National Marine Fisheries Service
Endangered Species Act Section 7 Consultation
Biological Opinion

Agencies:	United States Navy National Marine Fisheries Service
Activities Considered:	The U.S. Navy's conduct of training exercises in the Southern California Range Complex from January 2009 to January 2010 Letter of Authorization to authorize the U.S. Navy to "take" marine mammals incidental to the conduct of training exercises in the Southern California Range Complex January 2009 to January 2010
Consultation Conducted by:	Endangered Species Division of the Office of Protected Resources, National Marine Fisheries Service
Approved by:	
Date:	JAN 22 2008

Section 7(a)(2) of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1539(a)(2)) requires each federal agency to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. When a federal agency's action "may affect" a protected species, that agency is required to consult formally with the National Marine Fisheries Service or the U.S. Fish and Wildlife Service, depending upon the endangered species, threatened species, or designated critical habitat that may be affected by the action (50 CFR 402.14(a)). Federal agencies are exempt from this general requirement if they have concluded that an action "may affect, but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS or the U.S. Fish and Wildlife Service concur with that conclusion (50 CFR 402.14(b)).

For the actions described in this document, the action agencies are the United States Navy, which proposes to undertake the training activities described in this Opinion, and NMFS' Office of Protected Resources – Permits, Conservation, and Education Division, which proposes to issue a:Letter of Authorization for the U.S. Navy to "take" marine mammals incidental to those training exercises. The consulting agency for these proposals is NMFS' Office of Protected Resources - Endangered Species Division. This document represents NMFS' final biological opinion (Opinion) on the U.S. Navy's proposal to conduct training activities in the Southern California Range Complex from January 2009 through January 2010 and the National Marine Fisheries Service's Permits, Conservation, and Education Division proposal to issue a Letter of Authorization for the "take" of marine mammals, pursuant to the Marine Mammal Protection Act of 1972, incidental to the conduct of those training activities.

Those portions of this Opinion that address major training exercises, other training activities, and Research, Development, Test and Evaluations that occur in the Southern California Range Complex are based on our review of the U. S. Navy's draft and final Environmental Impact Statement for the Southern California Range Complex and after-action reports and monitoring reports associated with the several Composite Training Unit Exercises

(COMPTUEX) and Joint Task Force Exercises (JTFEX) that have been conducted in the Southern California Range Complex between February 2007 through December 2008.

This Opinion has been prepared in accordance with section 7 of the ESA and is based on information provided in the applications for the proposed permits, published and unpublished scientific information on the biology and ecology of threatened and endangered whales, sea lions, fur seals, sea turtles, salmon, steelhead, and abalone in the action area, and other sources of information that are discussed in greater detail in the *Approach to the Assessment* section of this Opinion.

Consultation History

On 1 April 2008, the U.S. Navy submitted an application to the Permits Division that requested authorization for the "take" of 37 species of marine mammals incidental to Navy training activities that would be conducted within the Southern California Range Complex over the course of five years. The Navy requested authorization to "take" individuals of 37 species of marine mammals by Level B Harassment (as the term "take" is defined by the Marine Mammal Protection Act); although the U.S. Navy did not anticipate it to occur, it requested authorization to take, by injury or mortality, up to 10 individuals each of 10 species of beaked whale over the course of the 5-year period.

In July 2007, the U.S. Navy published a Draft Environmental Impact Statement and Overseas Environmental Impact Statement on activities the U.S. Navy planned to conduct in the Hawai'i Range Complex. The DEIS evaluated the potential effects of alternatives to the Navy's use of the range, including current and additional training activities and Research, Development, Test and Evaluation activities in the range.

On 14 October 14, 2008, NMFS published a proposed rule in the Federal Register on the U.S. Navy's request for a letter of authorization to "take" marine mammals incidental to training activities the U.S. Navy planned to conduct in the Southern California Range Complex ((73 Federal Register 60836).

In December 2008, the U.S. Navy issued its Final Environmental Impact Statement and Overseas Environmental Impact Statement on activities it planned to conduct in the Southern California Range Complex. In this supplement to the DEIS, the U.S. Navy developed and selected a new preferred alternative.

On 14 January 2009, NMFS signed its final programmatic biological opinion on the U.S. Navy's proposal to conduct training activities in the Southern California Range Complex. On 21 January 2009, NMFS' Permits Division provided NMFS' Endangered Species Division with copies of the Letter of Authorization it planned to issue for training activities the U.S. Navy planned to conduct in the Southern California Range Complex from January 2009 through January 2010.

BIOLOGICAL OPINION

1.0 Description of the Proposed Action

The proposed action consists of two separate but related activities: (1) the U.S. Navy proposal to conduct a suite of training activities in the Southern California Range Complex during the twelve-month period beginning in January

2009 and (2) the National Marine Fisheries Service's Permits, Conservation, and Education Division's (Permits Division) roposal to issue a Letter of Authorization that would allow the U.S. Navy to take marine mammals incidental to the U.S. Navy's training activities in the Southern California Range Complex.

The U.S. Navy proposes to conduct a suite of activities in the Southern California Range Complex over the twelve-month period beginning in January 2009. These activities include:

1. Major exercises in the Southern California Operating Area (Composite Training Unit Exercises and Joint Task Force Exercises),
2. Unit-Level training exercises,
3. Research, Development, Test, and Evaluation Activities,
4. Establishment of a West Coast Shallow Water Training Range, and
5. Expansion and relocation of a Shallow Water Minefield.

The Permits Division's Letter of Authorization only relates to the first three activities; the Letter of Authorization does not address the establishment of a West Coast Shallow Water Training Range or the expansion or relocation of a Shallow Water Minefield, although any "take" of marine mammals resulting from the use of mid-frequency active sonar and underwater detonations that would occur in these areas is included in the Letter of Authorization. The Letter of Authorization the Permits Division proposes to issue to the U.S. Navy addresses the "take" of marine mammals associated with up to 1,977 hours of AN/SQS-53, 494 hours of AN/SQS-56, 2,719 dips of helicopter dipping sonar (AN/AQS-22), 4,256 sonobuoys, 87 MK-48 torpedo events, 86 MK-46 torpedo events, 815 hours of submarine mounted sonar (AN/BQQ-10), and 122 hours of submarine navigational sonar.

The remainder of this section of the Opinion discusses these categories of activities in greater detail. Anyone interested in more information on specific activities or all of the activities should refer to the U.S. Navy's Final Environmental Impact Statement on the Southern California Range Complex (U.S. Navy 2008).

1.1 Major Training Exercises

Major training events in the Southern California Operating Area (or major range events) are composed of several unit level range training activities conducted by several units operating together while commanded and controlled by a single commander. These exercises typically employ exercise scenarios that are developed to train and evaluate Strike Groups and Strike Forces in requisite naval tactical tasks. In major range events, most of the activities are identical in nature to activities conducted in individual, crew, and smaller-unit training events; however, in major range events, these disparate training tasks are conducted in concert, rather than in isolation. The U.S. Navy conducts two categories of major training exercises in the Southern California Range Complex: Composite Training Unit Exercises (or COMPTUEX) and Joint Task Force Exercises (or JTFEX).

1.1.1 Composite Training Unit Exercise

Composite Training Unit Exercises (or COMPTUEX) are Integration Phase, at-sea, major range events. When they involve carrier strike groups, these exercises integrate an aircraft carrier and carrier air wing with surface and submarine units. When they involve expeditionary strike groups, these exercises integrate amphibious ships with their associated air wing, surface ships, submarines, and Marine Expeditionary Unit.

Live-fire activities that may take place during a COMPTUEX include long-range air strikes, Naval Surface Fire Support (which are discussed in greater detail in narratives that follow), and surface-to-air, surface-to-surface, and air-to-surface missile exercises. A Marine Expeditionary Unit also conducts realistic training based on anticipated operational requirements and to further develop the required coordination between Navy and Marine Corps forces. Special Operations training may also be integrated with the exercise scenario. These exercises typically last for 21 days and may include two 1-day, scenario-driven, "mini" battle problems, culminating with a scenario-driven 3-day final battle problem. Composite Training Unit Exercises have generally occurred three to four times per year.

1.1.2 Joint Task Force Exercise

Joint Task Force Exercises are also major range events that are the culminating exercises in Integrated Phase training for Carrier and Expeditionary Strike Groups. For Expeditionary Strike Groups, Joint Task Force Exercises incorporate Amphibious Ready Group Certification Exercises for amphibious ships and Special Operations Capable Certification for Marine Expeditionary Units. When schedules allow, these exercises may be conducted concurrently for a Carrier Strike Group and an Expeditionary Strike Group. These exercises normally last for 10 days (not including a 3-day force protection exercise that occurs in-port) and are the final at-sea exercise for the Carrier or Expeditionary Strike Groups before they are deployed. These exercises have generally occurred three to four times per year.

1.1.3 Coordinated Unit-Level Training

Coordinated unit-level training events, which pursue training tailored for components of a Strike Group, are complex exercises of lesser scope than Major Range Events. This type of training includes:

- Ship ASW Readiness and Evaluation Measuring (SHAREM), which allow the Navy to collect and analyze data that can be used to quantitatively "assess" the readiness of surface ships for effectiveness. The program typically involves multiple ships, submarines, and aircraft in several coordinated events over a period of a week or less. A SHAREM may take place once per year in the Southern California Training Range.
- Sustainment Exercise. The U.S. Navy requires post-deployment training and maintenance to ensure that components of Strike Groups maintain an acceptable level of readiness when they return from deployments. Sustainment exercises are designed to challenge strike groups in all warfare areas and are similar to a COMPTUEX but they are shorter in duration. One to two sustainment exercises may occur each year in the Southern California Training Range.
- Integrated ASW Course (IAC) Phase II. These exercises are combined aircraft and surface ship events and consist of two 12-hour events conducted primarily on Southern California ASW Range over a 2-day period. Typical participants include four helicopters, two maritime patrol aircraft (previously P-3 aircraft), two

adversary submarines, and two Mk 30 or Mk 39 targets. Four of these exercises may occur per year in the Southern California Training Range.

Anti-Air Warfare Training

This training encompasses events and exercises that train ship and aircraft crews to employ the Navy's various weapons systems against simulated threat aircraft or targets. It includes surface-to-air gunnery surface- to-air and air-to-air missile exercises and aircraft force-on-force combat maneuvers

Air Combat Maneuvers. Air combat maneuvers involve aircraft engaged in offensive and defensive flight maneuvers against each other. These maneuvers typically involve supersonic flight and use of chaff and flares. Air Combat Maneuver operations within the Southern California Range Complex are primarily conducted within W-291. These operations typically involve from two to eight aircraft. However, based upon the training requirement, Air Combat Maneuver exercises may involve over a dozen aircraft. Sorties can be as short as 30 minutes or as long as 2 hours, but the typical Air Combat Maneuver mission has an average duration of 1 to 2 hours. No weapons are fired during these exercises.

The U.S. Navy plans to conduct about 3,970 of these maneuvers each year in the Southern California Range Complex, which is an increase from the 3,608 of these maneuvers that are conducted each year under current schedules.

Air Defense Exercise. Air Defense Exercises consist of air-to-air and surface-to-air missile training events. These operations are coordinated between surface ships and aircraft. Tasks include radar detection, positioning, maneuver to a simulated airborne or surface firing position, and recovery of aircraft aboard an aircraft carrier. Air-to-air refueling may be included. These operations vary widely in the numbers of ships and aircraft involved and consist of a full array of tactics and procedures that are practiced between air and surface units for defense of the force. No weapons are fired during these exercises.

The U.S. Navy plans to conduct about 550 of these exercises each year in the Southern California Range Complex, which is an increase from the 502 exercises conducted each year under current schedules.

Surface-to-Air Missile Exercise. A surface-to-air missile exercise involves surface combatants firing live missiles (RIM-7 Sea Sparrows, SM-1 or SM-2 Standard Missiles) at target towed behind a commercial air services Lear jet, or by a specialized BQM-74 target (a remote controlled target drone, with a parachute to enable recovery at sea). The surface ship must detect, track, and engage the target using its onboard weapon systems. There are two types of missiles. One type of missile is equipped with an instrumentation package, while the other type is equipped with a warhead. Recoverable target drones are refurbished and reused.

The surface-to-air missiles are launched from ships located within Warning Area W-291. The U.S. Navy plans to conduct about 6 of these exercises each year in the Southern California Range Complex, which is an increase from the 1 of these exercises the U.S. Navy conducts in the range complex under current schedules. An exercise typically lasts 2 to 3 hours.

The U.S. Navy plans to conduct about 6 of these exercises each year in the Southern California Range Complex, which is an increase from the 1 exercise that is conducted each year under current schedules.

Surface-to-Air Gunnery Exercise. A Surface-to-Air gunnery exercise requires an aircraft or missile that will fly high or low altitude threat profiles. Commercial aircraft also tow a target drone unit that ships track, target, and engage with their surface-to-air weapon systems. Weapons crews practice tracking a target and also engage the target using main battery guns (5-inch or 76 mm naval guns), or Close-In Weapon Systems. The exercise lasts about two hours, and typically includes several non-firing tracking runs followed by one or more (up to five) firing runs. The target must maintain an altitude above 500 ft for safety reasons and is not destroyed during the exercise.

Typically six rounds of 5-inch Variable Timed, Non-Fragmentation (VTNF) ammunition and 12 rounds of 76 mm ordnance per gun mount are expended by each main battery gun mount involved in the exercise. Ships equipped with Close-In Weapons Systems can expend between 900 to 1400 rounds per mount per firing run for each firing run. The Close-In Weapons Systems fire 20 mm inert, projectiles made of tungsten. The number of these rounds expended during an exercise varies depending on the class of the ship involves, the weapons system installed, and the available ammunition allowance.

Gunnery exercise activities are conducted within Warning Areas W-291. The U.S. Navy plans to conduct about 350 of these exercises each year in the Southern California Range Complex, which is an increase from the 262 exercises conducted each year under current schedules.

Air-to-Air Missile Exercise. In an air-to-air missile exercise, missiles are fired from aircraft against unmanned aerial target drones such as BQM-34s and BQM-74s. Additionally, weapons may be fired against flares or Tactical Air Launched Decoys dropped by supporting aircraft. Typically, about half of the missiles fired have live warheads and half have telemetry packages. The fired missiles and targets are not recovered, with the exception of the BQM drones, which have parachutes and will float to the surface where they are recovered by boat.

Air-to-air missile exercises include 1 to 6 jet target drones, a flight of two aircraft operating at high speeds, and a weapons recovery boat for target recovery, and are conducted within Warning Area W-291. Targets are engaged by aircraft equipped with air-to-air missiles. Targets are tracked by the aircraft and then the air-to-air missiles are launched at the targets. Recoverable target drones and all recoverable elements are refurbished and reused. The U.S. Navy plans to conduct about 13 of these exercises each year in the Southern California Range Complex, which is the same number conducted each year under current schedules.

Antisubmarine Warfare Training

Anti-submarine warfare events could occur anywhere within the Southern California Operating Area; however, the U.S. Navy identified and used seven areas for their analyses because they are representative of the marine mammal habitats and the bathymetric, seabed, wind speed, and sound velocity profile conditions within the entire Southern California Operating Area. For purposes of the analyses the U.S. Navy presented in its Final EIS on the Southern California Range Complex, all anti-submarine warfare events were modeled as occurring in these areas.

Anti-Submarine Warfare Tracking Exercise (*Helicopter*). Antisubmarine Warfare Tracking Exercise Helicopter involves helicopters using sonobuoys and dipping sonar to search for, detect, classify, localize, and track a simulated threat submarine. Sonobuoys are typically employed by a helicopter operating at altitudes below 3,000 ft. and are deployed in specific patterns cover many different size areas, depending on submarine threat and water conditions. Both passive and active sonobuoys are employed.

The dipping sonar is employed from an altitude of about 50 ft after the search area has been narrowed based on the an sonobuoy search. Both passive and active sonar are employed. As the location of the submarine is further narrowed, a Magnetic Anomaly Device (MAD) is used by the MH-60R/B to further confirm and localize the target's location. The target for this exercise is either an MK-39 Expendable Mobile ASW Training Target (EMATT) or live submarine and may be either non-evading and assigned to a specified track, or fully evasive depending on the state of training of the helicopter. These exercises usually take one to two hours and may involve a single aircraft, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft or ships, including a major range event. No ordnance is expended.

The U.S. Navy plans to conduct about 1,690 of these exercises each year in the Southern California Range Complex, which is an increase from the 544 exercises conducted each year under current schedules.

Anti-Submarine Warfare Torpedo Exercise (*Helicopter*). The Antisubmarine Warfare Torpedo Exercise involves helicopters using sonobuoys and dipping sonar to search for, detect, classify, localize, and track a simulated threat submarine, as in the ASW Tracking Exercise (Helicopter). Torpedo exercises proceed to the release of an exercise torpedo against the target, which is typically an MK-39 Expendable Mobile ASW Training Target (EMATT) or MK-30 target system.

The U.S. Navy plans to conduct about 245 of these exercises each year in the Southern California Range Complex, which is an increase from the 187 exercises conducted each year under current schedules.

Anti-Submarine Warfare Tracking Exercise (*Maritime Patrol Aircraft*). The Antisubmarine Warfare Tracking Exercise-Maritime Patrol Aircraft involves fixed-wing maritime patrol aircraft (P-3s or P-8s) employing sonobuoys to search for, detect, classify, localize, and track a simulated threat submarine with the goal of determining a firing solution that could be used to launch a torpedo and destroy the submarine. Sonobuoys are typically employed by maritime patrol aircraft operating at altitudes below 3,000 ft. Sonobuoys are deployed in specific patterns based on the expected threat submarine and specific water conditions. These patterns will cover many different size areas, depending on these two factors. Both passive and active sonobuoys are employed. For certain sonobuoys, tactical parameters of use may be classified. A sonobuoy field pattern delivered by maritime patrol aircraft will typically be much larger than a helicopter pattern, because maritime patrol aircraft can carry and deploy more buoys than a helicopter, and can monitor more buoys at one time. Maritime patrol aircraft also operate at higher altitudes, which allows them to monitor buoys over a larger search pattern area.

The target for these exercises are either an MK-39 Expendable Mobile ASW Training Target (EMATT) or live submarine and may be either non-evading and assigned to a specified track, or fully evasive depending on the state of training of the helicopter. These exercises usually last for two to four hours and no ordnance is expended. The

U.S. Navy plans to conduct about 29 of these exercises each year in the Southern California Range Complex, which is an increase from the 25 that are conducted each year under current schedules.

Anti-Submarine Warfare Torpedo Exercise (*Maritime Patrol Aircraft*). The Antisubmarine Warfare Torpedo Exercise Maritime Patrol Aircraft involves patrol aircraft using sonobuoys to search for, detect, classify, localize, and track a simulated threat submarine, as in the tracking exercise involving helicopters. In addition, the TORPEX proceeds to the release of an exercise torpedo against the target (typically an MK-39 Expendable Mobile ASW Training Target or MK-30 target system).

The U.S. Navy plans to conduct about 17 of these exercises each year in the Southern California Range Complex, which is an increase from the 15 exercises conducted each year under current schedules.

Anti-Submarine Warfare EER/IEER Sonobuoy Deployment. This training event is an at-sea flying exercise designed to train maritime patrol aircraft crews in the deployment and use of the Extended Echo Ranging (EER) and Improved Extended Echo Ranging (IEER) sonobuoy systems. EER and IEER sonobuoy systems are airborne anti-submarine warfare systems used in conducting "large area" searches for submarines. These systems are made up of airborne avionics anti-submarine warfare acoustic processing and sonobuoy types that are deployed in pairs. The IEER System's active sonobuoy component, the AN/SSQ-110A Sonobuoy, would generate a sonar "ping" and the passive AN/SSQ-101 Air Deployable Active Receiver Sonobuoy would "listen" 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. After visual searching an area for marine mammals, 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 generating a "ping." There is only one detonation in the pattern of buoys at a time. Extended Echo Ranging training events and IEER event differ only in the number and type of sonobuoys used. An EER event uses an SSQ-77 as the receiver buoy, while an SSQ-101 is the receiver buoy during IEER events. Both training events use SSQ-110A sonobuoy as the signal source.

The U.S. Navy plans to conduct three of these exercises each year in the Southern California Range Complex, which is an increase from the two exercises conducted each year under current schedules.

Anti-Submarine Warfare Tracking Exercise (*Surface*). The Antisubmarine Warfare Tracking Exercise involves a surface ship employing hull mounted or towed array sonar against a target which may be an MK-39 Expendable Mobile ASW Training Target or live submarine. The target may be either non-evading and assigned to a specified track or fully evasive depending on the state of training of the ship and crew. Passive and active sonar may be employed depending on the type of threat submarine, the tactical situation, and water conditions that may affect sonar effectiveness. Active sonar transmits at varying power levels, pulse types, and intervals, while passive sonar listens for noise emitted by the threat submarine. Passive sonar is typically employed first for tactical reasons, followed by active sonar to determine an exact target location; however, active sonar may be employed during the initial search phase against an extremely quiet submarine or in situations where the water conditions do not support

acceptable passive reception. There is no ordnance expended in this exercise. These exercises usually last two to four hours and may involve a single ship, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft or ships, including a major range event.

The U.S. Navy plans to conduct about 900 of these exercises each year in the Southern California Range Complex, which is an increase from the 847 exercises conducted each year under current schedules.

Anti-Submarine Warfare Torpedo Exercise (*Surface*). The Antisubmarine Warfare Torpedo Exercise-Surface involves a surface ship using hull-mounted and towed sonar arrays to search for, detect, classify, localize, and track a simulated threat submarine, as in the tracking exercise (surface) discussed in the preceding narrative. In addition, these torpedo exercises proceed to the release of an exercise torpedo against the target, which is typically an MK-39 Expendable Mobile ASW Training Target or MK-30 target system.

The U.S. Navy plans to conduct about 25 of these exercises each year in the Southern California Range Complex, which is an increase from the 21 exercises conducted each year under current schedules.

Anti-Submarine Warfare Tracking Exercise (*Submarine*). The Antisubmarine Warfare Tracking Exercise-Submarine involves a submarine employing hull mounted or towed array sonar against a target which may be an MK-39 Expendable Mobile ASW Training Target or live submarine. During this event, passive sonar is used almost exclusively; active sonar use is tactically proscribed because it would reveal the tracking submarine's presence to the target submarine. The preferred range for this exercise is an instrumented underwater training range with the capability to track the locations of submarines and targets, to enhance the after action learning component of the training. There is no ordnance expended in this exercise. These exercises usually lasts two to four hours. This exercise may involve a single submarine, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft, ships, and submarines, including a major range event.

The U.S. Navy plans to conduct about 40 of these exercises each year in the Southern California Range Complex, which is an increase from the 34 exercises conducted each year under current schedules.

Anti-Submarine Warfare Torpedo Exercise (*Submarine*). The Antisubmarine Warfare Torpedo Exercise-Submarine involves a submarine employing hull mounted and/or towed array sonar against a target which may be an MK-39 Expendable Mobile ASW Training Target or MK-30 Mobile ASW Target, followed by launch of a MK-48 exercise torpedo. The exercise torpedo is recovered by helicopter or small craft. The preferred range for this exercise is an instrumented underwater range, but it may be conducted in other operating areas depending on training requirements and available assets.

The U.S. Navy plans to conduct about 22 of these exercises each year in the Southern California Range Complex, which is an increase from the 18 exercises conducted each year under current schedules.

Active Acoustic Devices

During anti-submarine warfare training exercises, the U.S. Navy uses tactical military sonars that were designed to search for, detect, localize, classify, and track submarines. The U.S. Navy typically employs two types of sonars: passive and active:

1. Passive sonars only listen to incoming sounds and, since they do not emit sound energy in the water, lack the potential to acoustically affect the environment.
2. Active sonars generate and emit acoustic energy specifically for the purpose of obtaining information concerning a distant object from the received and processed reflected sound energy. These sonars may produce high-frequency, mid-frequency, or low-frequency active sonar (although the U.S Navy does not currently employ low-frequency active sonar systems in the Southern California Training Range)

The simplest active sonars emit omnidirectional pulses or "pings" and calculate the length of time the reflected echoes return from the target object to determine the distance between the sonar source and a target. More sophisticated active sonar emits an omnidirectional ping and then scans a steered receiving beam to calculate the direction and distance of a target. More advanced sonars transmit multiple preformed beams, listening to echoes from several directions simultaneously and providing efficient detection of both direction and range. The types of sound sources that would be used in the anti-submarine warfare exercises discussed in the preceding narratives include:

Sonar Systems Associated with Surface Ships. A variety of surface ships participate in Navy training exercises, including guided missile cruisers, destroyers, guided missile destroyers, and frigates. Some ships (e.g., aircraft carriers) do not have any onboard active sonar systems, other than fathometers. Others, like guided missile cruisers, are equipped with active as well as passive sonars for submarine detection and tracking. For purposes of the analyses in this consultation, the primarily surface ship sonars considered are AN/SQS-53 and its variants with a nominal source level of 235 decibels (dB_{rms}) re 1 μPa at 1 m[1] and AN/SQS-56 having a nominal source level of 225 dB.

