was spent near surface (0-10m); foraging dive statistics provided in Table 1 and used to calculate percentages of time in depth categories, adjusted for total time at surface | 48% in <10 m; 3% in 10-100 m; 7% in 101-300 m; 7% in 301-500 m; 4% in 501-636 m; 31% in >636 m | Six females or immatures/ September-October/ DTAG | Watwood et al. (2006) |
| **Sperm whale** | | | | | Feeding | Mediterranean Sea | 20% of total time was spent near surface (0-10m); foraging dive statistics provided in Table 1 and used to calculate percentages of time in depth categories, adjusted for total time at surface | 35% in <10 m; 4% in 10-100 m; 9% in 101-300 m; 9% in 301-500 m; 5% in 501-623 m; 38% in >636 m | Eleven females or immatures/ July/ DTAG | Watwood et al. (2006) |
| **Sperm whale** | | | | | Feeding | Gulf of Mexico | 28% of total time was spent near surface (0-10m); foraging dive statistics provided in Table 1 and used to calculate percentages of time in depth categories, adjusted for total time at surface | 41% in <10 m; 4% in 10-100 m; 8% in 101-300 m; 7% in 301-468 m; 40% >468 m | 20 females or immatures/ June-September/ DTAG | Watwood et al. (2006) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sperm whale** | | | | | Feeding/ Resting | North Pacific (Japan) | Dives to 400-1200 m; active bursts in velocity at bottom of dive suggesting search-and-pursue strategy for feeding; 14% of total time was spent at surface not feeding or diving at all, with 86% of time spent actively feeding; used numbers from Table 1 to determine percentages of time in each depth category during feeding then adjusted by total time at surface | 31% in <10 m (surface time); 8% in 10-200 m; 9% in 201-400 m; 9% in 401-600 m; 9% in 601-800m; 34% in >800 m | One female/ June/ Time-depth-recorder | Amano and Yoshioka (2003) |
| **Sperm whale** | | | | | Feeding/ Resting | North Atlantic (Caribbean) | Whales within 5 km of shore during day but moved offshore at night; calves remained mostly at 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 | | Two whales/ October/ Acoustic transponder | Watkins et al. (1993) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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% of total time in deep dives with 37% of time near surface or shallow dives (within 100 m of surface) | | One whale/ April/ Time-depth tag | Watkins et al. (2002) |
| **Sperm whale** | | | | | Feeding | Northern Pacific (Hawaii) | Cephalopods of several genera recovered | | Two animals/ unknown/ stomach contents | Clarke and Young (1998) |
| **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; squids 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) |

**Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

|  | **GENERAL INFORMATION** |  |  |  | **DEPTH SPECIFIC INFORMATION** |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pygmy sperm whale** |  |  |  |  | Feeding | South Pacific (New Zealand) | Primarily cephalopod prey of genus *Histioteuthis* sp, mostly immatures, which is know to undergo vertical migrations; also mysids 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 |  | 27 whales/ Year round/ Stomach contents | Beatson (2007) |
| **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) |  |  |  |  |  |  |  |

### Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cuvier's beaked whale** | Meso-pelagic or deep water 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 | Offshore, deep waters of continental slope (200-2,000 m) or deeper | Heyning (2002); Santos et al. (2001); Blanco and Raga (2000) | | Feeding | Northeast Pacific (Hawaii) | max dive depth = 1450 m; identified at least three dive categories including inter-ventilation (<4 m, parabolic shape), long duration (>1,000m, 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 mid-depths; no difference between day and night diving | | Two whales/September-November/Time-depth recorders | Baird et al. (2006a); Baird et al. (2005a) |
| **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); depth distribution taken from information in Table 2 | 27% in <2 m (surface); 29% in 2-220 m; 4% in 221-400 m; 4% in 401-600 m; 4% in 601-800 m; 5% in 801-1070; 27% in >1070 m | Seven whales/ June/ DTAGs | Tyack et al. (2006) |