Sonar Systems Associated with Submarines. Submarines are equipped with a variety of active and passive sonar systems (for the purposes of this assessment, these primarily represent the mid-frequency AN/BQQ-10 sonar and the high-frequency AN/BQQ-15 sonar) that they use to detect and target enemy submarines and surface ships. However, submarines rarely use active sonars and, when they do, sonar pulses are very short.

Sonar Systems Associated with Aircraft. Aircraft sonar systems that typically operate during Navy training exercises include sonobuoys and dipping sonar. Current dipping sonar systems used by the Navy are either AN/SQS-22 or AN/AQS -13. AN/AQS -13 is an older and less powerful dipping sonar system (maximum source level 216 dB re μPa-s^2 at 1m) than the AN/AQS -22 (maximum source level 217 dB re μPa-s^2 at 1m). In its modeling, the Navy assumed that all dipping sonar were AN/AQS -22. Maritime patrol aircraft (P-3s or P-8s) may deploy sonobuoys while helicopters may deploy sonobuoys or dipping sonars (the latter are used by carrier-based helicopters). Sonobuoys are expendable devices used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Dipping sonar is an active or passive sonar device lowered on cable by

[1] All decibels cited in this document use the same reference unless noted otherwise

helicopters to detect or maintain contact with underwater targets. In addition, the U.S. Navy employs tonal sonobuoys (DICASS, AN/SSQ-62) and the Extended Echo Ranging and Improved Extended Echo Ranging (EER/IEER) Systems discussed earlier.

Torpedoes. Torpedoes (primarily MK-46 and MK-48) are the primary anti-submarine warfare 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 and using the received echoes for guidance.

Acoustic Device Countermeasures. These countermeasures (which include the AN/SLQ-25 NIXIE) act as decoys by making sounds that simulate submarines to avert localization or torpedo attacks.

Training Targets. Anti-submarine warfare training targets are used to simulate target 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.

Range Sources. Range pingers are active acoustic devices that allow each of the in-water platforms on the range (e.g., ships, submarines, target simulators, and exercise torpedoes) to be tracked by hydrophones in the range transducer nodes. In addition to passively tracking the pinger signal from each range participant, the range transducer nodes also are capable of transmitting acoustic signals for a limited set of functions. These functions include submarine warning signals, acoustic commands to submarine target simulators (acoustic command link), and occasional voice or data communications (received by participating ships and submarines on range).

Anti-Surface Warfare Training

Anti-Surface Warfare is a type of naval warfare in which aircraft, surface ships, and submarines employ weapons, sensors, and operations directed against “enemy” surface ships or boats. Aircraft-to-surface anti-surface warfare training is conducted using air-launched cruise missiles or other precision guided munitions, aircraft cannon, warships employing torpedoes, naval guns, and surface-to-surface missiles. Submarines also attack surface ships using torpedoes or submarine-launched, anti-ship cruise missiles. Training in anti-surface warfare includes surface-to-surface gunnery and missile exercises, air-to-surface gunnery and missile exercises, and submarine missile or torpedo launch events. Training generally involves expenditure of ordnance against a towed target. A sinking exercise (SINKEX) is a specialized training event that provides an opportunity for ship, submarine, and aircraft crews to use multiple weapons systems to deliver live ordnance on a deactivated vessel, which is deliberately sunk.

Anti-surface warfare also encompasses maritime interdiction, that is, the interception of a suspect surface ship by a Navy ship for the purpose of boarding-party inspection or the seizure of the suspect ship. Training in these tasks is conducted in Visit, Board, Search and Seizure exercises.

Visit, Board, Search, and Seizure. Visit, Board, Search, and Seizure is conducted to train helicopter crews to insert personnel onto a vessel for the purpose of inspecting the ship’s personnel and cargo for compliance with applicable

laws and sanctions. These exercises requires a cooperative surface ship. The typical duration of these operations is approximately between 2 and 3 hours.

The U.S. Navy plans to conduct about 90 visit, board, search, and seizure training events each year in the Southern California Range Complex, which is an increase from the 56 of these training events conducted each year under current schedules.

Anti-Surface Missile Exercise. These exercises train fixed winged aircraft and helicopter crews to launch missiles at surface maritime targets, day and night, with the goal of destroying or disabling enemy ships or boats. In the typical helicopter event, one or two helicopters approach and acquire an at-sea surface target, which is then designated with a laser to guide the missile to the target. Specially prepared targets with an expendable target area on a stationary floating or remote controlled platform are employed. The missile passes through the expendable target without damaging the platform and explodes near the surface of the water. Live Hellfire missiles are expended.

In a typical fixed-wing event, a flight of two aircraft approach an at-sea surface target from an altitude dictated by the missile parameters. The majority of fixed-wing exercises involve the use of captive carry training missiles (inert missiles that are not released); the aircraft perform all detection, tracking, and targeting requirements without actually releasing a missile. An anti-surface missile exercise that does not involve live ordnance may involve a single aircraft, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft, including a major range event. Live ordnance, if employed by a strike fighter aircraft would be either a SLAM-ER or Maverick missile. A patrol aircraft may launch SLAM-ER, Maverick, or Harpoon missiles. An anti-surface missile exercise that involves fixed-wing aircraft that deliver live ordnance typically would be carried out in conjunction with a sinking exercise.

In the Southern California Training Range, these exercises occur in Southern California ASW Range (denoted SOAR), Missile Impact Range, and Shore Bombardment Area (denoted SHOBA). The U.S. Navy plans to conduct about 50 anti-surface missile exercises each year in the Southern California Range Complex, which is an increase from the 47 conducted each year under current schedules.

Air-to-Surface Bombing Exercise. These exercises involve training of strike fighter aircraft and patrol aircraft in delivery of bombs against surface maritime targets in day or night conditions. Exercises for strike fighters typically involve a flight of two aircraft delivering unguided or guided munitions that may be either live or inert. Exercises at night will normally be done with captive carry (no drop) simulated guided weapons because of safety considerations. The very large safety footprints of precision guided munitions limit their employment to events at-sea, typically in conjunction with a Sinking Exercise. The following munitions may be employed by strike fighter in the course of the Bombing Exercise: Unguided munitions: MK-76 and BDU-45 (inert training bombs); MK-80 series (inert or live); MK-20 Cluster Bomb (inert or live). Precision-guided munitions: Laser-guided bombs (inert or live); Laser-guided Training Rounds (inert); Joint Direct Attack Munition (inert or live). Maritime patrol aircraft use bombs to attack surfaced submarines and surface craft that would not present a major threat to the maritime patrol aircraft themselves. Maritime patrol aircraft are larger and slower than an F/A-18, so its bombing tactics differ markedly. Single maritime patrol aircraft approach the target at a low altitude carrying MK-82 (500 lb bomb; inert or live); MK-20 (Rockeye cluster bomb; inert or live); CBU-99 (cluster bomb; inert or live). In most training exercises, it drops

inert training munitions, such as the BDU-45 on a MK-58 smoke float used as the target. This exercise may involve single maritime patrol aircraft, a flight of two strike fighters, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft and/ or ships, including a major range event or Sinking Exercise.

In the Southern California Training Range, these exercises occur in the Southern California ASW Range, the Missile Impact Range, and the Shore Bombardment Area. The U.S. Navy plans to conduct about 40 air-to-surface bombing exercises each year in the Southern California Range Complex, which is an increase from the 32 conducted each year under current schedules.

Air-to-Surface Gunnery Exercise. These exercises involve training of strike fighter aircraft and helicopters to employ guns to attack surface maritime targets in day or night. Sea targets simulate enemy ships, boats, or floating or near-surface mines. Land targets simulate enemy formations, vehicles or facilities. Exercises involving strike fighter aircraft typically involve a flight of two aircraft firing approximately 250 rounds of inert ammunition against either land (most often) or water targets. Helicopter exercises typically involve a single helicopter flying at an altitude between 50 ft to 100 ft in a racetrack pattern around an at-sea target. Several gunners will each expend about 200 rounds of .50 cal and 800 rounds of 7.62 mm ordnance in each exercise. 40mm grenades fired from hand-held weapons also may be expended. The target is normally a non-instrumented floating object such as an expendable smoke float, steel drum, or cardboard box, but may be a remote controlled speed boat or jet ski type target. Gunners will shoot special target areas or at towed targets when using a remote controlled target to avoid damaging them. The exercise lasts about 1 hour.

In the Southern California Training Range, these exercises occur in Warning Area W-291. The U.S. Navy plans to conduct about 60 air-to-surface gunnery exercises each year in the Southern California Range Complex, which is an increase from the 47 conducted each year under current schedules.

Surface-to-Surface Gunnery Exercise. These exercises involve training of crews manning small boats to use a machine guns to attack and disable or destroy a surface target that simulates another ship, boat, floating mine or near shore land targets. A number of different types of boats are used depending on the unit using the boat and their mission. Boats are most used by Naval Special Warfare teams and Navy Expeditionary Combat Command units with a mission to protect ships in harbors and high value units, such as: aircraft carriers, nuclear submarines, liquid natural gas tankers, etc., while entering and leaving ports, as well as to conduct riverine operations, insertion and extractions, and various naval special warfare operations. The boats used by these units include: Small Unit River Craft, Combat Rubber Raiding Craft, Rigid Hull Inflatable Boats, Patrol Craft, and many other versions of these types of boats. These boats use inboard or outboard, diesel or gasoline engines with either propeller or water jet propulsion.

This exercise is usually a live fire exercise, but blanks may be used so that the boat crews can practice their ship handling skills without being concerned with the safety requirements involved with live weapons. Boat crews may use high or low speeds to approach and engage targets simulating other boats, swimmers, floating mines, or near shore land targets with .50 cal, 7.62 mm, or 40 mm machine guns (about 200, 800, and 10 rounds respectively). The most common exercise target is a 50 gallon steel drum that is expended during the exercise and not recovered.

This exercise also involves ships' gun crews engaging surface targets at sea with their main battery 5- inch and 76 mm naval guns as well as small arms (25 mm, .50 cal, or 7.62 mm machine guns). There are three types of main battery shipboard guns currently in use: 5-inch/54, 5-inch/62, and 76 mm. Both 5-inch guns use the same types of 5-inch projectiles for training exercises. The difference between the 5-inch guns is the longer range of the 5-inch/62 because of the larger powder propulsion charge. Targets employed include the QST-35 Seaborne Powered Target (SEPTAR), High Speed Maneuverable Surface Target, or a specially configured remote controlled water craft.

The exercise proceeds with the target boat approaching from about 10 nm distance. The target is tracked by radar, and when it is within five to nine nm, it is engaged by approximately 60 rounds of 5-inch or 76 mm, (fired with an offset so as not to actually hit the targets) over a period of about 3 hours. After impacting the water, the live rounds are expected to detonate within 3 ft of the surface. Inert rounds and fragments from the live rounds will sink to the bottom of the ocean. This exercise may involve a single firing ship, or be undertaken in the context of a coordinated larger exercise involving multiple ships, including a major range event.

Ships use machine guns to practice defensive marksmanship, typically against stationary floating targets. The target is typically a 10-foot diameter red balloon tethered by a sea anchor, or a 50 gallon steel drum, or other available target, such as a cardboard box. Targets are expended during the exercise and are not recovered.

In the Southern California Training Range, these exercises occur in Warning Area W-291 and the Shore Bombardment Area. The U.S. Navy plans to conduct about 350 of these exercises each year in the Southern California Range Complex, which is an increase from the 315 conducted each year under current schedules.

Sinking Exercise (SINKEX). Sinking exercises are designed to train ship and aircraft crews in delivering live and inert ordnance on a real target. Each SINKEX uses an excess vessel hulk as a target that is eventually sunk during the course of the exercise. The hulk ship is towed to a designated location where various platforms would use multiple types of weapons to fire shots at the hulk. Platforms can consist of air, surface, and subsurface elements. Weapons can include missiles, precision and non-precision bombs, gunfire and torpedoes. If none of the shots result in the hulk sinking, either a submarine shot or placed explosive charges would be used to sink the ship. Charges ranging from 45 to 90 kilograms (100 to 200 pounds), depending on the size of the ship, would be placed on or in the hulk.

The vessels used as targets are selected from a list of destroyers, tenders, cutters, frigates, cruisers, tugs, and transports that has been approved for that use by the U.S. Environmental Protection Agency. Examples of missiles that could be fired at the targets include AGM-142 from a B-52 bomber, Walleye AGM-62 from FA-18 aircraft, and a Harpoon from maritime patrol aircraft. Surface ships and submarines may use either torpedoes or Harpoons, surface-to-air missiles in the surface-to-surface mode, and guns. Other weapons and ordnance could include, but are not limited to, bombs, Mavericks, Penguins, and Hellfire.

In the Southern California Training Range, these exercises occur in Warning Area W-291. The U.S. Navy plans to conduct about 2 sinking exercises each year in the Southern California Range Complex, which is an increase from 1 conducted each year under current schedules.

Amphibious Warfare Training

Amphibious warfare training exercises are designed to provide a realistic environment for amphibious assault training, reconnaissance training, hydrographic surveying, surf condition observance, and communication. Training forces are normally a mix of three to five amphibious ships equipped with aircraft landing platforms for helicopter and fixed wing events and well decks for carrying landing craft and assault amphibian vehicles. The training force typically launches its aircraft, and landing craft up to 40 kilometers (25 miles) from a training beachhead. Amphibious vehicles are typically launched approximately 1,829 meters (2,000 yards) from the beach. The aircraft provide support while the landing craft approach and move onto the beach. The troops disperse from the landing craft and would utilize existing vegetation for cover and concealment while attacking enemy positions. The landing craft and troops proceed to a designated area where they stay 1 to 4 days. The backload operation takes place when actions on the objective are completed. The backload is typically accomplished over a 2- to 3-day period.

Naval Surface Fire Support. Naval Surface Fire Support (NSFS) trains surface ships' crews to employ main battery guns in support of amphibious operations and operations by forces ashore. Naval Surface Fire Support normally consists of the bombardment of a target within an impact area on San Clemente Island's Shore Bombardment Area, by one or more ships. The ship is often supported by Navy or Marine spotters ashore, or by spotters embarked in fixed-wing aircraft or helicopters in the air, to call for the fire support from the ship, and to adjust the fall of shot onto the target. Target shapes simulate vehicles, aircraft or personnel on the ground.

The ship positions itself in the Naval Surface Fire Support area offshore of San Clemente Island about four to six nm from the target area to receive information concerning the target and the type and exact location of the target from the assigned spotter. One or more rounds are fired at the target. The fall of the round is observed by the spotter, who then tells the ship if the target was hit or if the ship needs to adjust where the next round should fall. More shots are fired, and once the rounds are falling on the target, then the spotter will request a larger number of rounds to be fired to effectively destroy the target. Typically five rounds are fired in rapid succession (about one round every five to seven seconds). Ten or more minutes will pass, and then similar missions will be conducted until the allocated number of rounds for the exercise has been expended. About 70 rounds of 5-inch inert or high explosive ordnance (typically 53% live and 47% inert), in addition to about 5 rounds of illumination are expended during a Naval Surface Fire Support Exercise (FIREX). Portions of the exercise are conducted during both the day and the night to achieve full qualification. A ship would normally conduct three of these exercises at different levels of complexity over several months to become fully qualified.

A Shore Fire Control Party (SFCP) can consist of about 10 personnel who supply target information to the ship. From positions on the ground, the Navy, Marine, or naval special warfare personnel who make up the SFCP provide the target coordinates at which the ship's crew directs its fire. As the rounds fall, the SFCP records where the rounds falls and provide adjustments to the fall of shot, as necessary, to ensure the target is "destroyed."

This exercise may involve a single ship, or be undertaken in the context of a coordinated larger exercise involving multiple ships, aircraft conducting bombing exercise or close air support missions in support of troops on the ground, or artillery located ashore on San Clemente Island including a major range event. The locations and opportunities for live-fire from a ship at sea to targets ashore are very limited, and often the training range area is not adequate to establish and maintain surface fire support proficiency. A technology solution has been developed to precisely

determine the impact of rounds fired at a simulated or virtual land area containing virtual targets located in the ocean, which enables ships to complete Naval Surface Fire Support training in the absence of a land target or impact area.

Naval Surface Fire Support Exercises are conducted very similarity to Fire Support Exercise (Land) from a ship's perspective, even though these exercises are conducted completely at sea. About 5 to 70 rounds of 5-inch inert or high explosive ordnance and five rounds of illumination are expended per exercise over several hours. All exercises are conducted in daylight and outside of 12 nm from land in order to have sufficient sea space to maneuver the ship and lay out the IMPASS sonobuoy pattern.

These exercises typically occur over a 2- to 3-day period. The U.S. Navy plans to conduct about 52 naval surface fire support exercises each year in the Southern California Range Complex, which is an increase from the 47 exercises conducted each year under current schedules.

Expeditionary Fires Exercise. Expeditionary Fires Exercise/Supporting Arms Coordination Exercises are major training exercises oriented around Naval Surface Fire Support and Marine artillery fires in support of ground amphibious operations. The mission of the exercises is to achieve effective integration of Naval gunfire, close air support, and artillery fire support. These exercises typically last for eight days, during which an Expeditionary Strike Group commander runs a schedule-of-operations driven exercise.

Expeditionary Fires Exercise/Supporting Arms Coordination Exercise are the final evaluation of amphibious warfare, conventional warfare, and special operations capability and serves as the formal pre-deployment coordination exercise of the supporting arms capabilities of Expeditionary Strike Group. This exercise involves employment of live ordnance by an artillery battery (six howitzers), 81 mm mortars (eight mortars), four AH-1Ws attack helicopters, six fixed wing strike fighter or attack aircraft, two Naval Surface Fire Support ships, and associated spotting teams, controllers, and liaison personnel. Additional support elements can include an additional artillery battery for simulated naval gunfire and additional aircraft from a carrier air wing.

The U.S. Navy plans to conduct about 8 expeditionary fires exercises each year in the Southern California Range Complex, which is a slight increase from the 6 exercises conducted each year under current schedules.

Expeditionary Assault – Battalion Landing. Battalion landing operations are proposed for San Clemente Island because the island's challenging terrain, high plateaus, and shallow beaches provide the a superior littoral training environment, and the only range area in the U.S. inventory at which live Naval Surface Fire Support may be coordinated with amphibious landing operations. Proposed operations would employ a Marine Air Ground Task Force of approximately 1,500 personnel including infantry, armored vehicle, logistics, command and control, and aviation personnel and their aircraft, vehicles, and other weapons systems. This exercise would last up to 4 days and occur up to two times per year. The amphibious forces would land by helicopter and across the beach by amphibious landing craft and amphibious vehicles This exercise may involve a single ship, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft and/ or ships, including a major range event. The concept of operations around which the Battalion Landing is being analyzed includes the following:

Day 1. An opposition force of one infantry company would land by helicopter at VC-3 and take up positions to defend the airfield. The company of about 140 would bivouac in the field, remaining within the Infantry Operations Area. A small reconnaissance unit (12 Marines) would land by rubber boat at Eel Cove and proceed on foot in tactical formation, across open country, not using established roadways.

Day 2. Multiple company-sized units embarked in boats, landing craft, or vehicles would land at Northwest Harbor, West Cove, Wilson Cove, and Horse Beach. These units would execute a coordinated attack on a designated objective such as VC-3, using the Infantry Operations Area as the boundary of their operation. Tanks, Expeditionary Fighting Vehicles and other amphibious assault vehicles would remain in the Assault Vehicle Maneuver Corridor. The size (width) of the Assault Vehicle Maneuver Corridor is a critical factor in providing a realistic training venue for armored vehicles.

Day 3. Operations would continue across San Clemente Island in accordance with exercise objectives. Day 4. Forces would redeploy off the island. Aircraft would support all phases of the operation. Live-fire training operations would take place in day and night.

The U.S. Navy plans to conduct two battalion landing exercises each year in the Southern California Range Complex, which are new activities for this range complex.

Stinger Firing Exercise. The Stinger missile is a portable, shoulder fired weapon that also may be mounted on and fired from a vehicle. Stinger firing has occurred in the past; however not for several years. Proposed stinger training would be conducted from positions on-shore in the Shore Bombardment Area, toward the ocean, not over land, at target drones, either Ballistic Aerial Targets or Remotely Piloted Vehicles. Ballistic Aerial Targets are solid-rocket, ground-launched glider targets that are destroyed upon impact with the water; they are not recovered. Remotely Piloted Vehicles are small, gasoline-powered aircraft, are remote controlled, and can be used repeatedly if they are not damaged during an exercise.

The U.S. Navy plans to conduct four stinger firing exercises each year in the Southern California Range Complex, which are new activities for this range complex.

Amphibious Landings and Raids. San Clemente Island supports training of small units of Marines or Naval Special Warfare personnel in the conduct of amphibious operations using small boats, amphibious craft or assault amphibian vehicles. Training includes both live-fire and non-live-fire events, including reconnaissance missions, raids, tactical recovery of aircraft and personnel exercises, assault amphibian vehicle landing events. These events typically involve units of from 12 to 40 personnel, and may be conducted across beaches at Wilson Cove, Horse Beach Cove, Northwest Harbor, and Eel Point, and in any of various training areas designated on San Clemente Island.

The U.S. Navy plans to conduct about 66 amphibious landings and raids each year in the Southern California Range Complex, which is an increase from the 7 exercises conducted each year under current schedules.

Amphibious Operations. The ocean area adjacent to Camp Pendleton is designated as the Camp Pendleton Amphibious Assault Area or CPAAA. This area is utilized extensively for amphibious training by units of the 1st

Marine Expeditionary Force, 1st Marine Division, and 1st Marine Logistics Group. Training events conducted by these operating forces in this area include: reconnaissance unit training, small boat unit training, assault amphibian vehicle crew and unit training, and Marine Expeditionary Unit (Special Operations Capable) events, and Expeditionary Strike Group training. Initial training to qualify marines to operate amphibian vehicles is conducted by the Assault Amphibian School Battalion in the CPAAA. Naval Beach Groups, which operate Landing Craft, Air Cushioned vehicles utilize the CPAAA for training. The Amphibian Vehicle Test Branch conducts research, development, test and evaluation of vehicles including EFVs in the CPAAA. Events conducted in the CPAAA include:

- amphibious demonstrations
- amphibious raids
- amphibious assaults
- amphibious withdrawals
- basic amphibious training
- amphibious support training
- parachute operations
- submarine operations (wet deck/dry deck)
- diving operations
- scout swimmer training
- Tactical Recovery of Aircraft and Personnel (TRAP)

The U.S. Navy plans to conduct about 2,276 amphibious operations each year in the Southern California Range Complex, which is an increase from the 2,205 exercises conducted each year under current schedules.

Electronic Combat Training

Electronic Combat operations consist of air-, land-, and sea-based emitters simulating enemy systems and activating air, surface and submarine electronic support measures (ESM) and electronic countermeasures systems. Appropriately configured aircraft fly threat profiles against the ships so that crews can be trained to detect electronic signatures of various threat aircraft, or so that they can be trained to detect counter jamming of their own electronic equipment by the simulated threat.

The U.S. Navy plans to conduct about 775 electronic combat exercises each year in the Southern California Range Complex, which is an increase from the 748 exercises conducted each year under current schedules.

Mine Warfare Training

Mine warfare training involves training Navy personnel to detect, avoid, and neutralize mines to protect Navy ships and submarines, and offensive mine laying in naval operations. Naval mines are self-contained explosive devices placed in water to destroy ships or submarines and are deposited and left in place until triggered by the approach of

or a contact with an enemy ship, or are destroyed or removed. Naval mines can be laid by purpose-built minelayers, other ships, submarines, or airplanes. Mine warfare training includes Mine Countermeasures Exercises and Mine Laying Exercises.

Mine Countermeasures Exercise. Mine Countermeasures (MCM) consists of mine avoidance training and mine neutralization training. These events trains surface ships and aircraft to detect and either avoid or neutralize mines. Training utilizes simulated minefields constructed of moored or bottom mines, or instrumented mines that can record effectiveness of mine detection efforts. Mine or small object avoidance training for surface ships involves use of mid-frequency active sonar systems to detect mines. Submarines also have the capability to detect mines utilizing organic sonar; however, use of active sonar is tactically proscribed for submarines as it allows detection. Therefore, MCM training is primarily conducted by surface ships. Ship or submarine-mounted mid-frequency active sonar systems employed are: AN/SQS-53, AN/SQS-56, AN/SQQ-32, AN/BQQ-5 or 10. Helicopters engaged in airborne MCM training use equipment that includes: AN/AQS-20 Mine Hunting System (employing side-looking sonar); AN/AES-1 Airborne Laser Mine Detection System; and AN/ALQ-220 Organic Airborne Surface Influence Sweep

Mine countermeasures exercises typically last one or two hours for surface ships and helicopters, and may last up to 15 hours for specially configured MCM ships. Navy units typically conduct mine countermeasures training in stand-alone events, involving few aircraft, or single ships or submarines, however mine countermeasures training may occur in the context of a coordinated larger exercise involving multiple aircraft, ships, and submarines, including a major range event.

The U.S. Navy plans to conduct about 48 mine countermeasures exercises each year in the Southern California Range Complex, which is a slight increase from the 44 exercises conducted each year under current schedules.

Mine Neutralization. Mine Neutralization operations involve the detection, identification, evaluation, rendering safe, and disposal of mines and unexploded ordnance (which the Navy abbreviates as UXO) that constitutes a threat to ships or personnel. Mine neutralization training is conducted by a variety of air, surface and sub-surface assets.

Tactics for neutralizing 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 a military expeditionary assault, the U.S. Navy deploys 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 exercises. The total net explosive weight used against each mine ranges from less than less than 1 pound to 20 pounds.

Occasionally, marine mammals are used in mine detection training operations. The U.S. Navy's Very Shallow Water Mine Countermeasures Detachment of Commander Mine Warfare Command deploys trained Atlantic bottlenose dolphins of their marine mammal mine-hunting systems in several missions. Each mission includes up to four motorized small craft, several crew members and a trained dolphin. Exercises using dolphins are coordinated with other U.S. Navy units to avoid conflicts with other U.S. Navy activities, underwater acoustic emissions associated

with those activities, or civilian craft. Any unplanned situation that has the potential for exposing a dolphin to dangerous or conflicting underwater acoustic emissions or other interference is mitigated by recalling it into a small craft and moving the dolphin out of the area. As such, these marine mammals are continuously protected.

All underwater demolition activities are currently conducted in accordance with Commander Naval Surface Forces Pacific Instruction 3120.8F, Procedures for Disposal of Explosives at Sea/Firing of Depth Charges and Other Underwater Ordnance (Department of the Navy 2003) or other appropriate authority. Before any explosive is detonated, divers are transported a safe distance away from the explosive. Standard practices for tethered mines is to tie off the explosive counter charge as closely as possible to the mine case. For mines on the shallow water floor (less than 40 feet of water), only areas that avoid or minimize potential impacts to coral are used for explosive charges.

Mine neutralization operations take place offshore in the shallow water training range offshore near Cortex and Tanner Banks. The U.S. Navy plans to conduct about 732 mine neutralization exercises each year in the Southern California Range Complex, which are not conducted each year under current schedules.

Mine Laying. Mine laying operations are designed to train forces to conduct offensive (deploy mines to tactical advantage of friendly forces) and defensive (deploy mines for protection of friendly forces and facilities) mining operations. Mines can be laid from the air (FA-18/P-3) or by submarine.

Airborne mine laying involves one or more aircraft and either computer-simulated or inert exercise mines. Mine warfare operations are limited to either simulations of mines deployed from aircraft, where no actual mine ordnance is dropped, or the use of inert exercise mines or inert exercise submarine-deployed mines. The use of inert exercise mines is generally limited to areas greater than 100 fathoms, or 600 feet in depth. Before dropping inert exercise mines, the crew visually determines that the area is clear. Although the altitude at which inert exercise mines are dropped varies, the potential for drift during descent generally favors release at lower altitudes, where visual searches for marine mammals are more effective. When the inert exercise mine is released, a small parachute retards its entry into the ocean. The mine can be designed to float on the surface or near surface or to sink on a tether. Ultimately the mine sinks carrying the parachute with it. Standard Navy procedures are followed for the deployment of inert mines from submarines.

Fixed-winged aircraft and submarines lay offensive or defensive mines to create a tactical advantage for friendly forces. Offensive mines prevent enemy shipping from leaving an enemy port or area, or supplies from entering an enemy port or area. Defensive mines protect friendly forces and facilities by preventing enemy forces from entering the friendly port or area. At the basic level of training, fixed winged aircraft use precise navigation to lay a minefield pattern for a specific tactical situation. A flight of two strike fighter aircraft or a single Maritime patrol aircraft attempt to fly undetected to the area where the mines will be laid and use either a low or high altitude tactic to lay the mines. The aircrew typically drops a series of four inert training shapes (MK-76, BDU-45, or BDU-48), making multiple passes in the same flight pattern, and dropping one or more shapes each time. The shapes are scored for accuracy as they enter the water, and the aircrew is later debriefed on their performance. Advanced training scenarios involve multiple aircraft to evaluate the ability of an entire squadron to plan, load, and execute a mine-

laying mission. The aircraft drop their shapes in a pre-determined pattern and return to the carrier or base. Since the final location of each mine shape is of tactical importance, the drops are scored and the shapes are recovered.

Submarine mine laying exercises are typically "virtual" with no expenditure of any mine shape or any range requirements. The U.S. Navy plans to conduct about 18 mine laying exercises each year in the Southern California Range Complex, which is a slight increase from the 17 exercises conducted each year under current schedules.

Navy Special Operations Training

Naval Special Warfare forces (SEALs and Special Boat Units) train to conduct military activities in five Special Operations mission areas: unconventional warfare, direct action, special reconnaissance, foreign internal defense, and counterterrorism. Naval Special Warfare training events include: insertion/extraction operations using parachutes rubber boats, or helicopters; boat-to-shore and boat-to-boat gunnery; demolition training on land or underwater; reconnaissance; and small arms training.

NSW Land Demolition. Naval Special Warfare or Explosive Ordnance Disposal personnel train in use of explosive charges to destroy land mines, explosives such as improvised explosive devices, unexploded ordnance, structures, or other items as required. The size of an explosive charge is defined in terms of net explosive weight. Charge sizes typically employed range from 1 to 20 pounds (net explosive weight).

The U.S. Navy plans to conduct 674 of these exercises each year in the Southern California Range Complex, which is an increase from the 354 exercises conducted each year under current schedules.

Underwater Demolition. Naval Special Warfare or Explosive Ordnance Disposal personnel use small explosive charges to destroy obstacles or other structures in an underwater area that could cause interference with friendly or neutral forces and planned operations. There are basically three types of underwater demolition: Single charges, Mat Weave, and Obstacle Loading. Single charge training includes smaller explosives between 5 and 20 lb (2 and 9 kg) of C-4 and detonation cord. The charges are assembled on the beach and placed in 5-20 ft of water.

In a typical training scenario, Naval Special Warfare or Explosive Ordnance Disposal personnel locate barriers or obstacles designed to block amphibious vehicle access to beach areas, then use small explosive charges to destroy them. These training events typically use less than five pounds (net explosive weight) of explosives which are detonated near the shoreline in water less than 21 ft deep.

The U.S. Navy plans to conduct 85 single-charge exercises each year in the Southern California Range Complex, which is an increase from the 72 exercises conducted each year under current schedules. The U.S. Navy plans to conduct 18 multiple charge exercises each year, which is an increase from the current 14 exercises conduct each year under current schedules.

Small Arms Training. Navy personnel training in the use small arms and small unit tactics to defend unit positions or attack simulated enemy positions. Small arms training exercises may include use of 9 mm pistols, 12-gauge shotguns, 5.56 mm automatic rifles, .50 caliber, 7.62 mm, 5.56 mm machine guns, and 40 mm grenades. Training involving live-fire of small arms may be conducted on marksmanship training ranges with fixed firing points and

fixed targets, or may occur in free-play training events with firing positions dictated by the training scenario and use of mobile or pop-up targets. While small arms training events typically occur on designated ranges ashore on San Clemente Island, training of personnel also is conducted aboard surface ships at sea firing into the sea.

The U.S. Navy plans to conduct 205 of these exercises each year in the Southern California Range Complex, which is an increase from the 171 exercises conducted each year under current schedules.

Land Navigations. Training in land navigation is conducted on San Clemente Island by individuals and small units on foot utilizing maps, compasses, and other navigation aids on established courses.

The U.S. Navy plans to conduct 118 of these exercises each year in the Southern California Range Complex, which is an increase from the 99 exercises conducted each year under current schedules.

NSW/UAV/UAS Operations. Unmanned Aerial Vehicles (UAV) obtain information about the activities of an enemy or potential enemy or tactical area of operations by use of various onboard surveillance systems including: visual, aural, electronic, photographic, or other means. There are currently numerous types of Unmanned Aerial Vehicles employed to obtain intelligence data on threats. Unmanned Aerial Vehicles are typically flown at altitudes well above 3,000 ft in patterns to best collect the required data, yet remain beyond the reach threat weapon systems. The Unmanned Aerial Vehicles may be controlled by a pilot at a remote location, just as if the pilot were onboard, or may fly a preplanned, preprogrammed route from start to finish. Missions will typically last four to six hours, but will vary depending on the scheduled mission training. Training occurs in restricted airspace on and above San Clemente Island.

The U.S. Navy plans to conduct 1,176 of these exercises each year in the Southern California Range Complex, is an increase from the 72 exercises conducted each year under current schedules.

Insertion/Extraction. Naval Special Warfare and other personnel train to approach or depart an objective area using various transportation methods and tactics. These activities train forces to insert and extract personnel and equipment day or night. Tactics and techniques employed include insertion from aircraft by parachute, by rope, or from low, slow-flying helicopters from which personnel jump into the water. Parachute training is required to be conducted on surveyed drop zones to enhance safety. Insertion and extraction methods also employ submarine deliver of personnel into the water, and small inflatable boats.

Insertion and extraction training typically is conducted in the context of additional related exercises, and such as direct action training of naval special warfare personnel, live-fire small arms training, and NSFS spotter training.

The U.S. Navy plans to conduct 15 of these exercises each year in the Southern California Range Complex, which is an increase from the 5 exercises conducted each year under current schedules.

NSW Boat Operations. Naval Special Warfare personnel assigned to Special Boat Units train in open ocean and littoral activities, including in the vicinity of San Clemente Island. Training events include firing of crew-served machine guns and hand held weapons into land impact areas of the Shore Bombardment Area.

The U.S. Navy plans to conduct 320 of these exercises each year in the Southern California Range Complex, which is an increase from the 287 exercises conducted each year under current schedules.

SEAL Platoon Training Activities. SEAL platoons perform special operations using tactics that are applicable to the specific tactical situations where the Naval Special Warfare personnel are employed. They are specially trained, equipped, and organized to conduct special operations in maritime, littoral, and riverine environments. San Clemente Island is a principal training venue for SEAL platoons and other Naval Special Warfare personnel. Naval Special Warfare personnel train to move covertly or overtly, by sea, air, or land, to an area of operation as the tactical situation demands and perform those tasks required to capture a site, destroy a target, rescue personnel, or perform a multitude of operations against hostile forces, using weapons required by the tactical situation. Opposing forces and targets within training range areas are utilized for realism. Typically, Naval Special Warfare personnel employ a variety of live fire or blank small arms and explosive ordnance in the course of training. SEAL platoon training may be conducted in isolation, or may occur in the context of larger-scale events and exercises, including major range events.

The U.S. Navy plans to conduct 668 of these exercises each year in the Southern California Range Complex, which is an increase from the 340 exercises conducted each year under current schedules.

NSW Direct Action. Direct action training is a specialized Naval Special Warfare event involving a squad or platoon size force of personnel inserted into and later extracted from a hostile area by helicopter, small boat or other means to conduct live-fire offensive actions against simulated hostile forces or targets. These offensive actions can include: raids, ambushes, standoff attacks, designating or illuminating targets for precision-guided munitions, providing support for cover and deception operations, and sabotage. Small arms such as 7.62 mm, 5.56 mm, 9 mm, 12-gauge, 40 mm grenades, laser illuminators, and other squad or platoon weapons are typically employed

The U.S. Navy plans to conduct 190 of these exercises each year in the Southern California Range Complex, which is an increase from the 156 exercises conducted each year under current schedules.

Strike Warfare Training

Strike Warfare operations include training of fixed-wing fighter/attack aircraft in delivery of precision guided munitions, non-guided munitions, rockets, and other ordnance against land targets in all weather and light conditions. Training events typically involve a simulated strike mission with a flight of four or more aircraft. The strike mission may simulate attacks on “deep targets” (i.e., those geographically distant from friendly ground forces), or may simulate close air support of targets within close range of friendly ground forces. Laser designators from aircraft or ground personnel may be employed for delivery of precision guided munitions. Some strike missions involve no-drop events in which prosecution of targets is simulated, but video footage is often obtained by onboard sensors.

Bombing Exercise (*Land*). These exercises train crews of strike fighter aircraft or helicopter to deliver ordnance against land targets in day or night conditions. A bombing exercise may involve Close Air Support training in direct support of and in close proximity to forces on the ground, such as Naval Special Warfare or marine forces engaged

in training exercises on San Clemente Island. For strike fighter aircraft, in a typical exercise at the basic level, a flight of two aircraft will approach the target from an altitude of between 15,000 ft to less than 3,000 ft and, when on an established range, will usually establish a racetrack pattern around the target. The pattern is established in a predetermined horizontal and vertical position relative to the target to ensure that all participating aircraft follow the same flight path during their target ingress, ordnance delivery, target egress, and "downwind" profiles. This type of pattern is designed to ensure that only one aircraft will be releasing ordnance at any given time. The typical bomb release altitude is below 3,000 ft and within a range of 1,000 yards for unguided munitions; above 15,000 ft and may be in excess of 10 nm for precision-guided munitions. Exercises at night will normally be done with captive carry (no drop) weapons because of safety considerations. Laser designators from the aircraft dropping the bomb, a support aircraft, or ground support personnel are used to illuminate certified targets for use with lasers when using laser guided weapons.

Advanced-level training events for strike fighters typically involve a flight of four or more aircraft, with or without a designated opposition force. Participating aircraft attack the target using tactics which may require that several aircraft approach the target and deliver their ordnance simultaneously from different altitudes and/or directions. An E-2 aircraft is typically involved in this exercise from a command and control perspective, and an EA-18G aircraft may provide electronic combat support in major range events.

The following munitions may be employed by strike fighters in the course of the Bombing Exercise: Unguided munitions: MK-76 and BDU-45 (inert training bombs); MK-80 series (inert or live); MK-20 Cluster Bomb (inert or live). Precision-guided munitions: Laser-guided bombs (inert or live); Laser-guided Training Rounds (inert); Joint Direct Attack Munition (inert or live). Rockets: 5-inch Zuni rockets.

Helicopter training involves one or two helicopters approaching an assigned target. The target is attacked with guns, Zuni rockets, or a Hellfire missile. A laser is used to guide a Hellfire missile to the target. The laser designator is either the one of the attacking aircraft or a designator team (typically Naval Special Warfare or Marine forces) on the ground. The helicopter launches one live missile per exercise from an altitude of about 300 ft while in forward flight or in a hover, against a specially prepared target. The target can be a stationary target or a remote controlled vehicle whose infrared signature has been augmented with a heat source to better represent a typical threat vehicle.

The U.S. Navy plans to conduct about 216 of these exercises each year in the Southern California Range Complex, which is an increase from the 176 conducted each year under current schedules.

Combat Search and Rescue. Combat Search and Rescue training involves fixed-winged aircraft, helicopters and / or submarines using tactical procedures to rescue military personnel within a hostile area of operation. In a helicopter training scenario, helicopters fly below 3,000 ft the target area. Machine guns (7.62 mm or 5.56 mm) are mounted in the side door, and blank ammunition is normally used in this exercise. Chaff and flares may be expended if a surface-to-air or air-to-air threat or opposing force is employed to provide additional complexity. Naval Special Warfare personnel may be embarked during this exercise to act as the rescue party. This Naval Special Warfare squad would debark from the helicopter, "rescue" the personnel to be recovered, and return to the helicopter to be removed from the area. This basic exercise would last about one and a half hours. More advanced training would involve command and control aircraft and strike fighter aircraft in a role as a combat air patrol. In a submarine

training scenario, the submarine proceeds to a specified location near land, locates the persons to be rescued, and surfaces to embark them. This exercise may involve a single helicopter or submarine, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft or ships, including a major range event.

The U.S. Navy plans to conduct about eight of these exercises each year in the Southern California Range Complex, which is an increase from the seven conducted each year under current schedules.

Explosive Ordnance Disposal Activities. Explosive Ordnance Disposal personnel train to gain and maintain qualification and proficiency in locating, neutralizing or destroying unexploded ordnance and conducting other hazardous range clearance activities. Removal of unexploded ordnance is important for personnel safety and environmental sustainability of ranges. Operations are conducted in impact areas on San Clemente Island. These activities are similar in nature to the activities described under the heading Land Demolition, the difference being that EOD range clearance actions are not undertaken in a tactical training environment, but are administrative in nature.

The U.S. Navy plans to conduct 10 of these exercises each year in the Southern California Range Complex, which is an increase from the four that are conducted each year under current schedules.

United States Coast Guard Training

Coast Guard Sector San Diego is a command within the Coast Guard 11th District. The Sector San Diego Area Of Responsibility extends from the border with Mexico north to Dana Point. Coast Guard personnel regularly train in maritime rescue and patrol activities in the Southern California Range Complex, using a variety of boats, small ships, and helicopters.

The U.S. Coast Guard plans to continue conducting 1,022 of these training activities each year in the Southern California Range Complex.

Naval Auxiliary Landing Field Airfield Activities

The Naval Auxiliary Landing Field (NALF) on San Clemente Island supports aviation events, including training and logistics activities. The primary training activity conducted at the NALF is Field Carrier Landing Practice, which are characterized by touch-and-go practice in day and night conditions on a simulated aircraft carrier outline marked on the landing field. The NALF also supports regular resupply and personnel transport aircraft runs between San Clemente Island and mainland bases.

The U.S. Navy plans to conduct about 33,000 of these tests each year in the Southern California Range Complex, which is an increase from the 26,376 conducted each year under current schedules.

Research, Development, Test, and Evaluation Activities

Space and Naval Warfare Systems Center conducts research, development, test and evaluation; engineering; and Fleet support for command, control, and communications systems and ocean surveillance. Space and Naval Warfare System's tests on San Clemente Island include ocean engineering, missile firings, torpedo testing, manned and un-

manned submersibles, Unmanned aerial vehicles, electronic countermeasures, and other Navy weapons systems as follows:

Ship Torpedo Tests. This is a test event for reliability, maintainability, and performance of Exercise (EXTORP) and Recoverable Exercise Torpedoes (REXTORP). These events include torpedo firing.

The U.S. Navy plans to conduct about 20 of these tests each year in the Southern California Range Complex, which is a reduction from the 22 conducted each year under current schedules.

Unmanned Underwater Vehicles. These are in-water events for the development and operational testing of advanced designs of underwater vehicles, conducted in the vicinity of Naval Ordnance Test Station Pier.

The U.S. Navy plans to conduct about 15 of these tests each year in the Southern California Range Complex, which is an increase from the 10 conducted each year under current schedules.

Sonobuoy QA/QC Testing. This testing event evaluates random lots of sonobuoys and determine the quality of the set. The sonobuoys are dropped from an aircraft into the San Clemente Island Underwater Range area east of San Clemente Island. Defective buoys are recovered. All non-defective buoys are scuttled.

The U.S. Navy plans to conduct about 120 of these tests each year in the Southern California Range Complex, which is an increase from the 117 conducted each year under current schedules.

Ocean Engineering. Ocean engineering tests determine the characteristics, reliability, maintainability and endurance of various pieces of marine design. The items to be tested are left in the water off NOTS Pier for an extended period, and are monitored by Navy personnel.

The U.S. Navy plans to conduct about 242 of these tests each year in the Southern California Range Complex, which is the same number conducted each year under current schedules.

Marine Mammal Mine Shape Location/Research. In this series of events, trained marine mammals are taught to locate and mark inert mine shapes. The marine mammals, most of which are Atlantic bottlenose dolphins, are penned and cared for at Naval Base Point Loma, and transported to San Clemente Island for mine location and applied research.

The U.S. Navy plans to conduct about 30 of these tests each year in the Southern California Range Complex, which is an increase from the 5 conducted each year under current schedules.

Missile Flight Tests. Missile flight test events confirm performance, reliability, maintainability and suitability for operational use of various missiles in the Navy inventory. Tests involve launches from operational ships and aircraft from within either the Point Mugu Sea Range or the Southern California Range Complex against airborne targets in W-291, or land targets in the Missile Impact Range on San Clemente Island

The U.S. Navy plans to conduct about 20 of these tests each year in the Southern California Range Complex, which is an increase from the 5 conducted each year under current schedules.

NUWC Underwater Acoustics Testing. These tests are conducted to evaluate the accuracy of several acoustic and non-acoustic ship sensors. Tests occur at San Clemente Island Underwater Range.

The U.S. Navy plans to conduct about 139 of these tests each year in the Southern California Range Complex, which is an increase from the 44 conducted each year under current schedules.

Other Tests. The Southern California Range Complex supports diverse tests including surface warfare tests against fast-moving, small boats, mine countermeasures, naval gunfire, electronic combat and combat systems verification. Testing is conducted primarily in the waters west of San Clemente Island.

The U.S. Navy plans to conduct about 20 other tests each year in the Southern California Range Complex, which is a reduction from the 36 conducted each year under current schedules.

Commercial Air Services Increase

Commercial Air Services are services provided by nonmilitary aircraft in contracted support of military training activities; examples of support include air refueling, target towing, and simulation of threat aircraft. Under the Proposed Action, an increase in Commercial Air Services would be implemented. To provide the required training for Carrier and Expeditionary Strike Groups, a corresponding increase in Commercial Air Services acting as Opposition Forces would be required. This enhancement would increase the number of supersonic and subsonic aircraft within the Southern California Range Complex. Under the Proposed Action, the U.S. Navy would increase Commercial Air Services to address unmet training needs. Five dedicated Opposition Force aircraft are required for daily operations and would result in an overall increase in Air Combat Maneuvering operations of 20 percent (1,286 operations).

1.4 West Coast Shallow Water Training Range

In 1999, the Navy formally identified the requirement for a Shallow Water Training Range on the West Coast of the U.S. This requirement, validated in an Operational Requirements Document, identifies criteria for the Shallow Water Training Range. Criteria include the following:

- Shallow water (less than 500 ft [152 m])
- Located within existing operating area and beneath special use airspace
- Capability to interface with air and surface tracking systems to permit the conduct of multidimensional training
- Availability of range infrastructure, logistics support, and exercise control services
- Located near a current deep-water range to support related training and maximize training efficiency

- Seamless tracking of exercise participants moving between existing deep water range and shallow water training range
- Proximity to Fleet homeports and air stations to facilitate access by training units and management of personnel tempo

The Shallow Water Training Range component of the Proposed Action would provide underwater instrumentation for two additional areas of the current Southern California ASW Range: one 250-nm^2 (463-km^2) area to the west of the already instrumented (deep water) section, in the area of Tanner and Cortes Banks, and one 250-nm^2 (463-km^2) area between the deep water section and the southern section of San Clemente Island. If installed in these areas, use of the Shallow Water Training Range would increase the use of these areas for ASW training involving mid-frequency active sonar.

The proposed instrumentation would be in the form of undersea cables and sensor nodes, similar to instrumentation currently in place in Southern California ASW Range. The cables and sensors would be similar to those that instrument the current deep water range. The instrumented area would be connected to shore via multiple trunk cables.

The Shallow Water Training Range instrumentation would be an undersea cables system integrated with hydrophone and underwater telephone sensors, called nodes, connected to each other and then connected by up to eight trunk cables to a land-based facility where the collected range data would be used to evaluate the performance of participants in shallow water (120-ft to 600-ft deep) training exercises.

The basic features of the instrumentation and construction are. The transducer nodes are capable of both transmitting and receiving acoustic signals from ships operating within the instrumented areas of Southern California ASW Range (a transducer is an instrument that converts one form of energy into another, in this case, underwater sound into an electrical signal or vice-versa). Some nodes are configured to only support receiving signals, some can both transmit and receive, and others are transmit-only versions. The acoustic signals that are sent from the exercise participants (e.g., submarines, torpedoes, ships) to the receive-capable range nodes allow the position of the participants to be determined and stored electronically for both real-time and future evaluation. The transmit-capable nodes allow communication from the range to ships or other devices that are being tracked. Additional details include:

- The Shallow Water Training Range extension would consist of no more than 500 sensor nodes spread on the ocean floor over a 500-nm^2 area. The distance between nodes would vary between 0.5 nm and 3 nm, depending on water depth. Each sensor node would be similar in construction to the existing Southern California ASW Range instrumentation. The sensor nodes are small spherical shapes of less than 6 inches in diameter. The sensors would be either suspended up to 15 ft (4.5 m) in the water column or lie flat on the seafloor. Sensor nodes located in shallow water with a presence of commercial fishing activity would have an additional protective device surrounding or overlaying a sensor. These mechanical protective devices would be 3 to 4 ft (1 m), round or rectangular, with a shallow height. The final physical characteristics of the sensor nodes would be determined based upon local geographic conditions and to accommodate man-made threats such as fishing activity. Sensor nodes would be connected to each other by an interconnect

cable (standard submarine telecommunications cable with diameters less than 1 inch). Approximately 900 nm of interconnect would be deployed.