1 **Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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 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 | | Two whales/ September/ DTAGs | Johnson et al. (2004); Soto et al. (2006) |
| **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 (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 | | Four whales/ September-November/ Time-depth recorders | Baird et al. (2006a); Baird et al. (2005a) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | **GENERAL INFORMATION** | | | | **DEPTH SPECIFIC INFORMATION** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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) occurred once/2.5 hour; likely feeding in mid-depth, not bottom feeding; | | Three whales/ March-April/ Time-depth recorders | Baird et al. (2006a) |
| **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); depth distribution taken from information in Table 2 | 26% in <2 m (surface); 41% in 2-71 m; 2% in 72-200 m; 4% in 201-400 m; 4% in 401-600 m; 4% in 601-835; 19% in >835 m | Three whales/ June/ DTAGs | Tyack et al. (2006) |

1 **Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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; 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 | | Two whales/ September/ DTAGs | Johnson et al. (2004); Madsen et al. (2005) |
| **Ginkgo-toothed 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 (200-2,000 m) or deeper | | | Pitman (2002b) | | | | | |
| **Longman'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 (200-2,000 m) or deeper | Pitman (2002a); Pitman (2002b) | | | | | | | |

### Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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 specialization | 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. (2006b) | | 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 difference between day and night patterns and between males and females; depth distribution info from Table 5 in Baird et al. (2003a) | 96% at 0-30 m; 4% at >30 m | Eight whales/ Summer-fall/ Time-depth recorders | Baird et al. (2005b); Baird et al. (2003a) |
| **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) |

**Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pygmy killer whale** | Cephalopods and small fish, but also likely small delphinids | Mainly pelagic but close to shore near oceanic islands | Donahue and Perryman (2002) | | Feeding | Southwest Atlantic (Brazil) | Found in slope-oceanic areas; fed on cephalopods and fish | | 1 animal/ unknown/ stomach contents | Santos and Haimovici (2001) |
| **Short-finned pilot whale** | Fish and squid, including cod, turbot, herring, hake and dogfish | continental shelf breaks, slope waters and areas of high topographic relief; some evidence for deeper dives at night | Sinclair (1992); Olson and Reilly (2002); Baird et al. (2003b) | | Feeding | North Pacific (Hawaii) | Deepest dives (600-800 m) during the day but rate of deep (>100 m) diving was higher at night when dives were regularly to 300-500 m; long bouts of surface resting and shallow (<100 m) diving occurred only during the day | | 10 animals/ unk/ time-depth recorders | Baird et al. (2003b) |
| **Short-finned pilot whale** | | | | | | North Pacific (Southern California) | Prey were entirely cephalopods, particularly *Loligo opalescens*, which spawns at depths of 25-35 m | | Four animals/ Oct-Dec/ stomach contents | Sinclair(1992) |
| **Long-finned pilot whale** | Fish and squid, including cod, turbot, herring, hake and dogfish | continental shelf breaks, slope waters and areas of high topographic relief; distribution somewhat farther north but overlapping with *G. macrorhychus* | Baird et al. (2002b) | | Feeding | North Atlantic (Faroe Islands) | Most dives <36 m with 90% to 12-17m; 60% of time at less than 7 m; max depth 828 m | 60% at <7 m; 36% at 7-17m; 4% at 18-828 m | Three animals/ July/ time-depth recorders | Heide-Jorgenson et al. (2002) |

### Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| GENERAL INFORMATION | | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Long-finned pilot whale** | | | | | Feeding | Southern Ocean (Tasmania) | Prey items included species commonly found from 0-85 m plus several genera found from 400-700 m | | Two animals/ July/ stomach contents | Gales et al. (1992) |
| **Long-finned pilot whale** | | | | | Feeding | Northwest Atlantic (US mid-Atlantic region) | Prey items included long-finned squid and numerous other cephalopods; very few fish remains | | Eight animals/ March, April, September/ stomach contents | Gannon et al. (1997) |
| **Long-finned pilot whale** | | | | | Feeding | South Pacific (New Zealand) | Squid of genus *Nototodarus*, which tend to be found from 0-500 m, as well as a few other species that indicate feeding both near the surface and at the seabed ~150 m | | Five animals/ December/ stomach contents | Beatson et al. (2007) |
| **Long-finned pilot whale** | | | | | Feeding | Mediterranean (Ligurian Sea) | Daytime activities all within <16 m of surface; night dives just after sunset were deep (360 and 648 m) perhaps to take advantage of vertically migrating prey | | Five animals/ August/ time-depth recorders | Baird et al. (2002b) |
| **Long-finned pilot whale** | | | | | Feeding | Southwest Atlantic (Brazil) | Fed on offshore cephalopods | | unknown animals/ unknown/ stomach contents | Santos and Haimovici (2001) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Melon-headed whale** | Squid and fish, occasionally crustaceans in the water column; prey known to occur at depths to 1,500 m; may feed on similar prey types as Fraser's dolphins | Offshore, deeper waters; occasionally near shore in deep water areas | Perrin (2002c); Jefferson and Barros (1997) | | | | | | | |
| **Melon-headed whale** | | | | | Feeding | Northern Pacific (Hawaii) | Cephalopods of several genera recovered | | One animal/ unknown/ stomach contents | Clarke and Young (1998) |
| **Risso's dolphin** | Primarily squid eaters and presumably eat mainly at night; known to feed on oceanic species that are also bioluminescent | Water depths from 400-1,000 m but also on continental shelf; utilize steep sections of continental slope in GOM (350-975 m) | Baird (2002b); Baumgartner (1997); Bello (1992b) | | Feeding | Mediterranean (western) | Prey items were mainly squids and octopus, 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** | | | | | 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) |

**Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Risso's dolphin** | | | | | Feeding | Mediterranean (Ligurian Sea) | Diet composed of cephalopods found at daytime depths in excess of 300 m and which may undertake vertical migrations at night | | One animal/ August/ stomach contents | Wurtz et al. (1992) |
| **Risso's dolphin** | | | | | Feeding | Northern Pacific (Hawaii) | Cephalopods of several genera recovered | | One animal/ unknown/ stomach contents | Clarke and Young (1998) |
| **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 fishes and eels | | May-September/ behavioral observations | Rossbach and Herzing (1997) |

1 **Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bottlenose dolphin** | | | | | Feeding | Tropical Atlantic (Bahamas) | Daytime dives tended to be shallow (96% 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 | Daytime: 96% at <50 m, 4% at >50 m; Nighttime: 51% at <50 m, 8% at 50-100 m, 19% at 101-250 m, 13% at 251-450 m and 9% at >450 m | 3 animals/ June 2003/ satellite-linked time-depth recorders | Klatsky et al. (2007) |
| **Bottlenose dolphin** | | | | | Feeding | South Pacific (Australia) | 66% percent of time in top 5 m of water surface; maximum dive depth >150 m; no apparent diurnal pattern; no relationship between duration and maximum depth of dives | | 2 animals/ April-November/ satellite-linked time-depth recorders | Corkeron and Martin (2004) |
| **Rough-toothed dolphin** | fish and cephalopods, both coastal and oceanic | | Jefferson (2002b); Miyazaki and Perrin (1994) | | | | Max recorded dive to 70 m | | Unk | 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) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pantropical spotted dolphin** | Small epipelagic fishes, squids and crustaceans for offshore forms; near shore forms may feed on benthic fishes; perhaps some nocturnal feeding; probably opportunistic | Near shore and offshore, with possible shifts closer to shore in fall and winter; in eastern tropical Pacific often found in association with tuna; diet suggest feeding at night on vertically migrating prey | Perrin (2002a); Richard and Barbeau (1994); Robertson and Chivers (1987) | | Feeding | Southwest Pacific (Taiwan) | Feed primarily on mesopelagic prey, particularly myctophid lanternfish and cephalopods, with some seasonal differences; night distribution of prey appears to be 0-200 m while daytime distribution of prey is >300 m | | 45 animals/ year round/ stomach contents | Wang et al. (2003) |
| **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% of time was within 0-10 m; depth distribution taken from info in figure 4 | For activities conducted during daytime-only, the depth distribution would be 89% at 0-10 m, 10% at 11-50 m, 1% at 51-122 m; for activities conducted over a 24-hour period, the depth distribution needs to be modified to reflect less time at surface and deeper depth dives; 80% at 0-10 m, 8% at 11-20 m, 2% at 21-30 m, 2% at 31-40 m, 2% at 41-50 m, and 6% at 51-213 m. | Six animals/ year round/ time-depth recorders | Baird et al. (2001a) |
| **Pantropical spotted dolphin** | | | | | Feeding | Northern Pacific (Hawaii) | Remains of cephalopods and fish recovered | | One animal/ unknown/ stomach contents | Clarke and Young (1998) |

## Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | **GENERAL INFORMATION** | | | | **DEPTH SPECIFIC INFORMATION** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Striped dolphin** | Feed on pelagic fish and squid; squid make up 50-100% of stomach contents in Mediterranean samples | Continental slope, 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 (2002); Archer and Perrin (1999) | | Feeding | Mediterranean (Turkey) | Prey species (pelagic cephalopods) show lesser degree of vertical distribution compared to those utilized by *G. griseus* | | Three animals/ May-June/ stomach contents | Ozturk et al. (2007) |
| **Striped dolphin** | | | | | Feeding | Mediterranean (western) | Mixed diet of muscular and gelatinous body squids, 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% of prey | | unknown animals/ unknown/ stomach contents | Archer and Perrin (1999) |
| **Striped dolphin** | | | | | Feeding | Mediterranean (Ligurian Sea) | Diet composed of cephalopods, crustaceans and bony fishes; cephalopods and bony fishes apparently equal in importance; likely feeding in offshore waters and possibly in the upper water column; opportunistic feeders | | 23 animals/ unknown/ stomach contents | Wurtz and Marrale (1993) |

**Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Spinner dolphin** | Small mesopelagic fishes, although subpopulations consume benthic fishes | Pantropical; often high-seas, but coastal populations are also known; dives to 600 m or deeper | Perrin (2002d); Benoit-Bird and Au (2003) | | Feeding | Southwest Pacific (Sulu Sea, Philippines) | Mainly feed on mesopelagic 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 | | 45 animals/ unknown/ stomach contents | Dolar et al. (2003) |
| **Spinner dolphin** | | | | | Feeding | North Pacific (Hawaii) | Extremely close association with small, mesopelagic fishes; mean depth always within 10 m of the depth of the highest prey density; feeding at night occurs between 0-400 m as 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 | 100% at 0-50 m; nighttime: 100% at 0-400 m. | Several animals/ June and November/ active acoustic surveys | Benoit-Bird and Au (2003) |

**Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)**

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fraser's dolphin** | mesopelagic fish, crustaceans and cephalopods; take advantage of vertically migrating prey at night | tropical and oceanic except in places where deep water is close to islands; likely feed to at least 500 m and possibly at night | Dolar (2002); Dolar et al. (2003); Jefferson and Leatherwood (1994) | | Feeding | Caribbean (Dominica) | herding and feeding of fish school at surface during daylight hours; depth at location varied from 150-200 m to 2,000-2,500 m; short dives as animals sometimes approached the herded fish from below | | 60-80 animals/ October/ behavioral observations | Watkins et al. (1994) |
| **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 | | 37 animals/ unknown/ stomach contents | Dolar et al. (2003) |
| **Fraser's dolphin** | | | | | Feeding | Southwest Atlantic (Brazil) | Cephalopods and fish found in animals from shelf-slope regions | | 4 animals/ unknown/ stomach contents | Santos and Haimovici (2001) |
| **Fraser's dolphin** | | | | | Feeding | North Pacific (eastern tropical Pacific) | Mixed diet of mesopelagic fishes (most important component), shrimps and squids; likely feeding at depths from 250-500 m | | Three animals/ May/ stomach contents | Robison and Craddock (1982) |