- A series of sensor nodes would be connected via the interconnect cable to underwater junction boxes located in diver-accessible water depths. A junction box is rectangular in shape with dimensions of 10 to 15 ft (3 to 4.5 m) on each side. The junction boxes would connect to a shore-based facility via trunk cables (submarine cables up to 2-inch diameter with additional data capacity). The trunk cables eliminate the need to have numerous interconnect cables running to shore. Up to eight trunk cables with a combined length of 375 nm would be employed. Trunk cables would be protected in the seashore area by horizontal directionally drilled pipes running beneath the shoreline.
- The interconnecting cables and trunk cables would be deployed using a ship with an overall length of up to 300 ft (91 m). The trunk cable paths would be routed through the deep water as much as is possible. Trunk cable deployed in shallow water may require cable burial. Burial equipment would cut (hard bottom) or plow (soft sediment) a furrow 4 inches (10 cm) wide by up to 36 inches deep. Burial equipment (tracked vehicle or towed plow) would be deployed from a ship. The trunk cable, which passes through the seashore area, would terminate in Southern California Offshore Range's current cable termination facility at West Cove. From there, information gathered on the Shallow Water Training Range would be transmitted via an existing microwave datalink to the Southern California Offshore Range Operations Center on Naval Air Station North Island. The adjacent Southern California ASW Range has a single junction box located outside the nearshore area and places the trunk cable in a horizontal directionally drilled bore that terminates onshore. The size of the Shallow Water Training Range may require up to eight junction boxes and eight trunk cables. Multiple horizontal bores are in the Southern California ASW Range. Every effort would be made to take advantage of any excess bore capacity available in the Southern California ASW Range.
- The in-water instrumentation system would be structured to achieve a long operating life, with a goal of 20 years and minimum maintenance and repair throughout the life cycle. This is due to the high cost of performing at-sea repairs on transducer nodes and cables, the inherently long lead time to plan, permit, fund, and conduct such repairs (6 to 18 months) and the loss of range capability while awaiting completion.

  The Navy would submit cable area coordinates to the National Geospatial Intelligence Agency and request that the combined Shallow Water Training Range/Southern California ASW Range area be noted on charts within the appropriate warning area. This area would be noted in the U.S. Coast Pilot as a Military Operating Area, as are other areas on the West Coast. The Navy may promulgate a Notice to Mariners and a Notice to Airmen within 72 hours of the training activities, as appropriate.

Installation of the Shallow Water Training Range instrumentation array may be done in phases. For example, the Tanner Bank area could be installed first, followed by the eastern area. The decision as to whether or not to proceed in phases, how many phases, and the order in which the phases are executed is based on multiple factors, including weather, ship availability and capacity, production schedules for nodes and cable, installation time, total environmental impact of installation, funding availability, and efficiency.

1.5 Shallow Water Minefield

Currently, the Navy conducts Small Object Avoidance training in two existing ranges: the Kingfisher Range off San Clemente Island and the Advanced Research Projects Agency (ARPA) Training Minefield off La Jolla. Small Object Avoidance operations have three objectives: (1) mine detection and avoidance, (2) navigation and reporting, and (3) in the future, more advanced, safe, multiple avoidance training by finding a "safe route" through a minefield. The U.S. Navy proposes to establish an offshore shallow water minefield on Tanner Banks that would be about 2 nm (3.6 km) by 3 nm (5.6 km) in size. Mines would be placed on the ocean floor, with a total of 15 mine shapes in three rows of five. This offshore field would be utilized by surface ships deploying the Remote Mine Hunting System and Battlespace Preparation Autonomous Underwater Vehicle (BPAUV) to detect, classify, and localize underwater mines. The Remote Mine Hunting System and BPAUV are launched and recovered by the host ship using a davit system. After deployment, the host ship will stand off while the Remote Mine Hunting System enters the target zone to perform reconnaissance for mines. An area search is conducted following an operator-programmed search pattern. The Remote Mine Hunting System searches using low-power acoustic sonar, towed by an umanned underwater vehicle itself. A typical Remote Mine Hunting System training mission will last for about 8 hours.

To support Mine Warfare training requirements in shallow water, the Navy proposes to establish shallow water minefields within the Southern California Range Complex, including one off the southern end of San Clemente Island and one offshore Camp Pendleton in the Camp Pendleton Amphibious Assault Area. These mine training ranges would support Mine Warfare training for MH-60S helicopters, Littoral Combat Ships, and M-Class ships. MH-60S helicopters include an mine countermeasures package that requires a shallow water range (40-150 ft) (12-46 m) for deploying recoverable shapes and live ordnance usage.

Three of the five mine countermeasures systems would be deployed in the shallow water minefield off San Clemente Island: Airborne Mine Neutralization Systems for searching and neutralizing mines, Airborne Laser Mine Detection Systems for detecting mines, and Rapid Airborne Mine Clearance Systems for neutralizing surface and near-surface mines. Littoral Combat Ships and MH-60S mine countermeasures systems to be deployed at Camp Pendleton in the Camp Pendleton Amphibious Assault Area include: Organic Airborne and Surface Influence Sweep (OASIS), AN/AQS-20 (MH-60 and remote mine hunting systems), Airborne Laser Mine Detection Systems, BPAUV, USV Sweep, and Airborne Mine Neutralization Systems (inert). OASIS simulates the magnetic and acoustic signature of ships; AN/AQS-20 is a high-frequency sonar system used to locate mines;

Airborne Mine Neutralization Systems deployed in the Camp Pendleton Amphibious Assault Area would be inert. MH- 60S shallow water minefield operations are anticipated to reach 680 annual training activities. Each training exercise would last about 2 hours. Mine Counter Measures-1 Class ships would employ mine detection and location training exercises off San Clemente Island and in the Camp Pendleton Amphibious Assault Area.

1.6 Mitigation Measures Proposed by the U.S. Navy

As required to satisfy the requirements of the Marine Mammal Protection Act of 1972, as amended, the U.S. Navy's proposes to implement measures that would allow their training activities to have the least practicable adverse impact on marine mammal species or stocks (which includes considerations of personnel safety, practicality of implementation, and impact on the effectiveness of the "military readiness activity"). Those measures are summarized in this section of this Opinion; for a complete description of all of the measures applicable to the proposed exercises, readers should refer to the U.S. Navy's request for a letter of authorization and the Permits Division's proposed rule (73 Federal Register 60836):

1.0 *Measures Applicable to Hull-Mounted Surface and Submarine Active Sonar*.

1.1 Personnel Training

1.1.1 All lookouts onboard platforms involved in ASW training events will review the NMFS approved MSAT material prior to MFA sonar use.

1.1.2 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.

1.1.3 Navy lookouts will undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (NAVEDTRA 12968-D).

1.1.4 Lookout training will include on-the-job instruction under the supervision of a qualified, experienced watchstander. 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.

1.1.5 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.

1.2 Lookout and Watchstander Responsibilities

1.2.1 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.

1.2.2 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.

1.2.3 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.

1.2.4 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.

1.2.5 Personnel on lookout will employ visual search procedures employing a scanning methodology in accordance with the Lookout Training Handbook (NAVEDTRA 12968-D).

1.2.6 After sunset and prior to sunrise, lookouts will employ Night Lookouts Techniques in accordance with the Lookout Training Handbook.

1.2.7 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.

1.3 Operating procedures

1.3.1 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.

1.3.2 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.

1.3.3 All personnel engaged in passive acoustic sonar operation (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.

1.3.4 During MFA sonar training activities, personnel will utilize all available sensor and optical systems (such as night vision devices) to aid in the detection of marine mammals.

1.3.4 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.

1.3.5 Aircraft with deployed sonobuoys will use only the passive capability of sonobuoys when marine mammals are detected within 200 yards of the sonobuoy.

1.3.6 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.

1.3.7 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 decibels (dB) below normal operating levels if any detected animals are within 1,000 yards of the sonar dome (the bow)

(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.

(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 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.

(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).

1.3.8 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.

1.3.9 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.

1.3.10 Helicopters shall observe/survey the vicinity of an ASW exercise for 10 minutes before the first deployment of active (dipping) sonar in the water.

1.3.11 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.

1.3.12 Submarine sonar operators will review detection indicators of close-aboard marine mammals prior to the commencement of ASW events involving MFA sonar.

1.3.13 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 training activities. 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 1,000-meter (m) depth near a shoreline where there is a *rapid change in bathymetry* on the order of 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 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 1.3.7 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.

3.0 *Mitigation Associated with Surface-to-Surface Gunnery (up to 5-in. explosive rounds)*

- Lookouts will visually survey for floating weeds and kelp, and algal mats which may be inhabited by immature sea turtles in the target area. Intended impact shall not be within 600 yd (585 m) of known or observed floating weeds and kelp, and algal mats.
- A 600-yd radius buffer zone will be established around the intended target.
- From the intended firing position, lookouts will survey the buffer zone for marine mammals and sea turtles prior to commencement and during the exercise as long as practicable. Due to the distance between the firing position and the buffer zone, lookouts are only expected to visually detect breaching whales, whale blows, and large pods of dolphins and porpoises.
- When manned, target towing vessels will maintain a lookout. If a marine mammal or sea turtle is sighted in the vicinity of the exercise, the tow vessel will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.
- The exercise will be conducted only when the buffer zone is visible and marine mammals and sea turtles are not detected within the target area and the buffer zone.

4.0 *Mitigation Associated with Surface-to-Surface Gunnery (non-explosive rounds)*

- Lookouts will visually survey for floating weeds and kelp, and algal mats which may be inhabited by immature sea turtles in the target area. Intended impact will not be within 200 yd (183 m) of known or observed floating weeds and kelp, and algal mats.
- A 200-yd (183-m) radius buffer zone will be established around the intended target.
- From the intended firing position, lookouts will survey the buffer zone for marine mammals and sea turtles prior to commencement and during the exercise as long as practicable. Due to the distance between the firing position and the buffer zone, lookouts are only expected to visually detect breaching whales, whale blows, and large pods of dolphins and porpoises.
- When manned, target towing vessels will maintain a lookout. If a marine mammal or sea turtle is sighted in the vicinity of the exercise, the tow vessel will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.
- The exercise will be conducted only when the buffer zone is visible and marine mammals and sea turtles are not detected within the target area and the buffer zone.

5.0 *Mitigation Associated with Surface-to-Air Gunnery (explosive and nonexplosive rounds)*

- Vessels will orient the geometry of gunnery exercises in order to prevent debris from falling in the area of sighted marine mammals, sea turtles, algal mats, and floating kelp.

- Vessels will expedite the recovery of any parachute deploying aerial targets to reduce the potential for entanglement of marine mammals and sea turtles.
- When manned, target towing aircraft shall maintain a lookout. If a marine mammal or sea turtle is sighted in the vicinity of the exercise, the tow aircraft will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.

6.0 *Mitigiation Associated with Air-to-Surface Gunnery (explosive and non-explosive rounds)*

- If surface vessels are involved, lookouts will visually survey for floating kelp, which may be inhabited by immature sea turtles, in the target area. Impact should not occur within 200 yd (183 m) of known or observed floating weeds and kelp or algal mats.
- A 200-yd (183-m) radius buffer zone will be established around the intended target.
- If surface vessels are involved, lookout(s) will visually survey the buffer zone for marine mammals and sea turtles prior to and during the exercise.
- Aerial surveillance of the buffer zone for marine mammals and sea turtles will be conducted prior to commencement of the exercise. Aerial surveillance altitude of 500 ft to 1,500 ft (152-456 m) is optimum. Aircraft crew/pilot will maintain visual watch during exercises. Release of ordnance through cloud cover is prohibited: aircraft must be able to actually see ordnance impact areas.
- The exercise will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

7.0 *Mitigation Associated with Small Arms Training (grenades, explosive and nonexplosive rounds)*

- Lookouts will visually survey for floating weeds or kelp, algal mats, marine mammals, and sea turtles. Weapons will not be fired in the direction of known or observed floating weeds or kelp, algal mats, marine mammals, or sea turtles.

8.0 *Mitigation Associated with Air-to-Surface At-Sea Bombing Exercises (explosive bombs and cluster munitions, rockets)*

- If surface vessels are involved, lookouts will survey for floating kelp, which may be inhabited by immature sea turtles. Ordnance shall not be targeted to impact within 1,000 yd (914 m) of known or observed floating kelp, sea turtles, or marine mammals.
- A buffer zone of 1,000-yd (914-m) radius will be established around the intended target.
- Aircraft will visually survey the target and buffer zone for marine mammals and sea turtles prior to and during the exercise. The survey of the impact area will be made by flying at 1,500 ft (152 m) or lower, if safe to do so, and at the slowest safe speed. Release of ordnance through cloud cover is prohibited: aircraft must be able to actually see ordnance impact areas. Survey aircraft should employ most effective search tactics and capabilities.
- The exercises will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

9.0 *Mitigation Associated with Air-to-Surface At-Sea Bombing Exercises (nonexplosive bombs and cluster munitions, rockets)*

- If surface vessels are involved, lookouts will survey for floating kelp, which may be inhabited by immature sea turtles, and for sea turtles and marine mammals. Ordnance shall not be targeted to impact within 1,000 yd (914 m) of known or observed floating kelp, sea turtles, or marine mammals.
- A 1,000-yd (914-m) radius buffer zone will be established around the intended target.
- Aircraft will visually survey the target and buffer zone for marine mammals and sea turtles prior to and during the exercise. The survey of the impact area will be made by flying at 1,500 ft (152 m) or lower, if safe to do so, and at the slowest safe speed. Release of ordnance through cloud cover is prohibited: aircraft must be able to actually see ordnance impact areas. Survey aircraft should employ most effective search tactics and capabilities.
- The exercise will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

10.0 *Mitigation Associated with Air-to-Surface Missile Exercises (explosive and non-explosive)*

- Ordnance shall not be targeted to impact within 1,800 yd (1646 m) of known or observed floating kelp, which may be inhabited by immature sea turtles.
- Aircraft will visually survey the target area for marine mammals and sea turtles. Visual inspection of the target area will be made by flying at 1,500 ft (457 m) or lower, if safe to do so, and at slowest safe speed. Firing or range clearance aircraft must be able to actually see ordnance impact areas. Explosive ordnance shall not be targeted to impact within 1,800 yd (1646 m) of sighted marine mammals and sea turtles.

11.0 *Underwater Detonations (up to 20-lb charges)*

To ensure protection of marine mammals and sea turtles during underwater detonation training, the operating 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 or PTS during Major Exercises.

11.1 *Exclusion Zones*

All Mine Warfare and Mine Countermeasures 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 to those species. These exclusion zones shall extend in a 700-yd arc radius around the detonation site.

12.0 *Measures Applicable to Mine Laying.*

Mine Laying involves aerial drops of inert training shapes on target points. Aircrews are scored for their ability to accurately hit the target points. This training activity does not involve live ordnance. The probability of a marine species being in the exact spot in the ocean where an inert object is dropped is remote. However, as a conservative measure, initial target points will be briefly surveyed prior to inert ordnance release from an aircraft to ensure the

intended drop area is clear of marine mammals and sea turtles. To the extent feasible, the Navy shall retrieve inert mine shapes dropped during Mine Laying.

13.0 *Measures Applicable to Sinking Exercise*

The selection of sites suitable for Sinking Exercises involves a balance of operational suitability, requirements established under the Marine Protection, Research, and Sanctuaries Act (MPRSA) permit granted to the Navy (40 C.F.R. § 229.2), and the identification of areas with a low likelihood of encountering marine mammals. 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 nonmilitary air or watercraft. The MPRSA permit requires vessels to be sunk in waters which are at least 1,000 fathoms (6,000 ft) deep and at least 50 nm from land. In general, most marine mammals prefer areas with strong bathymetric gradients and oceanographic fronts for significant biological activity such as feeding and reproduction. Typical locations include the continental shelf and shelf-edge.

13.1 *Sinking Exercise Range Clearance Plan*

The Navy has developed range clearance procedures to maximize the probability of sighting any ships or marine mammals 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 training activities 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 (1.85 km) would be established around each target. This exclusion zone is based on calculations using a 990-lb H6 net explosive weight high explosive source detonated 5 ft (1.5 m) below the surface of the water, which yields a distance of 0.85 nm (1.57 km) (cold season) and 0.89 nm (1.64 km) (warm season) beyond which the received level is below the 182-dB re: 1 micropascal squared seconds (μPa^2-s) threshold established for the WINSTON S CHURCHILL (DDG-81) shock trials (U.S. Navy, 2001). An additional buffer of 0.5 nm (0.93 km) 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 (1.85 km) out an additional 0.5 nm (0.93 km), would be surveyed. Together, the zones extend out 2 nm (3.7 km) 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:
    - 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.

- 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.
- 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 any 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 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.
- On each day of the exercise, aerial surveillance of the exclusion and safety zones would commence 2 hours prior to the first firing.
- 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.
- If a marine mammal is 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.
- During breaks in the exercise of 30 minutes or more, the exclusion zone would again be surveyed for any marine mammal. If marine mammals are sighted within the exclusion zone, the OCE would be notified, and the procedure described above would be followed.
- 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 marine mammals 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.

- Every attempt would be made to conduct the exercise in sea states that are ideal for marine mammal sighting, Beaufort Sea State 3 or less. In the event of a 4 or above, survey efforts would be increased within the zones. This would be accomplished through the use of an additional aircraft, if available, and conducting tight search patterns.
- The exercise would not be conducted unless the exclusion zone could be adequately monitored visually.
- In the event that any marine mammals 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 Oceanographic and Atmospheric Administration (NOAA) Fisheries via the Navy's regional environmental coordinator for purposes of identification.
- An after action report 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.

14.0 *San Clemente Island Very Shallow Water Underwater Detonations Mitigation Measures*

- For each exercise, a safety-boat with an observer is launched 30 or more minutes prior to detonation and moves through the area around the detonation site. The task of the safety observer is to augment a shore observer's visual search of the mitigation zone for marine mammals and turtles. The safety-boat observer is in constant radio communication with the exercise coordinator and shore observer.
- At least 10 minutes prior to the planned initiation of the detonation event-sequence, the shore observer, on an elevated on-shore position, begins a continuous visual search with binoculars of the mitigation zone. At this time, the safety-boat observer informs the shore observer if any marine mammal or turtle has been seen in the zone and, together, both search the surface within and beyond the mitigation zone for marine mammals and turtles.
- The shore observer will indicate that the area is clear of animals after 10 or more minutes of continuous observation with no marine mammals or turtles having been seen in the mitigation zone or moving toward it.
- The observer will indicate that the area is not clear of animals any time a marine mammal or turtle is sighted in the mitigation zone or moving toward it and, subsequently, indicate that the area is clear of animals when the animal is out and moving away and no others have been sited.
- Initiation of the detonation sequence will only begin on receipt of an indication from the shore observer that the area is clear of animals and will be postponed on receipt of an indication from that observer that the area is not clear of animals.
- Following the detonation, visual monitoring of the mitigation zone continues for 30 minutes for the appearance of any marine mammal or turtle in the zone. Any marine mammal or sea turtle appearing in the area will be observed for signs of possible injury. Possibly injured marine mammals or turtles are reported to the Commander, Naval Region Southwest Environmental Director and the San Diego Detachment office of Commander, Pacific Fleet.

15.0 *Mitigation measures associated with events using EER/IEER Sonobuoys*

a. AN/SSQ-110A Pattern Deployment:

- Crews will conduct visual reconnaissance of the drop area prior to laying their intended sonobuoy pattern. This search should be conducted below 1500 feet (ft) at a slow speed when operationally feasible and weather conditions permit. In dual aircraft training activities, crews may conduct coordinated area clearances.

- Crews shall conduct a minimum of 30 minutes of visual and aural monitoring of the search area prior to commanding the first post (source/receiver sonobuoy pair) detonation. This 30 minute observation period may include pattern deployment time.

- For any part of the briefed pattern where a post will be deployed within 1000 yards (yds) of observed marine mammal activity, crews will deploy the receiver ONLY and monitor while conducting a visual search. When marine mammals are no longer detected within 1000 yds of the intended post position, crews will collocate the AN/SSQ-110A sonobuoy (source) with the receiver.

- When operationally feasible, crews will conduct continuous visual and aural monitoring of marine mammal activity, including monitoring of their aircraft sensors from first sensor placement to checking off-station and out of RF range of the sensors.

b. AN/SSQ-110A Pattern Employment:

(i) Aural Detection:

- Aural detection of marine mammals cues the aircrew to increase the diligence of their visual surveillance.
- If, following aural detection, no marine mammals are visually detected, then the crew may continue multi-static active search.

(ii) Visual Detection:

- If marine mammals are visually detected within 1000 yds of the AN/SSQ-110A sonobuoy 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 1000 yd safety zone.
- Aircrews may shift their multi-static active search to another post, where marine mammals are outside the 1000 yd safety zone.

c. AN/SSQ-110A Scuttling Sonobuoys:

(i) Aircrews shall make every attempt to manually detonate the unexploded charges at each post in the pattern prior to departing the training activities 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 a 1000 yd safety zone, visually clear of marine mammals, is maintained around each post as is done during active search training activities.

(ii) 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 method or tertiary method.

- Aircrews ensure all payloads are accounted for. Sonobuoys that cannot be scuttled shall be reported as unexploded ordnance via voice communications while airborne and, upon landing, via Naval message.

Mammal monitoring shall continue until out of their aircraft sensor range.

1.7 Mitigation Requirements Proposed by NMFS' Permits Division

When the U.S. Navy conducts the training activities on the Southern California Range Complex, as described in the relevant regulations, the regulations NMFS' Permits Division proposes to final requires the U.S. Navy to implement mitigation measures that include (but are not limited to) the following:

1 *Mitigation Measures for ASW training*:

i All lookouts onboard platforms involved in ASW training events shall review the NMFS-approved Marine Species Awareness Training (MSAT) material prior to use of mid-frequency active sonar.

ii All Commanding Officers, Executive Officers, and officers standing watch on the Bridge shall have reviewed the MSAT material prior to a training event employing the use of mid-frequency active sonar.

iii Navy lookouts shall undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (NAVEDTRA, 12968-D).

iv Lookout training shall include on-the-job instruction under the supervision of a qualified, experienced watchstander. Following successful completion of this supervised training period, Lookouts shall complete the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects).

v Lookouts shall be trained in the most effective means to ensure quick and effective communication within the command structure in order to facilitate implementation of mitigation measures if marine species are spotted.

vi On the bridge of surface ships, there shall be at least three people on watch whose duties include observing the water surface around the vessel.

vii All surface ships participating in ASW exercises shall, in addition to the three personnel on watch noted previously, have at all times during the exercise at least two additional personnel on watch as lookouts.

viii Personnel on lookout and officers on watch on the bridge shall have at least one set of binoculars available for each person to aid in the detection of marine mammals.

ix On surface vessels equipped with mid-frequency active sonar, pedestal mounted "Big Eye" (20x110) binoculars shall be present and in good working order.

x Personnel on lookout shall employ visual search procedures employing a scanning methodology in accordance with the Lookout Training Handbook (NAVEDTRA 12968-D).

xi After sunset and prior to sunrise, lookouts shall employ Night Lookouts Techniques in accordance with the Lookout Training Handbook.

xii Personnel on lookout shall 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.

xiii CPF shall distribute the final mitigation measures contained in the LOA and BO to the Fleet.

xiv Commanding Officers shall 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.

xv All personnel engaged in passive acoustic sonar operation (including aircraft, surface ships, or submarines) shall monitor for marine mammal vocalizations and report the detection of any marine mammal to the appropriate watch station for dissemination and appropriate action.

xvi During mid-frequency active sonar training activities, personnel shall utilize all available sensor and optical systems (such as Night Vision Goggles) to aid in the detection of marine mammals.

xvii Navy aircraft participating in exercises at sea shall conduct and maintain, when operationally feasible and safe, surveillance for marine mammals as long as it does not violate safety constraints or interfere with the accomplishment of primary operational duties.

xviii Aircraft with deployed sonobuoys shall use only the passive capability of sonobuoys when marine mammals are detected within 200 yards (182 m) of the sonobuoy.

xix Marine mammal detections shall be reported immediately 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.

xx Safety Zones - When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) the Navy shall ensure that MFAS transmission levels are limited to at least 6 dB below

normal operating levels if any detected marine mammals are within 1000 yards (914 m) of the sonar dome (the bow).

(A) Ships and submarines shall continue to limit maximum MFAS 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 (1828 m) beyond the location of the last detection.

(B) The Navy shall ensure that MFAS transmissions will be limited to at least 10 dB below the equipment's normal operating level if any detected animals are within 500 yards (457 m) of the sonar dome. Ships and submarines shall 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 2000 yards (1828 m) beyond the location of the last detection.