### Appendix B Summary Table. Summary of depth information for marine mammal species with densities in the MIRC. (cont'd)

| | GENERAL INFORMATION | | | | DEPTH SPECIFIC INFORMATION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Short-beaked common dolphin** | Small mesopelagic fishes and squids in the deep scattering layer; epipelagic schooling fishes and market squids | Wide range of habitats, including upwelling areas, oceanic and near shore regions | Perrin (2002b) | | Feeding | Southwest Atlantic (Brazil) | Cephalopods and fish found in animals from shelf regions | | 2 animals/ unknown/ stomach contents | Santos and Haimovici (2001) |
| **Short-beaked common dolphin** | | | | | Feeding | Northeast Atlantic (Bay of Biscay) | Oceanic diet dominated by myctophid fishes (90%), with less reliance on cephalopods; appear to forage preferentially on small schooling, vertically migrating mesopelagic fauna at dusk and early evening | | 63 animals/ June-August/ stomach contents | Pusineri et al. (2007) |
| **Short-beaked common dolphin** | | | | | Feeding | Unknown | Dives to 200 m, apparently from study reported by Evans (1994) | | Unknown/ unknown/ unknown | Perrin (2002b) |
| **Short-beaked common dolphin** | | | | | Feeding | Western North Pacific | Primarily myctophid fishes and other warm water fish species; most prey species found are those that migrate vertically to shallower depth at night (within few hundred m) or inhabit upper layer of ocean | | Ten animals/ September/ stomach contents | Ohizumi et al. (1998) |
| **Short-beaked common dolphin** | | | | | Feeding | Mediterranean Sea | Diet of shoaling fish and eurybathic cephalopods and crustaceans | | | Bearzi et al. (2003) |

# APPENDIX C RISK FUNCTION DEFINITIONS AND METRICS

This page intentionally left blank**.**

# APPENDIX C RISK FUNCTION DEFINITIONS AND METRICS

This Appendix provides background for the dose-function approach.

## C.1 Definitions and Metrics for Sound and Probability/Statistics

### C.1.1 Some Fundamental Definitions of Acoustics

*Static Pressure* (Acoustics): At a point in a fluid (gas or liquid), the *static pressure* is the pressure that would exist if there were no sound waves present (paraphrase from 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 (although a pressure wave may have a direction of propagation). *Pressure* has units of force/area. The International System (SI) derived unit of pressure is the pascal (Pa) defined as one N/m$^2$. Alternative units are many (lbs/ft$^2$, bars, inches of mercury, etc); some are listed at the end of this section.

*Acoustic Pressure*

Without limiting the discussion to small amplitude or linear waves, define *acoustic pressure* 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 (after Beranek, 1986).

*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 p is pressure and T is on the order of several periods of the lowest frequency component of the time series starting at time $\tau$. T can be greater, but should be specified as part of the metric.

*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 acoustic plane waves, the ratio is $\rho c$, where $\rho$ 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:

$$\text{Intensity} = (p_{rms})^2/\rho c$$

Such an inferred intensity should properly be labeled as the *equivalent plane-wave intensity in* the *propagation direction*.

*Energy Flux Density (EFD)*

*EFD* is the time integral of instantaneous intensity. For plane waves,

$$EFD = \frac{1}{\rho c}\int_{0}^{T} p^2(t)dt\,,$$

where $\rho c$ is the impedance. Units are J/m$^2$.

### C.1.2 Definitions Related To Sound Sources , Signals, and Effects

*Source Intensity*

Define *source intensity*, $I(\theta,\phi)$, as the intensity of the projected signal referred to a point at unit distance from the source in the direction $(\theta,\phi)$. $(\theta,\phi)$ 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 $W/m^2$, 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 (Also, Continuous Wave, CW, Monochromatic Wave, Unmodulated Signal)*

Each term means a single-frequency wave or signal. The actual bandwidth of the signal will depend on context, but could be interpreted as “single-frequency as far as can be determined.”