(C) The Navy shall ensure that MFAS transmissions are ceased if any detected marine mammals are within 200 yards of the sonar dome. MFAS transmissions will not resume 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.

(D) 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.

(E) If the need for power-down should arise as detailed in “Safety Zones” above, Navy shall follow the requirements as though they were operating at 235 dB – the normal operating level (i.e., the first power-down will be to 229 dB, regardless of at what level above 235 dB sonar was being operated).

xxi Prior to start up or restart of active sonar, operators shall check that the Safety Zone radius around the sound source is clear of marine mammals.

xxii Sonar levels (generally) - Navy shall operate sonar at the lowest practicable level, not to exceed 235 dB, except as required to meet tactical training objectives.

xxiii Helicopters shall observe/survey the vicinity of an ASW Exercise for 10 minutes before the first deployment of active (dipping) sonar in the water.

xxiv Helicopters shall not dip their sonar within 200 yards (183 m) of a marine mammal and shall cease pinging if a marine mammal closes within 200 yards (183 m) after pinging has begun.

xxv Submarine sonar operators shall review detection indicators of close-aboard marine mammals prior to the commencement of ASW training activities involving active mid-frequency sonar.

xxvi Night vision goggles shall be available to all ships and air crews, for use as appropriate.

xxvii The Navy shall abide by the letter of the "Stranding Response Plan for Major Navy Training Exercises in Southern California Range Complex" to include the following measures:

(A) Shutdown Procedures– When an Uncommon Stranding Event (USE – defined in NMFS' MMPA regulations) occurs during a Major Training Exercise in the Southern California Range Complex, the Navy shall implement the procedures described below.

(1) The Navy shall implement a Shutdown (as defined in regulations) when advised by a NMFS Office of Protected Resources Headquarters Senior Official designated in the SOCAL Stranding Communication Protocol that a USE involving live animals has been identified and that at least one live animal is located in the water. NMFS and Navy will maintain a dialogue, as needed, regarding the identification of the USE and the potential need to implement shutdown procedures.

(2) Any shutdown in a given area shall remain in effect in that area until NMFS advises the Navy that the subject(s) of the USE at that area die or are euthanized, or that all live animals involved in the USE at that area have left the area (either of their own volition or herded).

(3) If the Navy finds an injured or dead animal floating at sea during an MTE, the Navy shall notify NMFS immediately or as soon as operational security considerations allow. The Navy shall provide NMFS with species or description of the animal(s), the condition of the animal(s) including carcass condition if the animal(s) is/are dead), location, time of first discovery, observed behavior (if alive), and photo or video (if available). Based on the information provided, NMFS will determine if, and advise the Navy whether a modified shutdown is appropriate on a case-by-case basis.

(4) In the event, following a USE, that: a) qualified individuals are attempting to herd animals back out to the open ocean and animals are not willing to leave, or b) animals are seen repeatedly heading for the open ocean but turning back to shore, NMFS and the Navy shall coordinate (including an investigation of other potential anthropogenic stressors in the area) to determine if the proximity of MFAS training activities or explosive detonations, though farther than 14 nm from the distressed animal(s), is likely contributing to the animals' refusal to return to the open water. If so, NMFS and the Navy will further coordinate to determine what measures are necessary to improve the probability that the animals will return to open water and implement those measures as appropriate.

(B) Within 72 hours of NMFS notifying the Navy of the presence of a USE, the Navy shall provide available information to NMFS (per the SOCAL Communication Protocol) regarding the location, number and types of acoustic/explosive sources, direction and speed of units using MFAS, and marine mammal sightings information associated with training activities occurring within 80 nm (148 km) and 72 hours prior to the USE event. Information not initially available regarding the 80 nm (148 km), 72 hour period prior to the event will be provided as soon as it becomes available. The Navy will provide NMFS investigative teams with additional relevant unclassified information as requested, if available.

(C) Memorandum of Agreement (MOA) – The Navy and NMFS shall develop a MOA, or other mechanism consistent with federal fiscal law requirements (and all other applicable laws), that will establish a framework whereby the Navy can (and provide the Navy examples of how they can best) assist NMFS with stranding investigations in certain circumstances.

2 Mitigation for IEER - The following are protective 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.

i Crews shall conduct aerial visual reconnaissance of the drop area prior to laying their intended sonobuoy pattern. This search should be conducted below 500 yards (457 m) at a slow speed, if operationally feasible and weather conditions permit. In dual aircraft training activities, crews are allowed to conduct coordinated area clearances.

ii Crews shall conduct a minimum of 30 minutes of visual and acoustic monitoring of the search area prior to commanding the first post detonation. This 30-minute observation period may include pattern deployment time.

iii For any part of the briefed pattern where a post (source/receiver sonobuoy pair) will be deployed within 1,000 yards (914 m) of observed marine mammal activity, the Navy shall deploy the receiver ONLY and monitor while conducting a visual search. When marine mammals are no longer detected within 1,000 yards (914 m) of the intended post position, co-locate the explosive source sonobuoy (AN/SSQ-110A) (source) with the receiver.

iv 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.

v Aural Detection: If the presence of marine mammals is detected aurally, then that shall 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.

vi Visual Detection:

(A) If marine mammals are visually detected within 1,000 yards (914 m) 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 (914 m) safety buffer.

(B) Aircrews may shift their multi-static active search to another post, where marine mammals are outside the 1,000 yards (914 m) safety buffer.

vii Aircrews shall make every attempt to manually detonate the unexploded charges at each post in the pattern prior to departing the operations 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 yard (914 m) safety buffer, visually clear of marine mammals, is maintained around each post as is done during active search operations.

viii 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.

ix The navy shall 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.

x Marine mammal monitoring shall continue until out of own-aircraft sensor range.

3 *Mitigation for Demolitions (DEMOs) and Mine Countermeasure (MCM) Training* (Up to 20 lb).

i *Exclusion Zones* – Explosive charges shall not be detonated if a marine mammal is detected within 700 yards (640 m) of the detonation site.

ii *Pre-Exercise Surveys* - For MCM training activities, the Navy shall conduct a pre-exercise survey within 30 minutes prior to the commencement of the scheduled explosive event. The survey may be conducted from the surface, by divers, and/or from the air. If a marine mammal is detected within the survey area, the exercise shall be suspended until the animal voluntarily leaves the area.

iii *Post-Exercise Surveys* - Surveys within the same radius shall also be conducted within 30 minutes after the completion of the explosive event.

iv *Reporting* - Any evidence of a marine mammal that may have been injured or killed by the action shall be reported immediately to NMFS.

v *Mine Laying Training* – Though mine laying training operations involve aerial drops of inert training shapes on floating targets, measures 1, 2, and 3 for Demolitions and Mine counter-

measures (above) will apply to mine laying training. To the maximum extent feasible, the Navy shall retrieve inert mine shapes dropped during Mine Laying Training.

4 *Mitigation for SINKEX, GUNEX, MISSILEX, and BOMBEX*

i All weapons firing shall be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.

ii Extensive range clearance operations shall be conducted in the hours prior to commencement of the exercise.

iii An exclusion zone with a radius of 1.0 nm (1.85 km) shall be established around each target. An additional buffer of 0.5 nm (0.93 km) shall be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which extends out an additional 0.5 nm (0.93 km), shall be surveyed. Together, the zones extend out 2 nm (3.7 km) from the target.

iv A series of surveillance over-flights shall 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 shall 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 (SAR) Tactical Aid (TACAID).

(B) All visual surveillance activities shall be conducted by Navy personnel trained in visual surveillance. At least one member of the mitigation team shall have completed the Navy's marine mammal training program for lookouts.

(C) In addition to the overflights, the exclusion zone shall be monitored by passive acoustic means, when assets are available. This passive acoustic monitoring shall be maintained throughout the exercise. Potential assets include sonobuoys, which can be utilized to detect any vocalizing marine mammals in the vicinity of the exercise. The sonobuoys shall 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) shall 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 shall commence two hours prior to the first firing.

(E) The results of all visual, aerial, and acoustic searches shall 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.

(F) If a marine mammal observed within the exclusion zone is diving, firing shall be delayed until the animal is re-sighted outside the exclusion zone, or 30 minutes has elapsed.

(G) During breaks in the exercise of 30 minutes or more, the exclusion zone shall again be surveyed for any marine mammals. If marine mammals 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 shall be monitored for two hours, or until sunset, to verify that no marine mammals were harmed.

vi Aerial surveillance would be conducted using helicopters or other aircraft based on necessity and availability. These aircraft shall be capable of (and shall, to the extent practicable) flying at the slow safe speeds necessary to enable viewing of marine mammals with unobstructed, or minimally obstructed, downward and outward visibility. The Navy may cancel the exclusion and safety zone surveys 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.

vii Where practicable, the Navy shall conduct the exercise in sea states that are ideal for marine mammal sighting, i.e., Beaufort Sea State 3 or less. In the event of a Beaufort Sea State of 4 or above, the Navy shall utilize additional aircraft (conducting tight search patterns), if available, to increase survey efforts within the zones.

viii The exercise shall not be conducted unless the exclusion zone can be adequately monitored visually.

ix In the unlikely event that any marine mammals are observed to be harmed in the area, a detailed description of the animal shall be documented, the location noted, and if possible, photos taken. This information would be provided to NMFS.

(b) [Reserved]

The Permits Division proposes include the following monitoring and reporting requirements in the proposed Letter of Authorization:

a As outlined in the SOCAL Stranding Communication Plan, the Holder of the Authorization must notify NMFS immediately (or as soon as clearance procedures allow) if the specified activity identified in regulations is thought to have resulted in the mortality or injury of any marine mammals, or in any take of marine mammals not identified in NMFS' MMPA regulations.

b The Holder of the Letter of Authorization must conduct all monitoring and required reporting under the Letter of Authorization, including abiding by the letter of the SOCAL Monitoring Plan.

c The Navy shall complete an Integrated Comprehensive Monitoring Plan (ICMP) in 2009. This planning and adaptive management tool shall include:

(1) A method for prioritizing monitoring projects that clearly describes the characteristics of a proposal that factor into its priority.

(2) A method for annually reviewing, with NMFS, monitoring results, Navy R&D, and current science to use for potential modification of mitigation or monitoring methods.

(3) A detailed description of the Monitoring Workshop to be convened in 2011 and how and when Navy/NMFS will subsequently utilize the findings of the Monitoring Workshop to potentially modify subsequent monitoring and mitigation.

d General Notification of Injured or Dead Marine Mammals - Navy personnel shall ensure that NMFS (regional stranding coordinator) is notified immediately (or as soon as clearance procedures allow) if an injured or dead marine mammal is found during or shortly after, and in the vicinity of, any Navy training exercise utilizing MFAS, HFAS, or underwater explosive detonations. The Navy shall provide NMFS with species or description of the animal(s), the condition of the animal(s) (including carcass condition if the animal is dead), location, time of first discovery, observed behaviors (if alive), and photo or video (if available). The Navy shall consult the Stranding Response Plan to obtain more specific reporting requirements for specific circumstances.

e Annual SOCAL Monitoring Plan Report - The Navy shall submit a report annually on October 1 describing the implementation and results (through August 1 of the same year) of the SOCAL Monitoring Plan, described above. Data collection methods will be standardized across range complexes to allow for comparison in different geographic locations. Although additional information will be gathered, the marine mammal observers (MMOs) collecting marine mammal data pursuant to the SOCAL Monitoring Plan shall, at a minimum, provide the same marine mammal observation data required in NMFS' MMPA regulations.

The SOCAL Monitoring Plan Report may be provided to NMFS within a larger report that includes the required Monitoring Plan Reports from multiple Range Complexes.

f Annual SOCAL Exercise Report - The Navy shall submit an Annual SOCAL Exercise Report on October 1 of every year (covering data gathered through August 1 of the same year). This report shall contain information identified in NMFS' MMPA regulations..

(1) MFAS/HFAS Major Training Exercises - This section shall contain the following information for Major Training Exercises (MTEs) conducted in SOCAL:

(i) Exercise Information (for each MTE):

(A) Exercise designator

(B) Date that exercise began and ended

(C) Location

(D) Number and types of active sources used in the exercise

(E) Number and types of passive acoustic sources used in exercise

(F) Number and types of vessels, aircraft, etc., participating in exercise

(G) Total hours of observation by watchstanders

(H) Total hours of all active sonar source operation

(I) Total hours of each active sonar source (along with explanation of how hours are calculated for sources typically quantified in alternate way (buoys, torpedoes, etc.)).

(J) Wave height (high, low, and average during exercise)

(ii) Individual marine mammal sighting info (for each sighting in each MTE)

(A) Location of sighting

(B) Species (if not possible – indication of whale/dolphin/pinniped)

(C) Number of individuals

(D) Calves observed (y/n)

(E) Initial Detection Sensor

(F) Indication of specific type of platform observation made from (including, for example, what type of surface vessel, i.e., FFG, DDG, or CG)

(G) Length of time observers maintained visual contact with marine mammal

(H) Wave height (in feet)

(I) Visibility

(J) Sonar source in use (y/n).

(K) Indication of whether animal is <200yd, 200-500yd, 500-1000yd, 1000-2000yd, or >2000yd from sonar source in (x) above.

(L) Mitigation Implementation – Whether operation of sonar sensor was delayed, or sonar was powered or shut down, and how long the delay was.

(M) If source in use (J) is hullmounted, true bearing of animal from ship, true direction of ship's travel, and estimation of animal's motion relative to ship (opening, closing, parallel)

(N) Observed behavior – Watchstanders shall report, in plain language and without trying to categorize in any way, the observed behavior of the animals (such as animal closing to bow ride, paralleling course/speed, floating on surface and not swimming, etc.)

(iii) An evaluation (based on data gathered during all of the MTEs) of the effectiveness of mitigation measures designed to avoid exposing to mid-frequency sonar. This evaluation shall identify the specific observations that support any conclusions the Navy reaches about the effectiveness of the mitigation.

(2) ASW Summary - This section shall include the following information as summarized from both MTEs and non-major training exercises (i.e., unit-level exercises, such as TRACKEXs):

(i) Total annual hours of each type of sonar source (along with explanation of how hours are calculated for sources typically quantified in alternate way (buoys, torpedoes, etc.))

(ii) Cumulative Impact Report - To the extent practicable, the Navy, in coordination with NMFS, shall develop and implement a method of annually reporting non-major (i.e., other than COMPTUEX or JTFEX) training exercises utilizing hull-mounted sonar. The report shall present an annual (and seasonal, where practicable) depiction of non-major training exercises geographically across the SOCAL. The Navy shall include (in the SOCAL annual report) a brief annual progress update on the status of development until an agreed-upon (with NMFS) method has been developed and implemented.

(3) SINKEXs - This section shall include the following information for each SINKEX completed that year:

(i) *Exercise information (gathered for each SINKEX):*

(A) Location

(B) Date and time exercise began and ended

(C) Total hours of observation by watchstanders before, during, and after exercise

(D) Total number and types of rounds expended / explosives detonated

(E) Number and types of passive acoustic sources used in exercise

(F) Total hours of passive acoustic search time

(G) Number and types of vessels, aircraft, etc., participating in exercise

(H) Wave height in feet (high, low and average during exercise)

(I) Narrative description of sensors and platforms utilized for marine mammal detection and timeline illustrating how marine mammal detection was conducted

(ii) *Individual marine mammal observation (by Navy lookouts) information (gathered for each marine mammal sighting)*

(A) Location of sighting

(B) Species (if not possible, indicate whale, dolphin or pinniped)

(C) Number of individuals

(D) Whether calves were observed

(E) Initial detection sensor

(F) Length of time observers maintained visual contact with marine mammal

(G) Wave height

(H) Visibility

(I) Whether sighting was before, during, or after detonations/exercise, and how many minutes before or after

(J) Distance of marine mammal from actual detonations (or target spot if not yet detonated) – use four categories to define distance: 1) the modeled injury threshold radius for the largest explosive used in that exercise type in that OPAREA (91 m for SINKEX in SOCAL); 2) the required exclusion zone (1 nm for SINKEX in SOCAL); (3) the required observation distance (if different than the exclusion zone (2 nm for SINKEX in SOCAL); and, (4) greater than the required observed distance. For example, in this case, the observer would indicate if < 91 m, from 91 m – 1 nm, from 1 nm – 2 nm, and > 2 nm.

(K) Observed behavior – Watchstanders will report, in plain language and without trying to categorize in any way, the observed behavior of the animal(s) (such as animal closing to bow ride, paralleling course/speed, floating on surface and not swimming etc.), including speed and direction.

(L) Resulting mitigation implementation – Indicate whether explosive detonations were delayed, ceased, modified, or not modified due to marine mammal presence and for how long.

(M) If observation occurs while explosives are detonating in the water, indicate munition type in use at time of marine mammal detection.

(4) IEER Summary. This section shall include an annual summary of the following IEER information:

(i) Total number of IEER events conducted in the SOCAL

(ii) Total expended/detonated rounds (buoys)

(iii) Total number of self-scuttled IEER rounds

(5) Explosives Summary - To the extent practicable, the Navy will provide the information described below for all of their explosive exercises. Until the Navy is able to report in full the information below, they will provide an annual update on the Navy's explosive tracking methods, including improvements from the previous year.

(i) Total annual number of each type of explosive exercises (of those identified as part of the "specified activity" in this final rule) conducted in the SOCAL

(ii) Total annual expended/detonated rounds (missiles, bombs, etc.) for each explosive type

g Sonar Exercise Notification - The Navy shall submit to the NMFS Office of Protected Resources (specific contact information to be provided in LOA) either an electronic (preferably) or verbal report within fifteen calendar days after the completion of any major exercise (COMPTUEX or JTFEX) indicating:

(1) Location of the exercise

(2) Beginning and end dates of the exercise

(3) Type of exercise (e.g., COMPTUEX, JTFEX, or Multi Strike Group)

h SOCAL 5-yr Comprehensive Report - The Navy shall submit to NMFS a draft report that analyzes and summarizes all of the multi-year marine mammal information gathered during ASW and explosive exercises for which annual reports are required (Annual SOCAL Exercise Reports and SOCAL Monitoring Plan Reports). This report will be submitted at the end of the fourth year of the rule (November 2012), covering activities that have occurred through June 1, 2012.

i Comprehensive National ASW Report - By June 2014, the Navy shall submit a draft Comprehensive National Report that analyzes, compares, and summarizes the active sonar data gathered (through January 1, 2014) from the watchstanders in accordance with the Monitoring Plans for the SOCAL, the Atlantic Fleet Active Sonar Training, the Southern California (SOCAL) Range Complex, the Marianas Range Complex, the Northwest Training Range, the Gulf of Alaska, and the East Coast Undersea Warfare Training Range.

j The Navy shall respond to NMFS comments and requests for additional information or clarification on the SOCAL Comprehensive Report, the draft National ASW report, the Annual SOCAL Exercise Report, or the Annual SOCAL Monitoring Plan Report (or the multi-Range Complex Annual Monitoring Plan Report, if that is how the Navy chooses to submit the information) if submitted within 3 months of receipt. These reports will be considered final after the Navy has addressed NMFS' comments or provided the requested information, or three months after the submittal of the draft if NMFS does not comment by then.

k In 2011, the Navy shall convene a Monitoring Workshop in which the Monitoring Workshop panelists will be asked to review the Navy's Monitoring Plans and monitoring results and make individual recommendations (to the Navy and NMFS) of ways of improving the Monitoring Plans. The recommendations shall be reviewed by the Navy, in consultation with NMFS, and modifications to the Monitoring Plan shall be made, as appropriate.

2.0 Approach to the Assessment

2.1 Overview of NMFS' Assessment Framework

NMFS uses a series of sequential analyses to assess the effects of federal actions on endangered and threatened species and designated critical habitat. The first analysis identifies those physical, chemical, or biotic aspects of proposed actions that are likely to have individual, interactive, or cumulative direct and indirect effect on the environment (we use the term "potential stressors" for these aspects of an action). As part of this step, we identify the spatial extent of any potential stressors and recognize that the spatial extent of those stressors may change with time (the spatial extent of these stressors is the "action area" for a consultation).

The second step of our analyses starts by determining whether endangered species, threatened species, or designated critical habitat are likely to occur in the same space and at the same time as these potential stressors. If we conclude that such co-occurrence is likely, we then try to estimate the nature of that co-occurrence (these represent our *exposure analyses*). In this step of our analyses, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an Action's effects and the populations or subpopulations those individuals represent.

Once we identify which listed resources (endangered and threatened species and designated critical habitat) are likely to be exposed to potential stressors associated with an action and the nature of that exposure, in the third step of our analyses we examine the scientific and commercial data available[2] to determine whether and how those listed resources are likely to respond given their exposure (these represent our *response analyses*). The final steps of our analyses — establishing the risks those responses pose to listed resources — are different for listed species and designated critical habitat (these represent our *risk analyses*).

RISK ANALYSES FOR ENDANGERED AND THREATENED SPECIES. Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species as those "species" have been listed, which can include true biological species, subspecies, or distinct population segments of vertebrate species. Because the continued existence of listed species depends on the fate of the populations that comprise them, the viability (that

[2] Although section 7(a)(2) of the Endangered Species Act of 1973, as amended, requires us to use the best scientific and commercial data available, at this stage of our analyses, we consider all lines of evidence. We summarize how we identify the "best scieitific and commercial data available" in a subsequent subsection titled "Evidence Available for the Consultation"

is, the probability of extinction or probability of persistence) of listed species depends on the viability of the populations that comprise the species. Similarly, the continued existence of populations are determined by the fate of the individuals that comprise them; populations grow or decline as the individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our risk analyses reflect these relationships between listed species and the populations that comprise them, and the individuals that comprise those populations. Our risk analyses begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's effects. Our analyses then integrate those individuals risks to identify consequences to the populations those individuals represent. Our analyses conclude by determining the consequences of those population-level risks to the species those populations comprise.

We measure risks to listed individuals using the individual's "fitness," which are changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual's probable response to an Action's effects on the environment (which we identify in our *response analyses*) are likely to have consequences for the individual's fitness.

When individual, listed plants or animals are expected to experience reductions in fitness, we would expect those reductions to also reduce the abundance, reproduction rates, or growth rates (or increase variance in one or more of these rates) of the populations those individuals represent (see Stearns 1992). Reductions in one or more of these variables (or one of the variables we derive from them) is a *necessary* condition for reductions in a population's viability, which is itself a *necessary* condition for reductions in a species' viability. Therefore, when listed plants or animals exposed to an Action's effects are *not* expected to experience reductions in fitness, we would not expect that Action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (for example, see Anderson 2000, Mills and Beatty 1979, Stearns 1992). As a result, if we conclude that listed plants or animals are *not* likely to experience reductions in their fitness, we would conclude our assessment because an Action that is not likely to affect the fitness of individuals is not likely to jeopardize the continued existence of listed species.

If, however, we conclude that listed plants or animals are likely to experience reductions in their fitness, our assessment tries to determine if those fitness reductions are likely to be sufficient to reduce the viability of the populations those individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, or variance in these measures to make inferences about the population's extinction risks). In this step of our analyses, we use the population's base condition (established in the *Environmental Baseline* and *Status of Listed Resources* sections of this Opinion) as our point of reference. Finally, our assessment tries to determine if changes in population viability are likely to be sufficient to reduce the viability of the species those populations comprise. In this step of our analyses, we use the species' status (established in the *Status of the Species* section of this Opinion) as our point of reference.

Biological opinions, then, distinguish among different kinds of "significance" (as that term is commonly used for NEPA analyses). First, we focus on potential physical, chemical, or biotic stressors that are "significant" in the sense of "salient" in the sense of being distinct from ambient or background. We then ask if (a) exposing individuals to those potential stressors is likely to (a) represent a "significant" adverse experience in the life of individuals that

have been exposed; (b) exposing individuals to those potential stressors is likely to cause the individuals to experience "significant" physical, chemical, or biotic responses; and (c) any "significant" physical, chemical, or biotic response are likely to have "significant" consequence for the fitness of the individual animal. In the latter two cases (items (b) and (c)), the term "significant" means "clinically or biotically significant" rather than statistically significant.

For populations (or sub-populations, demes, etc.), we are concerned about whether the number of individuals that experience "significant" reductions in fitness and the nature of any fitness reductions are likely to have a "significant" consequence for the viability (= probability of demographic, ecological, or genetic extinction) of the population(s) those individuals represent. Here "significant" also means "clinically or biotically significant" rather than statistically significant.

For "species" (the entity that has been listed as endangered or threatened, not the biological species concept), we are concerned about whether the number of populations that experience "significant" reductions in viability (= increases in their extinction probabilities) and the nature of any reductions in viability are likely to have "significant" consequence for the viability (= probability of demographic, ecological, or genetic extinction) of the "species" those population comprise. Here, again, "significant" also means "clinically or biotically significant" rather than statistically significant.