*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% 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.1.3 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. 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.

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

$$10 \log [(100\ \mu\text{Pa})^2 / (1\ \mu\text{Pa})^2] \text{ dB re } 1\ \mu\text{Pa}$$

= 40 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 $\text{SL}(\theta,\phi) = 10 \log[I(\theta,\phi)/I_0]$, where $I_0$ 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.

*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 $\mu\text{Pa}^2$ s. Since impedance for water is 1.5 $10^{12}$ μPa(s/m), the EFD is then

$$(1\ \mu\text{Pa}^2\,\text{s}) / (1.5\ 10^{12}\ \mu\text{Pa}(\text{s}/\text{m})) = 6.66\ 10^{-13}\ \mu\text{Pa-m} = 6.66\ 10^{-19}\ \text{J}/\text{m}^2$$

Thus an EFDL of 0 dB (re 1 $\mu\text{Pa}^2$ s) corresponds to an EFD of 6.66 $10^{-19}$ J/$\text{m}^2$ (in water).

It follows that thresholds of interest for impacts on marine life have values in water as follows:

190 dB (re 1 $\mu\text{Pa}^2$ s) = $10^{19}$ x 6.66 $10^{-19}$ J/$\text{m}^2$ = 6.7 J/$\text{m}^2$

200 dB (re 1 $\mu\text{Pa}^2$ s) = 66.7 J/$\text{m}^2$

215 dB (re 1 $\mu\text{Pa}^2$ s) = 2106.1 J/$\text{m}^2$

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 0.0006 kW-hr.

## C.1.4 Some Constants and Conversion Formulas

**Length**
1 nm = 1.85325 km
1 m = 3.2808 ft

**Speed**
1 knot = 0.514791 m/s = 1.85325 km/hr
1 mph= 0.447 m/s= 1.6093 km/hr
1 m/s = 1.94254 knots

**Pressure**
1 Pa = 1 $N/m^2$ = 1 $J/m^3$ = 1 kg/m $s^2$
1 Pa = $10^6 \mu$ Pa = 10 $dyn/cm^2$ = 10 μbar
1 μPa = $10^{-5}$ $dyn/cm^2$ = $1.4504 \cdot 10^{-10}$ psi
1 atm = 1.014 bar = 14.7097 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

**Energy (Work)**
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

**Acoustic Intensity**
1 $W/m^2$= 1 Pa (m/s) = $10^6$ μPa (m/s)
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/s)
1 lb/ft s = 14.596 $J/m^2s$ = 14.596 $W/m^2$
1 $W/m^2$ = $10^7$ $erg/m^2s$ = $10^3$ $erg/cm^2s$

**Acoustic Energy Flux Density**
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.1.5 Additional Definitions for Metrics Used in Air

*Weighted Sound Levels*

For sound pressure measurements in air related to hearing, it is common practice to weight the spectrum to reduce the influence of the high and low frequencies so that the response is similar that of the human ear to noise. *A-weighting* is the most common filter, with the weight resembling the ear's responses. Other popular weightings are B and C. The table below gives a sampling of the filter values for selected frequencies.

**Table C-1. Filter Values for Selected Frequencies**

| Frequency (Hz) | A-Weighting (dB) | B-Weighting (dB) | C-Weighting (dB) |
|---|---|---|---|
| 10 | -70 | -38 | -14 |
| 20 | -50 | -24 | -6 |
| 40 | -35 | -14 | -2 |
| 80 | -23 | -7 | -1 |
| 160 | -13 | -3 | 0 |
| 320 | -7 | -1 | 0 |
| 640 | -2 | 0 | 0 |
| 2000 | +1 | 0 | 0 |
| 5000 | +1 | -1 | -1 |
| 10,000 | -3 | -4 | -4 |
| 12,000 | -4 | -6 | -6 |
| 20,000 | -9 | -11 | -11 |

Decibel levels based on these weighted are usually labeled: dBA or dB(A) for A weighting, etc.

*Sound Exposure Level (SEL)*

For a time-varying sound pressure p(t), *sound exposure level* is computed as

$$\mathrm{SEL} = 10 \log \left[ \frac{1}{t_0} \int_0^T p^2(t)\,dt \Big/ p_0^2 \right],$$

where $t_0$ is 1 second, T is the total duration of the signal (in the same units as those of $t_0$, namely seconds) and $p_0$ is the reference pressure (usually 20 µPa).

SEL is thus a function of p(t), T, and the reference pressure. When the impedance of the medium of interest is approximately constant, then SEL can be viewed as the total energy level for the time interval from 0 to T. It has explicit reference units of $p_0$ for pressure with implicit units of seconds for time.

SEL is almost never used in underwater sound, primarily because it does not account for changes in impedance (as, for example, in sound propagation through sediments). Instead, energy flux density level is the standard.

When p(t) is A-weighted, then the measure is called the *A-weighted SEL* or *ASEL*. Likewise for other weightings.

*Equivalent Sound Level ($L_{eq}$)*

The *equivalent sound level ($L_{eq}$)* is defined as the A-weighted sound pressure level (SPL) averaged over a specified time period T. It is useful for noise that fluctuates in level with time. $L_{eq}$ is also sometimes called the *average sound level ($L_{AT}$)*, so that $L_{eq} = L_{AT}$. (see, e.g., Crocker, 1997)

If $p_A(t)$ is the instantaneous A-weighted sound pressure and $p_{ref}$ the reference pressure (usually 20 µPa), then

$$L_{eq} = 10 \log \left\{ \left( \frac{1}{T} \int_0^T p_A{}^2(t)\,dt \right) \Big/ p_{ref}^2 \right\}.$$

It is thus equivalent to an average A-weighted intensity or power level.

Note that since the averaging time can be specified to be anything from seconds to hours, $L_{eq}$ has become popular as a measure of environmental noise. For community noise, T may be assigned a value as high as 24 hours or more.

*Day/Night Sound Level ($L_{dn}$)*

Following Magrab (1975), $L_{dn}$ was introduced by the EPA in 1974 to provide a single-number measure of community noise exposure over a specified period. It was designed to improve $L_{eq}$ by adding a correction of 10 dB for nighttime levels to account for increased annoyance to the population.

$L_{dn}$ is calculated as the level resulting from a weighted averaging of intensities:

$$10^{L_{dn}/10} = (0.625)10^{L_d/10} + (0.375)10^{(L_n+10)/10}$$

It is thus a long-term-average, weighted function of SPL.

## C.2 Definitions for Probability and Statistics (from various public internet sources)

*Random Variables*

The outcome of an experiment need not be a number, for example, the outcome when a coin is tossed can be 'heads' or 'tails'. However, we often want to represent outcomes as numbers. A random variable is a function that associates a unique numerical value with every outcome of an experiment. The value of the random variable will vary from trial to trial as the experiment is repeated.

A random variable has either an associated probability distribution (discrete random variable) or probability density function (continuous random variable).

Examples:

- A coin is tossed ten times. The random variable X is the number of tails that are noted. X can only take the values 0, 1, ..., 10, so X is a discrete random variable.
- A light bulb is burned until it burns out. The random variable Y is its lifetime in hours. Y can take any positive real value, so Y is a continuous random variable.

*Expected Value (Mean Value)*

The expected value (or population mean) of a random variable indicates its average or central value. It is a useful summary value (a number) of the variable's distribution.

Stating the expected value gives a general impression of the behaviour of some random variable without giving full details of its probability distribution (if it is discrete) or its probability density function (if it is continuous).

Two random variables with the same expected value can have very different distributions. There are other useful descriptive measures which affect the shape of the distribution, for example variance.

The expected value of a random variable X is symbolized by E(X) or µ.

If X is a discrete random variable with possible values x1, x2, x3, ..., xn, and p(xi) denotes P(X = xi), then the expected value of X is defined by:

sum of xi.p(xi)

where the elements are summed over all values of the random variable X.