RISK ANALYSES FOR DESIGNATED CRITICAL HABITAT. Our "destruction or adverse modification" determinations must be based on an action's effects on the conservation value of habitat that has been designated as critical to threatened or endangered species. If an area encompassed in a critical habitat designation is likely to be exposed to the *direct or indirect consequences of the proposed action on the natural environment*, we ask if primary or secondary constituent elements included in the designation (if there are any) or physical, chemical, or biotic phenomena that give the designated area value for the conservation are likely to respond to that exposure.

In this step of our assessment, we must identify (a) the spatial distribution of stressors and subsidies produced by an action; (b) the temporal distribution of stressors and subsidies produced by an action; (c) changes in the spatial distribution of the stressors with time; (d) the intensity of stressors in space and time; (e) the spatial distribution of constituent elements of designated critical habitat; and (f) the temporal distribution of constituent elements of designated critical habitat.

If primary or secondary constituent elements of designated critical habitat (or physical, chemical, or biotic phenomena that give the designated area value for the conservation of listed species) are likely to respond given exposure to the *direct or indirect consequences of the proposed action on the natural environment*, we ask if those responses are likely to be sufficient to reduce the quantity, quality, or availability of those constituent elements or physical, chemical, or biotic phenomena.

In this step of our assessment, we must identify or make assumptions about (a) the habitat's probable condition before any exposure as our point of reference (that is part of the impact of the *Environmental Baseline* on the conservation value of the designated critical habitat); (b) the ecology of the habitat at the time of exposure; (c) where the

exposure is likely to occur; and (d) when the exposure is likely to occur; (e) the intensity of exposure; (f) the duration of exposure; and (g) the frequency of exposure.

In this step of our assessment, we recognize that the conservation value of critical habitat, like the base condition of individuals and populations, is a dynamic property that changes over time in response to changes in land use patterns, climate (at several spatial scales), ecological processes, changes in the dynamics of biotic components of the habitat, etc. For these reasons, some areas of critical habitat might respond to an exposure when others do not. We also consider how designated critical habitat is likely to respond to any interactions and synergisms between or cumulative effects of pre-existing stressors and proposed stressors.

If the quantity, quality, or availability of the primary or secondary constituent elements of the area of designated critical habitat (or physical, chemical, or biotic phenomena) are reduced, we ask if those reductions are likely to be sufficient to reduce the conservation value of the designated critical habitat for listed species in the action area. In this step of our assessment, we combine information about the contribution of constituent elements of critical habitat (or of the physical, chemical, or biotic phenomena that give the designated area value for the conservation of listed species, particularly for older critical habitat designations that have no constituent elements) to the conservation value of those areas of critical habitat that occur in the action area, given the physical, chemical, biotic, and ecological processes that produce and maintain those constituent elements in the action area. We use the conservation value of those areas of designated critical habitat that occur in the action area as our point of reference for this comparison. For example, if the critical habitat in the action area has limited current value or potential value for the conservation of listed species, that limited value is our point of reference for our assessment.

If the conservation value of designated critical habitat in an action area is reduced, the final step of our analyses ask if those reductions are likely to be sufficient to reduce the conservation value of the entire critical habitat designation. In this step of our assessment, we combine information about the constituent elements of critical habitat (or of the physical, chemical, or biotic phenomena that give the designated area value for the conservation of listed species, particularly for older critical habitat designations that have no constituent elements) that are likely to experience changes in quantity, quality, and availability given exposure to an action with information on the physical, chemical, biotic, and ecological processes that produce and maintain those constituent elements in the action area. We use the conservation value of the entire designated critical habitat as our point of reference for this comparison. For example, if the designated critical habitat has limited current value or potential value for the conservation of listed species, that limited value is our point of reference for our assessment.

2.2 Application of this Approach in this Consultation

NMFS initially identified several aspects of the training exercises the U.S. Navy plans to undertake in the Southern California Range Complex during the twelve-month period beginning in January 2009 that represent potential hazards to threatened or endangered species or critical habitat that has been designated for them:

1. ships and ship traffic associated with an exercise;
2. active sonar systems that would be employed during an exercise;

3. underwater detonations associated with an exercise;
4. aircraft operations that occur during an exercise,
5. amphibious landings, and
6. gunfire and missile exercises.

Our section 7 consultation considered the number of endangered or threatened marine animals (that is, those marine animals that are under the jurisdiction of the National Marine Fisheries Service) that might be exposed to these different stressors, the nature of those exposures, the animal's probable responses upon being exposed, and the risks those responses might pose to individual animals, the populations those individuals represent, and the species those populations comprise.

2.2.1 Exposure Analyses

As discussed in the introduction to this section of this Opinion, exposure analyses are designed to identify the listed resources that are likely to co-occur with these effects in space and time and the nature of that co-occurrence. Our exposure analyses are designed to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an Action's effects and the populations or subpopulations those individuals represent.

Exposure to Navy Vessel Traffic

To estimate the number of endangered or threatened species that are likely to be exposed to vessel traffic associated with those U.S. Navy training and other activities in the Southern California Range Complex, we began with encounter rates (that is, n/L, or the number of marine mammal groups per unit distance or, in our case, groups per nautical mile) reported by various investigators in Southern California (for example, Barlow 1994, 1995; Ferguson 2003). When data were available, we used encounter rates that reflected seasonal and geographic differences, then multiplied encounter rates by the number of hours vessels participating in a training activity might travel multiplied by nominal travel speeds of 10 knots (= nominal number of vessels • vessel speed • hours of travel). Finally, we multiplied the resulting number of encounters by the mean group size for the different species to estimate the number of individuals that might be exposed to vessel traffic. That is

No. individuals exposed to vessel traffic = (Encounter rate • Hours of transit) • mean group size

where encounter rate might represent the number of groups encountered per unit distance (using nautical miles as the reference point) or unit time (hours).

Exposure to Active Sonar

Despite the numerous surveys that have been conducted in Southern California and reports from whale-watch vessels in these waters, there is almost no empirical information on the distribution and abundance of marine mammals relative to active sonar associated with Navy training exercises in the Southern California Range Complex. We do not know whether or to what degree the distribution or abundance of marine animals changes before, during, or after an exercise or whether those changes follow the same pattern or whether the pattern varies from species to

species. As a result, we cannot rely on empirical observations to estimate the number of endangered or threatened marine animals that might be exposed to active sonar during the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009. Instead, the U.S. Navy, NMFS, and most other entities (for example, oil and gas industries for drilling platforms, geophysics organizations that conduct seismic surveys, etc.) that try to estimate the number of marine animals that might be exposed to active sound sources in the marine environment rely on computer models, computer simulations, or some kind of mathematical algorithm to estimate the number of animals that might be exposed to a sound source. All of these approaches rely on assumptions that oversimplify the circumstances that determine whether marine animals are likely to be exposed to an area ensonified by active sonar in the marine environment, although the reasons for that oversimplification are understandable.

In this Opinion, we considered two different approaches to estimating the number of whales that might interact with sound fields associated with mid-frequency active sonar in the Southern California Range Complex:

1. the method the U.S. Navy used to develop the "take" (as that term is defined pursuant to the MMPA) estimates that were necessary to apply for an authorization to take marine mammals incidental to training activities pursuant to the MMPA and for the effects analyses in the Environmental Impact Statement the U.S. Navy and NMFS' Permits Division prepared for activities the U.S. Navy proposes to conduct in the Southern California Range Complex. The incidental "take" the Permits Division proposes to authorize in the proposed Letter of Authorization reflect these "take" estimates; and

2 an exposure model NMFS' Endangered Species Division developed using components of an established ecological model (the Hollings' disc equation) to estimate the number of endangered and threatened marine mammals that are likely to be exposed to active sonar during activities the U.S. Navy proposes to conduct in the Southern California Range Complex (the data necessary to estimate the number of sea turtles that might be exposed to active sonar was not available).

The first approach cited in this list was designed to estimate the number of times marine mammals might be "taken" (as that term is defined pursuant to the MMPA) as a result of their exposure to active sonar or underwater detonations during training activities, which is a subset of the number of animals that might be respond given exposure. As a result, the estimates produced by this approach is not comparable to the exposure estimates we produce in this Opinion. Nevertheless, although the results of U.S. Navy's modeling efforts and the results of NMFS' exposure models are similar, they represent very different estimates ("number of times marine mammals are 'taken' given that they have been exposed and respond to that exposure" versus "number of times marine mammals might be exposed").

1. U.S. NAVY EXPOSURE ESTIMATES FOR PROPOSED ACTIONS IN THE SOUTHERN CALIFORNIA RANGE COMPLEX. Over the past year, the U.S. Navy updated its approach to estimating the number of marine mammals that might be exposed to the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the five-year period beginning in January 2009. What follows is a brief summary of the Navy's current approach (for more details, refer to Appendix F of the U.S. Navy's Final Environmental Impact Statement on the Southern California Range Complex; U.S. Navy 2008a).

The U.S. Navy's updated approach focuses on a suite of representative provinces based on sound velocity profiles, bathymetries, and bottom types. Within each of these provinces, the U.S. Navy modeled transmission losses in 5 meter increments and used the results to build sound fields (based on maximum sound pressure levels). The U.S. Navy then calculates an "impact volume," which is the volume of water in which an acoustic metric exceeds a specified threshold; in this case, the Navy used one of three acoustic metrics: energy flux density (in a limited band or across a full band), peak pressure, or positive impulse. By multiplying these "impact volumes" by estimates of animal densities in three dimensions (densities distributed by area and depth), the U.S. Navy estimated the expected number of animals that might be exposed to an acoustic metric (energy flux density, peak pressure, or positive impulse) at levels that exceed thresholds that had been specified in advance. Specifically, the U.S. Navy calculated impact volumes for sonar operations (using energy flux density to estimate the probability of injury), peak pressure, and a Goertner modified positive impulse (for onset of slight lung injury associated with explosions).

To calculate "impact volumes," the U.S. Navy used a "risk continuum" or a curve that the U.S. Navy and NMFS developed that relates the probability of a behavioral response given exposure to a received level that is generally represented by sound pressure level, but included sound exposure level to deal with threshold shifts. The risk continuum, which the U.S. Navy and NMFS' Permits Division adapted from a mathematical model presented in Feller (1968), was estimated using three data sources: (1) data from controlled experiments conducted at the U.S. Navy's Space and Naval Warfare Systems Center in San Diego, California (Finneran *et al.* 2001, 2003, 2005; Finneran and Schlundt 2004; Schlundt *et al.* 2000), (2) data from a reconstruction of an incident in which killer whales were probably exposed to mid-frequency active sonar (Fromm 2004, Department of the Navy 2003), and (3) a suite of studies of the response of baleen whales to low-frequency sound sources (Nowacek *et al.* 2004). The U.S. Navy and NMFS' Permits Division estimated the proportion of a population that is expected to exhibit behavioral responses that NMFS' would classify as "take" (as that term is defined by the MMPA) by multiplying the different "impact volumes" at particular received levels by the "risk continuum."

This approach would also tend to overestimate the number of marine mammals that might be exposed, because marine mammals are highly mobile and are likely to use their mobility to avoid stimuli like active sonar, just as they avoid vessel traffic. Consequently, the results of this approach would be conservative, in the sense that they would tend to overestimate the number of animals that are likely to be "taken" by the activities the U.S. Navy plans to conduct in the Southern California Range Complex.

2. NMFS' EXPOSURE ESTIMATES USING COMPONENTS OF AN ECOLOGICAL PREDATOR-PREY MODEL. The models the U.S. Navy and the Permits Division used provide estimates of the number of marine mammals that might be "taken," as that term is defined by the MMPA, by active sonar and underwater detonations, particularly as a result of either noise-induced hearing loss (temporary or permanent threshold shifts) or behavioral responses. However, our jeopardy analyses must consider all potential effects of proposed actions, including direct or indirect beneficial and adverse effects that do not necessarily rise to the level of "take." For example, jeopardy analyses must consider the direct beneficial or adverse effects of actions on endangered or threatened individuals as well as indirect effects that results from how competitors, prey, symbionts, or the habitat of those listed individuals respond to an action. We cannot begin those analyses with estimates of the number of individuals that might be "taken" (as that term is

defined by the MMPA) because our analyses must consider direct and indirect effects that do not necessarily represent one or more form of "take."

As discussed earlier in this section of this Opinion, we conduct our jeopardy analyses by first identifying the potential stressors associated with an action, then we determine whether endangered species, threatened species, or designated critical habitat are likely to occur in the same space and at the same time as these potential stressors. If we conclude that such co-occurrence is likely, we then try to estimate the nature of that co-occurrence. These two steps represent our *exposure analyses*, which are designed to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an Action's effects and the populations or subpopulations those individuals represent.

For our exposure analyses, NMFS developed a model to estimate the number of times endangered or threatened marine mammals might be exposed to active sonar or underwater detonations. The core of this model estimates the number of individuals that might be exposed (N) as a function of an area (A) and the estimated density of animals (D) in that area. That is, $N = D \bullet A$ (Buckland *et al.* 1993, 2001), where, for the purposes of our analyses, A is the total area that would be ensonified by active sonar or contained within the shock wave or sound field produced by an underwater detonation.

We relied on published sources of information to estimate the density of endangered and threatened marine mammals in waters off Southern California., then we relied on a component of an established ecological model developed by Holling (1959) to estimate D or the ensonified area. Holling (1959) studied predation of small mammals on pine sawflies and found that predation rates increased with increasing densities of prey populations. In that paper, Holling proposed a model that is commonly called the "disc equation" because it describes the path of foraging predators as a moving disc that represents the predator's sensory field (normally with two-dimensions) as it searches for prey (see Figure 2). Although, Holling developed what is commonly called "the disc equation" to describe a predator's functional response to prey densities, a component of his equation estimates the number or prey a predator is likely to encounter during a foraging bout. This component of the disc equation combines the diameter of the predator's speed (s; units are distance/time), the predator's sensory field ($2r$; units are distance; here we use nautical miles), the time the predator spends searching for prey (T_s; units are distance) to estimate the area searched by a predator (the units (distance/time)(distance)(time) = $(\text{distance})^2$ = area). Because a predator is not likely to detect all prey within an area, a "detectability" variable (denoted k; which ranges from 0.0 to 1.0) expresses this limitation. This produces the equation

$$\text{No. prey encountered} = [k(s \bullet 2r \bullet T_s)] \bullet \text{“prey” per unit area}$$

The first component of this equation ($s \bullet 2r \bullet T_s$) provides the ensonified area which, when multiplied by animal density ("prey" per unit area), provides an estimate of the number of animals in an area (Buckland *et al.* 1993, 2001). From this equation, it is easy to see that increasing a predator's speed increases the area the predator searches and, therefore, the number of prey a predator would encounter. Similarly, increasing the detectability of prey or the prey density (number of prey per unit area) would increase the number of "prey" a predator would encounter.

NMFS adapted this component of the Holling's disc equation by treating Navy vessels to "predators," whose sensory field (2*r*, in square kilometers) represented the sound field of an active sonar system and speed (*s*) represented 10 knots, and whose search time represented the duration of an exercise (in hours). We treated the different species of endangered or threatened marine mammals as "prey." We assumed the "detectability" of marine animals reflected the amount of time a marine mammal would spend at depths that would bring them into the sound field of an active sonar system (in the case of whales), the amount of time a marine mammal would occur in a "sonar shadow" created by islands such as San Clemente Island, or the amount of time a pinniped spent in the water (in this case, Guadalupe fur seals). This left us with the equation

$$\text{No. individuals encountered} = [k(s \bullet 2r \bullet T_s)] \bullet \text{density of marine mammal species}$$

For our analyses, we used density estimates for marine mammals that represented the seasons and geographic areas we considered in our models when those data were available.

We used this model to develop and simulate one scenario for this consultation: a scenario that assumed that marine mammal densities never changed and that individual animals did not move during the course of an exercise (this is the closest approximation of the U.S. Navy's models). We developed, but did not use, two other scenarios for this consultation. The first scenario we considered but did not use assumed that marine mammals would try to avoid exposure to active sonar transmissions (for a review of literature supporting this assumption, see *Behavioral Avoidance* in the Response Analyses that we present later in this Opinion), but the data necessary on the rate at which whale densities would change in response to initial or continued exposure or when training activities would actually occur were not available for this consultation so we could reach conclusions based on this scenario. The second we considered but did not use captured changes in animal densities over the course of a season, but the information on the actual timing of the different training activities were not available for this consultation so we could not reach conclusions based on this scenario. As a result, although we developed and considered these three exposure scenarios for this consultation, we only report the results of the first of those exposure scenarios in this Opinion and that scenario forms the basis for our analysis of the effects of the proposed action on endangered and threatened species in the action area.

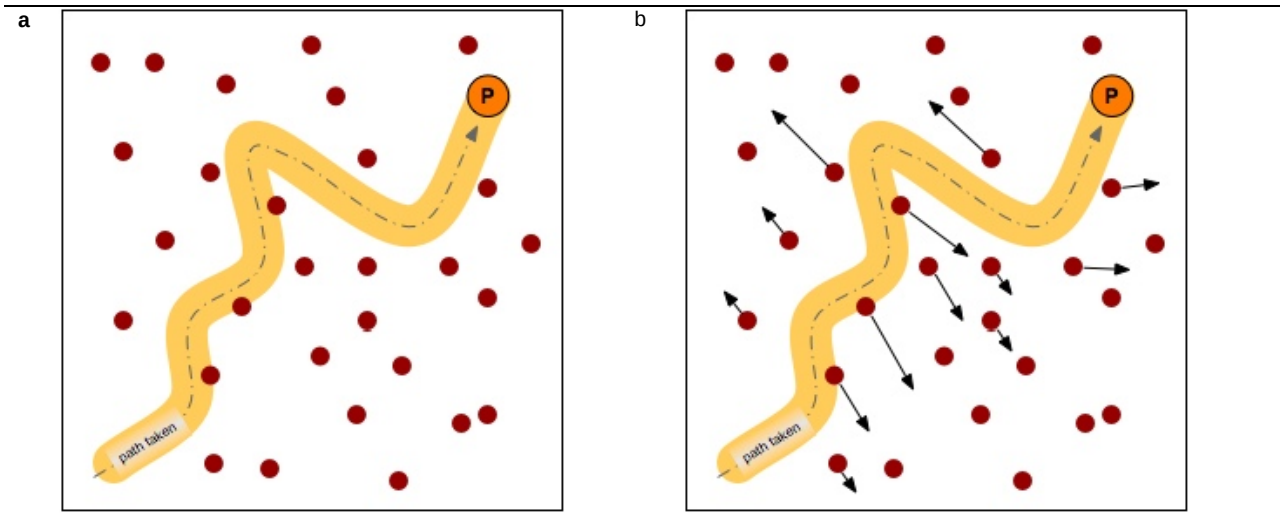

Figure 1. A representation of Hollings disc equation with a predator (denoted P) moving on a path (dashed line) through a field of potential prey (smaller circles). The thick orange line surrounding the predator's path represents the predator's sensory radius; increasing the size of this sensory radius increases the width of the area search per unit time. Similarly, assuming that everything else is equal, increasing a predator's speed would also increase the area the predator searches in a unit of time. The number of prey a predator encounters on a path = (the area searched)(prey density) = (search velocity)(sensory diameter)(time spent searching)(prey density). **Figure 1a** illustrates a situation in which prey do not try to avoid a predator. **Figure 1b** illustrates a situation in which marine mammals actively try to avoid the sound field, which the exposure models NMFS developed simulated by reducing marine mammal density during an exercise over time. See text for further explanation.

The exposure model we developed assumed ship speeds of 10 knots (or 18.25 kilometers per hour), which is the same assumption contained in the Navy's models. The "sensory field" (2r) in the model represented the U.S. Navy's estimates of the area that would be ensonified at different received levels presented in the U.S. Navy's Environmental Impact Statements for the Southern California Range Complex, adjusted to eliminate overlap (U.S. Navy 2007, 2008). Our exposure model was also based on the Navy's estimates of the number of hours of the different kinds of active sonar that would be employed in the different exercises. Finally, our exposure model used density estimates NMFS' Southwest Fisheries Science Center developed from data compiled from vessel surveys conducted from 1986 to 2008, abundance estimates from the 2007 stock assessment reports, and the draft 2008 stock assessment reports; these are the same density estimates the U.S. Navy used in its NEPA analyses and the Permits Division used for its rulemaking processes.

2.2.2 Response Analyses

As discussed in the introduction to this section of this Opinion, our response analyses are designed to identify the physical, physiological, and behavioral responses of endangered or threatened species that are likely to be exposed to stressors produced by an action. Because the responses of animals to a potential stressor are influenced by the animal's pre-existing physical, physiological, or behavioral state, our response analyses consider the *Status of the Species* and the impacts of the *Environmental Baseline*.

The potential stressors associated with the training exercises the U.S. Navy proposes to conduct in the Southern California Range Complex are likely to produce two general classes of responses:

1. responses that are influenced by an animal's assessment of whether a potential stressor poses a threat or risk (see Figure 3: Animal Does Not Respond, Stress Response, and Behavioral Response). For example, an animal's behavioral response to active sonar or an approaching vessel will depend on whether (a) an animal detects the some physical, visual, or acoustic cue from the sonar or vessel and (b) the animal classifies those cues as a potential threat (Blumstein and Bouskila 1996). The results of that assessment, which is influenced by the animal's physical and physiological state, can trigger physiological stress responses or lead to the animal to execute a behavioral response from its behavioral repertoire using a decision-making process that weighs the costs and benefits of alternative behaviors and recognizes the existing of trade-offs (Beale 2007, Blumstein and Bouskila 1996).
2. responses that are not influenced by the animal's assessment of whether a potential stressor poses a threat or risk (see Figure 3: Physical Damage, Mask Signal Reception, and Impair Call/Song Transmission).

Figure 3 illustrates the structure of our response analyses and shows the relationships between exposures, responses, and potential fitness consequences to individual animals that experience or exhibit particular responses or sets of responses (also see Southall *et al*. 2008 for an earlier version of this figure). This figure, and the analyses that are based on it, was derived from an extensive review of the scientific and commercial data available from published and unpublished documents (we present the specific references in our *Response Analyses*). The procedures we used to identify those data are presented in a subsequent sub-section of thissection; the specific studies, papers, and data that support our response analyses are presented in the *Response Analyses* section of this Opinion.

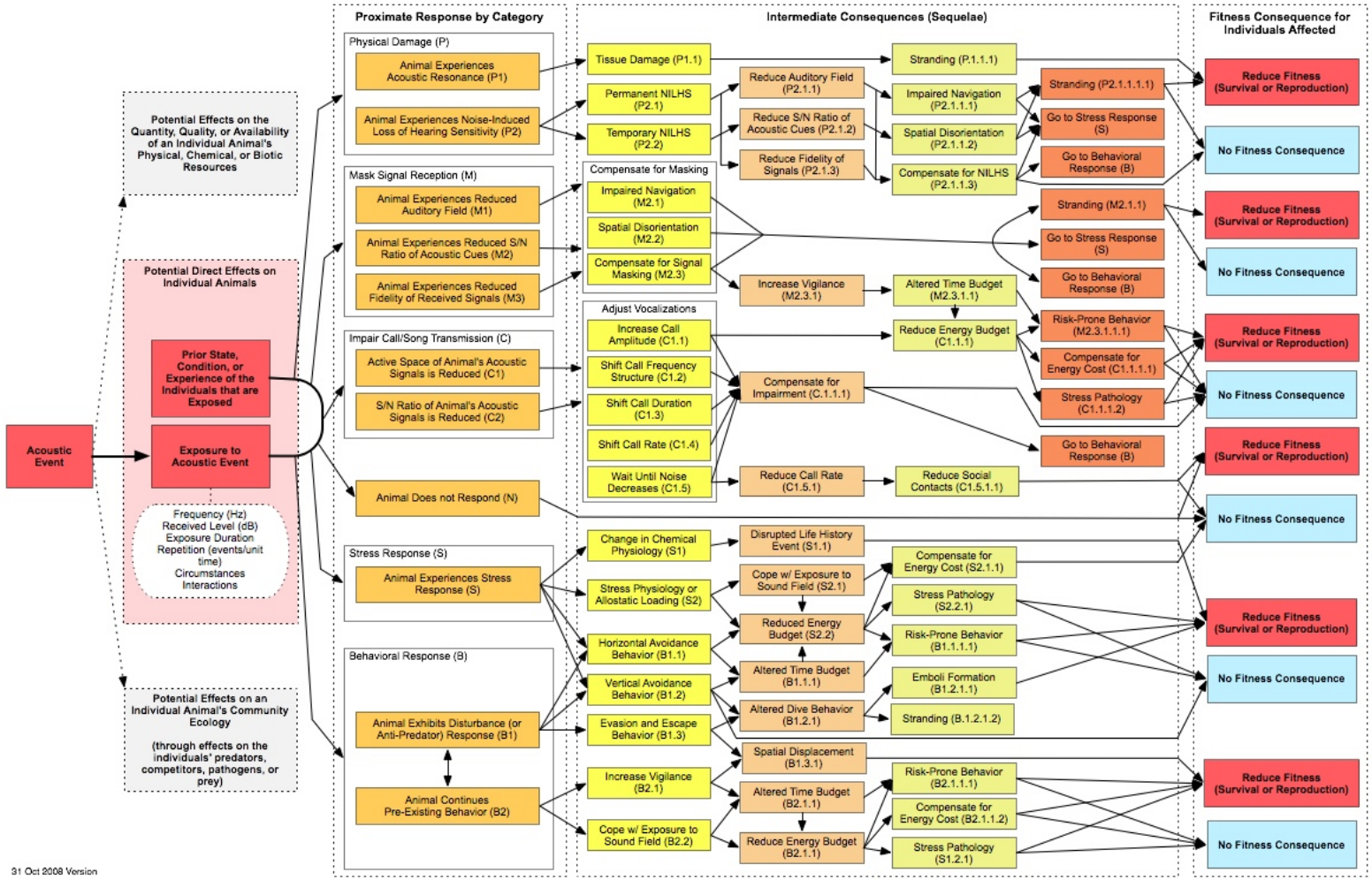

Figure 3. Conceptual model of the potential responses of endangered and threatened species upon being exposed to active sonar and the pathways by which those responses might affect the fitness of individual animals that have been exposed. See text contained in "Application of this Approach" and "Response Analyses" for an explanation and supporting literature.

We used empricial Bayesian analysis to estimate the probability of one or more of the proximate responses identified in Figure 3 given an exposure event from the data that were available. Bayes rule (also called Bayes' theorem) calculates the probability of an event given prior knowledge of the event's probability using the equation

$$\text{Prob}(R_i|D) = [\Pr(D|R_i) \times \Pr(R_i)]/\Sigma[\Pr(D|R_j) \times \Pr(R_j)]$$

Where *R* represents the set of mutually exclusive and exhaustive physical, physiological, and behavioral responses to an exposure with probabilities, $\Pr(R_i)$, $\Pr(R_j)$ represents alternatives to that particular response, and D represents the data on responses. In this formulation, $\Pr(R_i)$ in the numerator, represents the prior probability of a response which we derived from (1) the number of reports in the literature, that is, the number of papers that reported a particular response (here we distinguished between the number of reports for all cetaceans, the number of reports for all odonotocetes, and the number of reports for all mysticetes) and (2) an uninformed prior, which assumed that all responses that had non-zero values were equally probable.

To apply this procedure to our response analyses for active sonar exposure, we formed the set of potential responses using the "proximate responses" identified in Figure 3 (see Table 1). Then we identified the number of instances in which animals were reported to have exhibited one or more of those proximate responses based on published studies or studies available as gray literature. For example, Nowacek *et al* (2004) reported one instance in which North Atlantic right whales exposed to alarm stimuli did not repond to the stimulus and several instances in which right whales exhibited "disturbance" responses. We coded these two responses (no response and disturbance response) separately.

For the response analyses we will include in any Opinions we prepare on any Letters of Authorization the Permits Division issues, we will multiply our exposure estimates (which provided us with the number of instances of exposure) by these posterior probabilities (which identify the probability of a particular response given an exposure) to estimate the number of animals in the exposed population that might respond with particular responses. If, for the purposes of illustration, we assumed that 100 fin whales might be exposed to active sonar and further assumed that their probability of no responding, avoidance responses, and evasive response was 0.5414, 0.0650, and 0.0440, respectively, we would assume that 54 of the 100 fin whales would not respond to the exposure, 6 might respond by avoiding the sound field, and 4 might respond by evading the sound field.

To estimate the number of animals that might be "taken" in any Opinions we prepare on any Letters of Authorization the Permits Division issues, we will classify the responses as one or more form of "take" (for example, we would distinguish between *avoidance*, or an animal that shifts its position before a perceived predatory stimulus has an opportunity to attack, and *evasion*, or an escape response to a perceived attack) and use the method we described in the preceding paragraph to estimate the amount of "take."

2.2.3 Risk Analyses

As discussed in the Introduction to this section, the final steps of our analyses — establishing the risks those responses pose to endangered and threatened species or designated critical habitat — begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's effects. Our analyses then

integrate those individuals risks to identify consequences to the populations those individuals represent. Our analyses conclude by determining the consequences of those population-level risks to the species those populations comprise.

Table 1. Grouping of proximate responses (identified in Figure 3) into categories for response analyses

	Proximate Response	Grouping for Bayesian Analyses
1	No response	No Response
2	Acoustic resonance	Physical Trauma
3	Noise-induced hearing loss (P)	Not used for formal analyses
4	Noise-induced hearing loss (T)	Not used for formal analyses
5	Reduced auditory field (reduced active space)	Not used for formal analyses
6	Siignal masking	Not used for formal analyses
7	Increase call amplitude of vocalizations	Vocal Adjustments
8	Shift frequency structure of vocalizations	
9	Shift call duration of vocalizations	
10	Shift call rate of vocalizations	
11	Shift timing of vocalizations	
12	Physiological stress	Not used for formal analyses
13	Avoid sound field	Avoidance Response
14	Avoid received levels in sound field	
15	Abandon area of exercise	Evasive Response
16	Increase vigilance	Not used for formal analyses
17	Exhibit "disturbance" behavior	Behavioral Disturbance
18	Continue current behavior (coping)	No Response
19	Unspecified behavioral responses (adverse)	Unspecified behavioral responses (adverse)
20	Unspecified behavioral responses (not adverse)	Unspecified behavioral responses (not adverse)
21	Behaviors that cannot be classified	Not used for formal analyses

We measure risks to listed individuals using the individual's "fitness," which are changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual's probable response to an Action's effects on the environment (which we identify in our *response analyses*) are likely to have consequences for the individual's fitness.

When individual, listed plants or animals are expected to experience reductions in fitness, we would expect those reductions to also reduce the abundance, reproduction rates, or growth rates (or increase variance in one or more of these rates) of the populations those individuals represent (see Stearns 1992). If we conclude that listed plants or animals are *not* likely to experience reductions in their fitness, we would conclude our assessment.

Our risk analyses reflect these relationships between listed species and the populations that comprise them, and the individuals that comprise those populations. Our risk analyses begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's effects. Our analyses then integrate those individuals

risks to determine if the number of individuals that experience reduced fitness (or the magnitude of any reductions) is likely to be sufficient to reduce the viability of the populations those individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, or variance in these measures to make inferences about the population's probability of becoming demographically, ecologically, or genetically extinct in 10, 25, 50, or 100 years). In this step of our analyses, we use the population's base condition (established in the *Environmental Baseline* and *Status of Listed Resources* sections of this Opinion) as our point of reference.

Our risk analyses conclude by determining whether changes in the viability of one or more population is or is not likely to be sufficient to reduce the viability of the species (measured using probability of demographic, ecological, or genetic extinction in 10, 25, 50, or 100 years) those populations comprise. For these analyses, we combine our knowledge of the patterns that accompanied the decline, collapse, or extinction of populations and species that are known to have declined, collapsed, or become extinct in the past as well as a suite of population viability models.

When we conduct these analyses, our assessment is designed to establish that a decline, collapse, or extinction of an endangered or threatened species is not likely; we do not conduct these analyses to establish that such an outcome is likely. In this step of our analyses, we use the species' status (established in the *Status of the Species* section of this Opinion) as our point of reference.

2.3 Evidence Available for the Consultation

To conduct these analyses, we considered all lines of evidence available through published and unpublished sources that represent evidence of adverse consequences or the absence of such consequences. Over the past decade, a considerable body of scientific information on anthropogenic and its effects on marine mammals and other marine life has become available. Many investigators have studied the potential responses of marine mammals and other marine organisms to human-generated sounds in marine environments or have integrated and synthesized the results of these studies (for example, Abgrail *et al.* 2008, Bowles *et al.* 1994; Croll *et al.* 1999, 2001; Frankel and Clark 1998; Gisiner 1998, McCauley and Cato 2001; NRC 1994 1996, 2000, 2003, 2005; Norris 1994; Reeves 1992, Richardson *et al.* 1995, Southall *et al*. 2007, Tyack 2000, 2007; Wright *et al.* 2007).

To support the U.S. Navy's NEPA analyses and the Permits Division's rulemaking processes, NMFS' Southwest Fisheries Science Center calculated marine mammal density estimates based on compiled densities from vessel surveys conducted from 1986 to 2008, abundance estimates from the 2007 stock assessment reports, and the draft 2008 stock assessment reports. We assume those density estimates represent the best scientific and commercial data available and based on exposure analyses on those estimates.

To supplement that body of knowledge, we conducted electronic literature searches using the Library of Congress' *First Search* and *Dissertation Abstracts* databases, SCOPUS, *Web of Science*, and Cambridge Abstract's *Aquatic Sciences and Fisheries Abstracts* (ASFA) database services. The *First Search* databases provide access to general biological literature, master's theses, and doctoral dissertations back to 1980; ASFA provides access to journal articles, magazine articles, and conference proceedings back to 1964. Our searches specifically focus on the *ArticleFirst*, *BasicBiosis*, *Dissertation Abstracts*, *Proceedings* and *ECO* databases, which index the major journals

dealing with issues of ecological risk (for example, the journals *Environmental Toxicology and Chemistry*, *Human and Ecological Risk Assessment*), marine mammals (*Journal of Mammalogy*, *Canadian Journal of Zoology*, *Journal of Zoology*, *Marine Mammal Science*), sea turtles (*Copeia*, *Herpetologia*, *Journal of Herpetology*), ecology (*Ambio*, *Bioscience*, *Journal of Animal Ecology*, *Journal of Applied Ecology*, *Journal of the Marine Biological Association of the UK*, *Marine Pollution Bulletin, Oikos*), bioacoustics (*Bioacoustics*, *Journal of the Acoustical Society of America*), and animal behavior (*Advances in the Study of Behavior, Animal Behavior, Behavior, Behavioral Ecology and Sociobiology, Ethology*). We manually searched issues of the *Journal of Cetacean Research and Management* and *Reports of the International Whaling Commission*.

Our prior experience demonstrated that electronic searches produce the lowest number of false positive results (references produced by a search that are not relevant) and false negative results (references not produced by a search that are relevant) if we use paired combinations of the keywords: sonar, mid-frequency sonar, acoustic, marine acoustic, military exercises, sound, and noise paired with the keywords cetacean, dolphin, marine mammal, pinniped, porpoise, sea turtle, seal, and whale. To expand these searches, we modified these keyword pairs with the keywords effect, impact, mortality event, response, behavior (including the spelling "behaviour" as well as "behavior"), stranding, unusual mortality event. To collect data for our exposure analyses, we used the keyword: encounter rate paired with marine mammal, cetacean, and whale.

We supplemented the results of these electronic searches by acquiring all of the references we had gathered that, based on a reading of their titles or abstracts, appeared to comply with the keywords presented in the preceding paragraph. If a reference's title did not allow us to eliminate it as irrelevant to this inquiry, we acquired it. We continued this process until we gathered all (100 percent) of the relevant references cited by the introduction and discussion sections of the relevant papers, articles, books, and, reports and all of the references cited in the materials and methods, and results sections of those documents. We did not conduct hand searches of published journals for this consultation. We organized the results of these searches using commercial bibliographic software.

To supplement our searches, we examined the literature that was cited in documents and any articles we collected through our electronic searches. If, based on a reading of the title or abstract of a reference, the reference appeared to comply with the keywords presented in the preceding paragraph, we acquired the reference. If a reference's title did not allow us to eliminate it as irrelevant to this inquiry, we acquired it. We continued this process until we identified all (100 percent) of the relevant references cited by the introduction and discussion sections of the relevant papers, articles, books, and, reports and all of the references cited in the materials and methods, and results sections of those documents. We did not conduct hand searches of published journals for this consultation. We organized the results of these searches using commercial bibliographic software.

From each document, we extracted the following: when the information for the study or report was collected, the study design, which species the study gathered information on, the sample size, acoustic source(s) associated with the study (noting whether it was part of the study design or was correlated with an observation), other stressors associated with the study, study objectives, and study results, by species. We estimated the probability of responses from the following information: the known or putative stimulus; exposure profiles (intensity, frequency, duration of exposure, and nature) where information is available; and the entire distribution of responses exhibited by the individuals that have been exposed. Because the response of individual animals to stressors will often vary with time

(for example, no responses may be apparent for minutes or hours followed by sudden responses and vice versa) we also noted any temporal differences in responses to an exposure.

We ranked the results of these searches based on the quality of their study design, sample sizes, level of scrutiny prior to and during publication, and study results. We ranked carefully-designed field experiments (for example, experiments that control variables, such as other sources of sound in an area, that might produce the same behavioral responses) higher than field experiments were not designed to control those variables. We ranked carefully-designed field experiments higher than computer simulations. Studies that were based on large sample sizes with small variances were generally ranked higher than studies with small sample sizes or large variances.

Despite the information that is available, this assessment involved a large amount of uncertainty about the basic hearing capabilities of marine mammals; how marine mammals use sounds as environmental cues, how they perceive acoustic features of their environment; the importance of sound to the normal behavioral and social ecology of marine mammals; the mechanisms by which human-generated sounds affect the behavior and physiology (including the non-auditory physiology) of marine mammals, and the circumstances that are likely to produce outcomes that have adverse consequences for individual marine mammals and marine mammal populations (see NRC 2000 for further discussion of these unknowns).

2.4 Treatment of "Cumulative Impacts" (in the sense of NEPA)

Several organizations have argued that several of our previous biological opinions on the U.S. Navy's use of active sonar failed to consider the "cumulative impact" (in the NEPA sense of the term) of active sonar on the ocean environment and its organisms, particularly endangered and threatened species and critical habitat that has been designated for them (for example, see NRDC 2007 and Ocean Mammal Institute 2007). In each instance, we have had to explain how biological opinions consider "cumulative impacts" (in the NEPA sense of the term).

The U.S. Council on Environmental Quality defined "cumulative effects" (which we refer to as "cumulative impacts" to distinguish between NEPA and ESA uses of the same term) as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions" (40 CFR 1508.7). The effects analyses of biological opinions considered the "impacts" on listed species and designated critical habitat that result from the incremental impact of an action by identifying natural and anthropogenic stressors that affect endangered and threatened species throughout their range (the *Status of the Species*) and within an Action Area (the *Environmental Baseline*, which articulate the pre-existing *impacts* of activities that occur in an Action Area, including the past, contemporaneous, and future *impacts* of those activities). We assess the effects of a proposed action by adding their direct and indirect effects to the *impacts* of the activities we identify in an *Environmental Baseline* (50 CFR 402.02), in light of the impacts of the status of the listed species and designated critical habitat throughout their range; as a result, the results of our effects analyses are equivalent to those contained in the "cumulative impact" sections of NEPA documents.

2.5 A Brief Background on Sound

Sound is a wave of pressure variations propagating through a medium (for the sonar considered in this Opinion, the medium is marine water). Pressure variations are created by compressing and relaxing the medium. Sound measurements can be expressed in two forms: *intensity* and *pressure*. Acoustic intensity is the average rate of energy transmitted through a unit area in a specified direction and is expressed in watts per square meter (W/m^2). Acoustic intensity is rarely measured directly, it is derived from ratios of *pressures*; the standard reference pressure for underwater sound is 1 microPascal (μPa); for airborne sound, the standard reference pressure is 20 μPa (Richardson *et al.* 1995).

Acousticians have adopted a logarithmic scale for sound intensities, which is denoted in decibels (dB). Decibel measurements represent the ratio between a measured pressure value and a reference pressure value (in this case 1 μPa or, for airborne sound, 20 μPa.). The logarithmic nature of the scale means that each 10 dB increase is a ten-fold increase in power (e.g., 20 dB is a 100-fold increase, 30 dB is a 1,000-fold increase). The term "sound pressure level" implies a decibel measure and a reference pressure that is used as the denominator of the ratio. Throughout this Opinion, we use 1 microPascal (denoted re: 1μPa) as a standard reference pressure unless noted otherwise.

It is important to note that decibels underwater and decibels in air are not the same and cannot be directly compared. Because of the different densities of air and water and the different decibel standards in water and air, a sound with the same intensity (i.e., power) in air and in water would be approximately 63 dB quieter in air.

Sound frequency is measured in cycles per second, or Hertz (abbreviated Hz), and is analogous to musical pitch; high-pitched sounds contain high frequencies and low-pitched sounds contain low frequencies. Natural sounds in the ocean span a huge range of frequencies: from earthquake noise at 5 Hz to harbor porpoise clicks at 150,000 Hz. These sounds are so low or so high in pitch that humans cannot even hear them; acousticians call these infrasonic and ultrasonic sounds, respectively. A single sound may be made up of many different frequencies together. Sounds made up of only a small range of frequencies are called "narrowband", and sounds with a broad range of frequencies are called "broadband"; airguns are an example of a broadband sound source and sonars are an example of a narrowband sound source.

When considering the influence of various kinds of noise on the marine environment, it is necessary to understand that different kinds of marine life are sensitive to different frequencies of sound. Most dolphins, for instance, have excellent hearing at very high frequencies between 10,000 and 100,000 Hz. Their sensitivity at lower frequencies below 1000 Hz; however, is quite poor. On the other hand, the hearing sensitivity of most sea turtles appear to be best at frequencies between about 200 Hz and 700 Hz. As a result, sea turtles might be expected to suffer more harmful effects from loud, low frequency noise than would dolphins.

Because ears adapted to function underwater are physiologically different from human ears, comparisons using decibels would still not be adequate to describe the effects of a sound on a whale. When sound travels away from its source, its loudness decreases as the distance traveled by the sound increases. Thus, the loudness of a sound at its source is higher than the loudness of that same sound a kilometer distant. Acousticians often refer to the loudness of a sound at its source as the *source level* and the loudness of sound elsewhere as the *received level*. For example, a humpback whale 3 kilometers from an airgun that has a source level of 230 dB may only be exposed to sound that is

160 dB loud. As a result, it is important not to confuse source levels and received levels when discussing the loudness of sound in the ocean.

As sound moves away from a source, its propagation in water is influenced by various physical characteristics, including water temperature, depth, salinity, and surface and bottom properties that cause refraction, reflection, absorption, and scattering of sound waves. Oceans are not homogeneous and the contribution of each of these individual factors is extremely complex and interrelated. The physical characteristics that determine the sound's speed through the water will change with depth, season, geographic location, and with time of day (as a result, in actual sonar operations, crews will measure oceanic conditions, such as sea water temperature and depth, to calibrate models that determine the path the sonar signal will take as it travels through the ocean and how strong the sound signal will be at given range along a particular transmission path).

Sound tends to follow many paths through the ocean, so that a listener would hear multiple, delayed copies of transmitted signals (Richardson *et al.* 1995). Echoes are a familiar example of this phenomenon in air. In order to determine what the paths of sound transmission are, one rule is to seek paths that deliver the sound to the receiver the fastest. These are called acoustic rays. If the speed of sound were constant throughout the ocean, acoustic rays would consist of straight-line segments, with reflections off the surface and the bottom. However, because the speed of sound varies in the ocean, most acoustic rays are curved.

Sound speed in seawater is general about 1,500 meters per second (5,000 feet per second) although this speed varies with water density, which is affected by water temperature, salinity (the amount of salt in the water), and depth (pressure). The speed of sound increases as temperature and depth (pressure), and to a lesser extent, salinity, increase. The variation of sound speed with depth of the water is generally presented by a "sound speed profile," which varies with geographic latitude, season, and time of day.

In shallow waters of coastal regions and on continental shelves, sound speed profiles become influenced by surface heating and cooling, salinity changes, and water currents. As a result, these profiles tend to be irregular and unpredictable, and contain numerous gradients that last over short time and space scales. As sound travels through the ocean, the intensity associated with the wavefront diminishes, or attenuates. This decrease in intensity is referred to as propagation loss, also commonly called transmission loss. In general, in a homogeneous lossless medium, sound intensity decreases as the square of the range due to sample spherical spreading. In other words, a source level of 235 dB will have decreased in intensity to a received level of 175 dB after about 914 meters (1,000 yards).

2.6 Action Area

The action area for this biological opinion encompasses the marine, coastal, and terrestrial area contained within the Southern California Range Complex (see Figure 1). We assume that any of the proposed activities that are likely to occur landward of the mean higher high water line — including activities that may affect threatened or endangered species of sea turtle landward of the mean higher high water line — are addressed in separate section 7 consultations with the U.S. Fish and Wildlife Service.

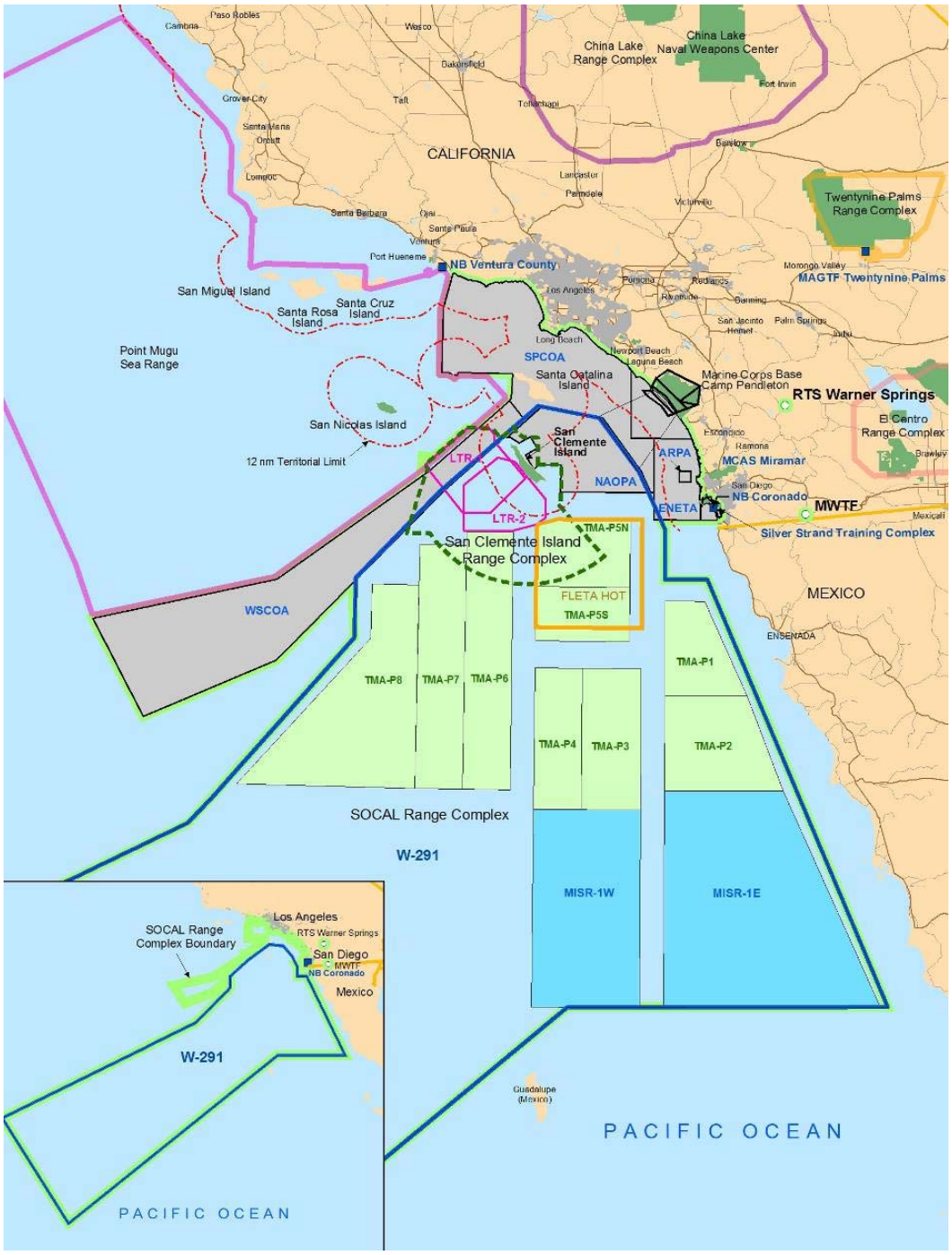

Figure 1. The Southern California Operating Area

3.0 Status of Listed Resources

NMFS has determined that the actions the U.S. Navy proposes to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009 may affect the following species provided protection under the ESA:

Blue whale	*Balaenoptera musculus*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Killer whale, Southern Resident	*Orcinus orca*	Endangered
North Pacific right whale	*Eubalaena japonica*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Steller sea lion, eastern population	*Eumetopias jubatus*	Threatened
Guadalupe fur seal	*Arctocephalus townsendii*	Threatened
Green sea turtle	*Chelonia mydas*	Threatened
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Endangered
Olive ridley sea turtle	*Lepidochelys olivacea*	Endangered
Green sturgeon, southern	*Acipenser medirostris*	Threatened
Chinook salmon, California coastal	*Oncorhynchus tschawytscha*	Threatened
Chinook salmon, Central Valley Spring		Threatened
Chinook salmon, Sacramento River		Endangered
Steelhead, South-Central California	*Oncorhynchus mykiss*	Threatened
Steelhead, Southern California		Endangered
White Abalone	*Haliotis sorensenii*	Endangered

No crtical habitat for endangered or threatened species under NMFS' jurisdiction has been designated in the action area.