If X is a continuous random variable with probability density function f(x), then the expected value of X is defined by:

integral of xf(x)dx

Example

Discrete case : When a die is thrown, each of the possible faces 1, 2, 3, 4, 5, 6 (the xi's) has a probability of 1/6 (the p(xi)'s) of showing. The expected value of the face showing is therefore:

$$\mu = E(X) = (1 \times 1/6) + (2 \times 1/6) + (3 \times 1/6) + (4 \times 1/6) + (5 \times 1/6) + (6 \times 1/6) = 3.5$$

Notice that, in this case, E(X) is 3.5, which is not a possible value of X.

*Variance (Square of the Standard Deviation)*

The (population) variance of a random variable is a non-negative number which gives an idea of how widely spread the values of the random variable are likely to be; the larger the variance, the more scattered the observations on average.

Stating the variance gives an impression of how closely concentrated round the expected value the distribution is; it is a measure of the 'spread' of a distribution about its average value.

Variance is symbolized by V(X) or Var(X) or sigma^2

The variance of the random variable X is defined to be:

$$V(X)=E(X^2)-E(X)^2$$

where E(X) is the expected value of the random variable X.

Notes:

- The larger the variance, the further that individual values of the random variable (observations) tend to be from the mean, on average;
- The smaller the variance, the closer that individual values of the random variable (observations) tend to be to the mean, on average;
- Taking the square root of the variance gives the standard deviation, i.e.:

  sqrt(V(X))=sigma

- The variance and standard deviation of a random variable are always non-negative.

*Probability Distribution*

The probability distribution of a discrete random variable is a list of probabilities associated with each of its possible values. It is also sometimes called the probability function or the probability mass function.

More formally, the probability distribution of a discrete random variable X is a function which gives the probability p(xi) that the random variable equals xi, for each value xi:

$$p(xi) = P(X=xi)$$

It satisfies the following conditions:

1. 0 <= p(xi) <= 1
2. sum of all p(xi) is 1

*Cumulative Distribution Function*

All random variables (discrete and continuous) have a cumulative distribution function. It is a function giving the probability that the random variable X is less than or equal to x, for every value x.

Formally, the cumulative distribution function F(x) is defined to be:

$$F(x) = P(X<=x)$$

for

$$\text{infinity} < x < \text{infinity}$$

For a discrete random variable, the cumulative distribution function is found by summing up the probabilities as in the example below.

For a continuous random variable, the cumulative distribution function is the integral of its probability density function.

*Probability Density Function*

The probability density function of a continuous random variable is a function which can be integrated to obtain the probability that the random variable takes a value in a given interval.

More formally, the probability density function, $f(x)$, of a continuous random variable $X$ is the derivative of the cumulative distribution function $F(x)$:

$$f(x) = d/dx\ F(x)$$

Since $F(x) = P(X<=x)$ it follows that:

$$\text{integral of } f(x)dx = F(b)-F(a) = P(a<X<b)$$

If $f(x)$ is a probability density function then it must obey two conditions:

1. That the total probability for all possible values of the continuous random variable $X$ is integral of $f(x)dx = 1$
2. That the probability density function can never be negative: $f(x) > 0$ for all $x$.

*Normal (gaussian) Density Function*

The normal distribution (the "bell-shaped curve" which is symmetrical about the mean) is a theoretical function commonly used in inferential statistics as an approximation to sampling distributions (see also Elementary Concepts). In general, the normal distribution provides a good model for a random variable, when:

1. There is a strong tendency for the variable to take a central value
2. Positive and negative deviations from this central value are equally likely
3. The frequency of deviations falls off rapidly as the deviations become larger

As an underlying mechanism that produces the normal distribution, one may think of an infinite number of independent random (binomial) events that bring about the values of a particular variable. For example, there are probably a nearly infinite number of factors that determine a person's height (thousands of genes, nutrition, diseases, etc.). Thus, height can be expected to be normally distributed in the population.