3.1 Species Not Considered Further in this Opinion

As described in the Approach to the Assessment, NMFS uses two criteria to identify those endangered or threatened species or critical habitat that are not likely to be adversely affected by the various activities the U.S. Navy proposes to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009.

The first criterion was *exposure* or some reasonable expectation of a co-occurrence betweeon one or more potential stressor associated with the U.S. Navy's activities and a particular listed species or designated critical habitat: if we conclude that a listed species or designated critical habitat is not likely to be exposed to U.S. Navy's activities, we must also conclude that the critical habitat is not likely to be adversely affected by those activities. The second criterion is the probability of a *response* given exposure, which considers *susceptibility*: species that may be exposed to sound transmissions from active sonar, for example, but are likely to be unaffected by the sonar (at sound pressure levels they are likely to be exposed to) are also not likely to be adversely affected by the sonar. We applied these criteria to the species listed at the beginning of this section; this subsection summarizes the results of those evaluations.

NORTH PACIFIC RIGHT WHALES. Historically, the endangered North Pacific right whale occurred in waters off Southern California (Clapham *et al.* 2004; Scarff 1986). 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 2000 (Waite *et al*. 2003). The relative rarity of reports of this species off Southern California and the extremely low population numbers of this species suggests that these right whales have a very low probability of being exposed to ship and aircraft traffic and sonar transmissions associated with the activities considered in this Opinion.

In the event right whales are exposed to mid-frequency sonar, the information available on right whales vocalizations suggests that right whales produce moans less than 400 Hz in frequency (Watkins and Schevill 1972; Thompson *et al.* 1979; Spero 1981). Based on this information right whales exposed to received levels of active mid-frequency sonar are not likely to hear mid-frequency (1 kHz–10 kHz) sounds; therefore, they are not likely to respond physiologically or behaviorally to those received levels. Consequently, we conclude that the proposed activities may affect, but are not likely to adversely affect endangered northern right whales so this species will not be considered in greater detail in the remainder of this opinion.

SOUTHERN RESIDENT KILLER WHALES. Three populations of killer whales may occur in the waters of the Southern California Range Complex: Eastern North Pacific (ENP) Southern Residents, ENPOffshores, and ENP transients. Of these only the ENP Southern Resident killer whales are listed under the ESA. This population is most commonly seen in the inland waters of Washington state and southern Vancouver Island, although individuals from this population have been observed in Monterey Bay, California in January, 2000 and March, 2003, near the Farallon Islands in February 2005 and off Point Reyes in January 2006 (Pacific Fishery Management Council and NMFS 2006). Although one killer whale from ENP Transient killer whales (which are not listed pursuant to the ESA) was captured in the California/Oregon drift gillnet fishery in 1995 (Carretta *et al*. 2006), no Southern Resident killer whales have been reported to have interacted with any California-based fisheries.

STELLER SEA LIONS – EASTERN POPULATION. Steller sea lions are also not expected to be present in the action area. Steller sea lions range along the North Pacific Rim from northern Japan to California (Loughlin *et al*. 1984), with centers of abundance and distribution in the Gulf of Alaska and Aleutian Islands, respectively. In U.S. waters, there are two separate stocks of Steller sea lions: an eastern U.S. stock, which includes animals east of Cape Suckling, Alaska (144°W longitude), and a western U.S. stock, which includes animals at and west of Cape Suckling (Loughlin 1997). The closest rookery to the action area is Año Nuevo Island, which declined by 85% between 1970

and 1987 (LeBoeuf *et al.* 1991). Steller sea lions are rarely sighted in Southern California waters and have not been reported to have interacted with fisheries off southern California fisheries in more than a decade: the last documented interaction with California-based fisheries was in northern California, in 1994 in the California-Oregon drift gillnet fishery (NMFS 2000). Because their probability of occurring in waters off southern California is very small[3], Steller sea lions are not likely to be exposed to training activities in the Southern California Range Complex and, as a result, are not likely to be adversely affected by the proposed training activities.

GREEN STURGEON. Green sturgeon range from the Bering Sea, Alaska, to Enseñada, Mexico. In 2006, NMFS listed the southern distinct population segment of green sturgeon was recently listed as a threatened species (71 FR 17757); the northern population of green sturgeon is not listed as endangered or threatened. The southern population of green sturgeon consists of coastal and Central Valley green sturgeon populations south of the Eel River and is only known to spawn in the Sacramento River.

A few green sturgeon have been observed off the southern California coast, including fish less than 100 cm total length (Fitch and Lavenberg 1971, cited in Moyle *et al.* 1995; Fitch and Schultz 1978, cited in Moyle *et al.* 1995). Green sturgeon abundance increases north of Point Conception, California (Moyle *et al.*, 1995). The data NMFS collected to support its proposal to designated critical habitat for the southern population of green sturgeon led NMFS to conclude that these green sturgeon occupy coastal bays and estuaries from Monterey Bay, California, to Puget Sound, Washington. Although this does not mean that individuals from this population never occur in waters southern of Monterey Bay, it does suggest that they rarely occur in these waters. Because their probability of occurring in waters off southern California is very small, southern green sturgeon are not likely to be exposed to training activities in the Southern California Range Complex and, as a result, are not likely to be adversely affected by the proposed training activities.

CHINOOK SALMON AND STEELHEAD. The best scientific and commercial data available led us to conclude that listed chinook salmon and steelhead rarely occur in the action area and, as a result, had probabilities of being exposed that were sufficiently small to be discountable. Nevertheless, we considered all of the information available from published (for example, salmon stock assessment reports from the Pacific Fisheries Management Council 2006a, 2006b, 2005, 2004) and unpublished sources (unpublished data from the California Department of Fish and Game on commercial landings of salmon) on the probability of listed chinook salmon and steelhead being exposed to mid-frequency active sonar, we also considered their probability of responding to that exposure. As low-frequency hearing specialists, that probability was also very small (Hastings and Popper 2005); however, we concluded that establishing that these species had discountable probabilities of being exposed to mid-frequency sonar was sufficient to summarize the basis for conclusion on these species.

[3] Some ambiguity can accompany this usage of the word “rare” because it might denote a species that occurs regularly in an area, but occurs at low densities or it can denote a species that has a low probability of occurring in an area, regardless of its density. We use the word “rare” only in the latter sense; we would report species in the former sense as occurring regularly, but at low densities.

WHITE ABALONE. Historically, white abalone occurred from Point Conception, California to Punta Abreojos, Baja California, Mexico. They are the deepest-living of the west coast abalone species (Hobday and Tegner 2000): they had been caught at depths of 20-60 m (66-197 ft) but had been reported as having had the highest abundance at depths of 25-30 m (80-100 ft; Cox 1960, Tutschulte 1976). At these depths, white abalone are found in open low relief rock or boulder habitat surrounded by sand (Tutschulte 1976, Davis *et al*. 1996).

Over the past 30 years, the white abalone populations have declined precipitously in abundance primarily as a result of exploitation. Surveys conducted at Tanner and Cortez Banks have yielded numbers of white abalone in the low hundreds (Butler *et al*. 2006). Surveys conducted off the western side of San Clemente Island in August 2004 yielded only 6 animals at 37-50 m depth (Navy 2005 *in* Navy 2006a). The effects of activities associated with the Undersea Warfare Operations on invertebrates are not known, particularly the impacts of sound.

Other operations undertaken as part of Composite Training Unit or Joint Task Force Exercises, such as those involving underwater detonations, are not likely to affect white abalone because the number of bottom-placed charges are few, these chanrges are not likely to adversely affect rocky habitat, and Sinking Exercises occur in at least 3,000 m of water, where white abalone are non-existent.

White abalone could be exposed to cable-laying activities associated with the establishment of the proposed West Coast Shallow Water Training Range, which would occur in Tanner and Cortes Banks which support the last extant colonies of white abalone in the U.S. However, if the U.S. Navy avoids rock substrate, as stated in their EIS, white abalone would not be exposed to bottom disturbance associated with laying cable for the training range. We assume, however, that the U.S. Navy plans to fulfill this commitment to avoid rocky substrate by surveying areas before they lay cable. Consequently, we conclude that the proposed Composite Training Unit or Joint Task Force Exercises may affect, but is not likely to adversely affect endangered white abalone because their probability of occurring in the action area during the proposed exercies is also sufficiently small to be discountable. Therefore, this species will not be considered in greater detail in the remainder of this opinion.

3.2 Climate Change

There is now widespread consensus within the scientific community that atmospheric temperatures on earth are increasing (warming) and that this will continue for at least the next several decades (IPCC 2001, Oreskes 2004). There is also consensus within the scientific community that this warming trend will alter current weather patterns and patterns associated with climatic phenomena, including the timing and intensity of extreme events such as heat-waves, floods, storms, and wet-dry cycles. Threats posed by the direct and indirect effects of global climatic change is or will be common to all of the species we discuss in this Opinion. Because of this commonality, we present this narrative here rather than in each of the species-specific narratives that follow.

The IPCC estimated that average global land and sea surface temperature has increased by 0.6°C (±0.2) since the mid-1800s, with most of the change occurring since 1976. This temperature increase is greater than what would be expected given the range of natural climatic variability recorded over the past 1,000 years (Crowley 2000). The IPCC reviewed computer simulations of the effect of greenhouse gas emissions on observed climate variations that have been recorded in the past and evaluated the influence of natural phenomena such as solar and volcanic activity.

Based on their review, the IPCC concluded that natural phenomena are insufficient to explain the increasing trend in land and sea surface temperature, and that most of the warming observed over the last 50 years is likely to be attributable to human activities (IPCC 2001). Climatic models estimate that global temperatures would increase between 1.4 to 5.8°C from 1990 to 2100 if humans do nothing to reduce greenhouse gas emissions (IPCC 2001). These projections identify a suite of changes in global climate conditions that are relevant to the future status and trend of endangered and threatened species (Table 3).

Climate change is projected to have substantial direct and indirect effects on individuals, populations, species, and the structure and function of marine, coastal, and terrestrial ecosystems in the foreseeable future (Houghton *et al.* 2001, McCarthy *et al.* 2001, Parry *et al.* 2007). The direct effects of climate change would result in increases in atmospheric temperatures, changes in sea surface temperatures, changes in patterns of precipitation, and changes in sea level. Oceanographic models project a weakening of the thermohaline circulation resulting in a reduction of heat transport into high latitudes of Europe, an increase in the mass of the Antarctic ice sheet, and a decrease in the Greenland ice sheet, although the magnitude of these changes remain unknown.

Table 2. Phenomena associated with projections of global climate change including levels of confidence associated with projections (adapted from IPCC 2001 and Campbell-Lendrum Woodruff 2007)

Phenomenon	Confidence in Observed Changes (observed in the latter 20th Century)	Confidence in Projected Changes (during the 21st Century)
Higher maximum temperatures and a greater number of hot days over almost all land areas	Likely	Very likely
Higher minimum temperatures with fewer cold days and frost days over almost all land areas	Very likely	Very likely
Reduced diurnal temperature range over most land areas	Very likely	Very likely
Increased heat index over most land areas	Likely over many areas	Very likely over most areas
More intense precipitation events	Likely over many mid- to high-latitude areas in Northern Hemisphere	Very likely over many areas
Increased summer continental drying and associated probability of drought	Likely in a few areas	Likely over most mid-latitude continental interiors (projections are inconsistent for other areas)
Increase in peak wind intensities in tropical cyclones	Not observed	Likely over some areas
Increase in mean and peak precipitation intensities in tropical cyclones	Insufficient data	Likely over some areas

The indirect effects of climate change would result from changes in the distribution of temperatures suitable for calving and rearing calves, the distribution and abundance of prey, and the distribution and abundance of competitors or predators. For example, variations in the recruitment of krill (*Euphausia superba*) and the reproductive success of krill predators have been linked to variations in sea-surface temperatures and the extent of sea-ice cover during the winter months. Although the IPCC (2001) did not detect significant changes in the extent of

Antarctic sea-ice using satellite measurements, Curran (2003) analyzed ice-core samples from 1841 to 1995 and concluded Antarctic sea ice cover had declined by about 20% since the 1950s.

The Antarctic Peninsula, which is the northern extension of the Antarctic continent, contains the richest areas of krill in the Southern Ocean. The extent of se ice cover around this Peninsula has the highest degree of variability relative to other areas within the distribution of krill. Relatively small changes in climate conditions are likely to exert a strong influence on the seasonal pack-ice zone in the Peninsula area, which is likely to affect densities of krill in this region. Because krill are important prey for baleen whales or form critical component of the food chains on which baleen whales depend, increasing the variability of krill densities or causing those densities to decline dramatically is likely to have adverse effect on populations of baleen whales in the Southern Ocean.

Reid and Croxall (2001) analyzed a 23-year time series of the reproductive performance of predators that depend on krill for prey — Antarctic fur seals (*Arctocephalus gazella*), gentoo penguins (*Pygoscelis papua*), macaroni penguins (*Eudyptes chrysolophus*), and black-browed albatrosses (*Thalassarche melanophrys*) — at South Georgia Island and concluded that these populations experienced increases in the 1980s followed by significant declines in the 1990s accompanied by an increase in the frequency of years with reduced reproductive success. The authors concluded that macaroni penguins and black-browed albatrosses had declined by as much as 50 percent in the 1990s, although incidental mortalities in longline fisheries probably contributed to the decline of the albatross. These authors concluded, however, that these declines result, at least in part, from changes in the structure of the krill population, particularly reduced recruitment into older age classes, which lowers the number of predators this prey species can sustain. The authors concluded that the biomass of krill within the largest size class was sufficient to support predator demand in the 1980s but not in the 1990s.

Similarly, a study of relationships between climate and sea-temperature changes and the arrival of squid off southwestern England over a 20-year period concluded that veined squid (*Loligo forbesi*) migrate eastwards in the English Channel earlier when water in the preceding months is warmer, and that higher temperatures and early arrival correspond with warm phases of the North Atlantic oscillation (Sims *et al.* 2001). The timing of squid peak abundance advanced by 120- 150 days in the warmest years compared with the coldest. Seabottom temperature were closely linked to the extent of squid movement and temperature increases over the five months prior to and during the month of peak squid abundance did not differ between early and late years. These authors concluded that the temporal variation in peak abundance of squid seen off Plymouth represents temperature-dependent movement, which is in turn mediated by climatic changes associated with the North Atlantic Oscillation.

Climate-mediated changes in the distribution and abundance of keystone prey species like krill and climate-mediated changes in the distribution of cephalopod populations worldwide is likely to affect marine mammal populations as they re-distribute throughout the world's oceans in search of prey. Blue whales, as predators that specialize in eating krill, seem likely to change their distribution in response to changes in the distribution of krill (for example, see Payne *et al.* 1986, 1990 and Weinrich 2001); if they did not change their distribution or could not find the biomass of krill necessary to sustain their population numbers, their populations seem likely to experience declines similar to those observed in other krill predators, which would cause dramatic declines in their population sizes or would increase the year-to-year variation in population size; either of these outcomes would dramatically increase the extinction probabilities of these whales.

Sperm whales, whose diets can be dominated by cephalopods, would have to re-distribute following changes in the distribution and abundance of their prey. This statement assumes that projected changes in global climate would only affect the distribution of cephalopod populations, but would not reduce the number or density of cephalopod populations. If, however, cephalopod populations collapse or decline dramatically, sperm whale populations are likely to collapse or decline dramatically as well.

The response of North Atlantic right whales to changes in the North Atlantic Oscillation also provides insight into the potential consequences of a changing climate on large whales. Changes in the climate of the North Atlantic have been directly linked to the North Atlantic Oscillation, which results from variability in pressure differences between a low pressure system that lies over Iceland and a high pressure system that lies over the Azore Islands. As these pressure systems shift from east to west, they control the strength of westerly winds and storm tracks across the North Atlantic Ocean. The North Atlantic Oscillation Index, which is positive when both systems are strong (producing increased differences in pressure that produce more and stronger winter storms) and negative when both systems are weak (producing decreased differences in pressure resulting in fewer and weaker winter storms), varies from year to year, but also exhibits a tendency to remain in one phase for intervals lasting several years.

Sea surface temperatures in the North Atlantic Ocean are closely related to this Oscillation and influences the abundance of marine mammal prey such as zooplankton and fish. In the 1970s and 1980s, the North Atlantic Oscillation Index have been positive and sea surface temperatures increased. These increased are believed to have produced conditions that were favorable for the copepod (*Calanus finmarchicus*), which is the principal prey of North Atlantic right whales (Conversi *et al.* 2001) and may have increased calving rates of these whales (we cannot verify this association because systematic data on North Atlantic right whale was not collected until 1982; Greene *et al.* 2003). In the late 1980s and 1990s, the NAO Index was mainly positive but exhibited two substantial, multi-year reversals to negative values. This was followed by two major, multi-year declines in copepod prey abundance (Pershing *et al.* 2001, Drinkwater *et al.* 2003). Calving rates for North Atlantic right whales followed the declining trend in copepod abundance, although there was a time lag between the two (Greene *et al.* 2003).

Although the NAO Index has been positive for the past 25 years, atmospheric models suggest that increases in ocean temperature associated with climate change forecasts may produce more severe fluctuations in the North Atlantic Oscillation. Such fluctuations would be expected to cause dramatic shifts in the reproductive rate of critically endangered North Atlantic right whales (Drinkwater *et al.* 2003; Greene *et al.* 2003) and possibly a northward shift in the location of right whale calving areas (Kenney 2007).

Changes in global climatic patterns are also projected to have profound effect on the coastlines of every continent by increasing sea levels and increasing the intensity, if not the frequency, of hurricanes and tropical storms. Based on computer models, these phenomena would inundate nesting beaches of sea turtles, change patterns of coastal erosion and sand accretion that are necessary to maintain those beaches, and would increase the number of turtle nests that are destroyed by tropical storms and hurricanes. Further, the combination of increasing sea levels, changes in patterns of coastal erosion and accretion, and changes in rainfall patterns are likely to affect coastal estuaries, submerged aquatic vegetation, and reef ecosystems that provide foraging and rearing habitat for several species of sea turtles. Finally, changes in ocean currents associated with climate change projections would affect the migratory patterns of sea turtles. The loss of nesting beaches, by itself, would have catastrophic effect on sea turtles

populations globally if they are unable to colonize any new beaches that form of if the beaches that form do not provide the sand depths, grain patterns, elevations above high tides, or temperature regimes necessary to allow turtle eggs to survive. When combined with changes in coastal habitats and oceans currents, the future climates that are forecast place sea turtles at substantially greater risk of extinction than they already face.

3.3 Introduction to this Status of Listed Species

The rest of this section of our Opinion consists of narratives for each of the threatened and endangered species that occur in the action area and that may be adversely affected by the additional activities the U.S. Navy proposes to undertake in the Southern California Range Complex from January 2009 to Januiary 2014. In each narrative, we present a summary of information on the distribution and population structure of each species to provides a foundation for the exposure analyses that appear later in this Opinion. Then we summarize information on the threats to the species and the species' status given those threats to provide points of reference for the jeopardy determinations we make later in this Opinion. That is, we rely on a species' status and trend to determine whether or not an action's direct or indirect effects are likely to increase the species' probability of becoming extinct.

After the Status subsection of each narrative, we present information on the diving and social behavior of the different species because that behavior helps determine whether aerial and ship board surveys are likely to detect each species. We also summarize information on the vocalizations and hearing of the different species because that background information lays the foundation for our assessment of the how the different species are likely to respond to sounds produced by detonations.

More detailed background information on the status of these species and critical habitat can be found in a number of published documents including status reviews, recovery plans for the blue whale (NMFS 1998a), fin whales (2007), fin and sei whale (NMFS 1998b, NMFS 2007), humpback whale (NMFS 1991a), right whale (NMFS 1991b), a status report on large whales prepared by Perry *et al.* (1999), recovery plans for sea turtles (NMFS and USFWS 1998a, 1998b, 1998c, 1998d, and 1998e), and recovery plans for listed salmon. Richardson *et al.* (1995) and Tyack (2000) provide detailed analyses of the functional aspects of cetacean communication and their responses to active sonar. Finally, Croll *et al.* (1999), NRC (1994, 1996, 2000, 2003, 2005), and Richardson *et al.* (1995) provide information on the potential and probable effects of active sonar on the marine animals considered in this Opinion.

3.3.1 Blue whale

Distribution

Blue whales are found along the coastal shelves of North America and South America (Rice 1974; Donovan 1984; Clarke 1980) in the North Pacific Ocean. In the North Pacific Ocean, blue whales occur in summer foraging areas in the Chukchi Sea, the Sea of Okhotsk, around the Aleutian Islands, and the Gulf of Alaska; in the eastern Pacific, they occur south to California; in the western Pacific, they occur south to Japan. Blue whales in the eastern Pacific winter from California south; in the western Pacific, they winter from the Sea of Japan, the East China and Yellow Seas, and the Philippine Sea (Gambell 1985).

In the western north Atlantic Ocean, blue whales are found from the Arctic to at least the mid-latitude waters of the North Atlantic (CeTAP 1982, Wenzel *et al.*1988, Yochem and Leatherwood 1985, Gagnon and Clark 1993). Blue whales have been observed frequently off eastern Canada, particularly in waters off Newfoundland, during the winter. In the summer month, they have been observed in Davis Strait (Mansfield 1985), the Gulf of St. Lawrence (from the north shore of the St. Lawrence River estuary to the Strait of Belle Isle), and off eastern Nova Scotia (Sears *et al.* 1987). In the eastern north Atlantic Ocean, blue whales have been observed off the Azores Islands, although Reiner *et al.* (1993) do not consider them common in that area.

In 1992, the U.S. Navy conducted an extensive acoustic survey of the North Atlantic using the Integrated Under-water Surveillance System's fixed acoustic array system (Clark 1995). Concentrations of blue whale sounds were detected in the Grand Banks off Newfoundland and west of the British Isles. In the lower latitudes, one blue whale was tracked acoustically for 43 days, during which time the animal traveled 1400 nautical miles around the western North Atlantic from waters northeast of Bermuda to the southwest and west of Bermuda (Gagnon and Clark 1993).

In the central North Pacific Ocean, blue whale vocalizations have been recorded off the island of Oahu in the main Hawai'ian Islands and off Midway Island in the western edge of the Hawai'ian Archipelago (Barlow *et al.* 1994b; Northrop *et al.* 1971; Thompson and Friedl 1982), although blue whales are rarely sighted in Hawai'ian waters and have not been reported to strand in the Hawai'ian Islands. Nishiwaki (1966) reported that blue whales occur in the Aleutian Islands and in the Gulf of Alaska. Although blue whales have not been observed off Alaska since 1987 (Leatherwood *et al.* 1982; Stewart *et al.* 1987; Forney and Brownell 1996). No distributional information exists for the western region of the North Pacific.

In the eastern North Pacific Ocean, blue whales forage in offshore waters from Alaska to California in the summer and fall, then migrate south from Mexico to Costa Rica in winter (Calambokidis et al. 1990, Calambokidis 1995, NMFS 2006, Reilly and Thayer 1990). Blue whales occupy waters off California primarily from June through November; based on calling intensity, the reach a peak in density in September (Burtenshaw *et al*. 2004). From December through May, blue whales are infrequent in waters off California (Forney and Barlow 1998; Larkman and Veit 1998). In waters off southern California, blue whales commonly occur in waters off the Channel Islands and Santa Rosa and San Miguel Islands where currents provide dense layers of the euphausiids on which they forage.

Blue whales have also been reported year-round in the northern Indian Ocean, with sightings in the Gulf of Aden, Persian Gulf, Arabian Sea, and across the Bay of Bengal to Burma and the Strait of Malacca (Mizroch *et al.* 1984). The migratory movements of these whales are unknown.

Historical catch records suggest that "true" blue whales and "pygmy" blue whale (*B. m. brevicada*) may be geographically ddistinct (Brownell and Donaghue 1994, Kato *et al.* 1995). The distribution of the "pygmy" blue whale is north of the Antarctic Convergence, while that of the "true" blue whale is south of the Convergence in the austral summer (Kato *et al.* 1995). "True" blue whales occur mainly in the higher latitudes, where their distribution in mid-summer overlaps with that of the minke whale (*Balaenoptera acutorostrata*). During austral summers, "true" blue whales are found close to edge of Antarctic ice (south of 58° S) with concentrations between 60°-80° E and 66°-70° S (Kasamatsu *et al.* 1996).

Population Structure

For this and all subsequent species, the term "population" refers to groups of individuals whose patterns of increase or decrease in abundance over time are determined by internal dynamics (births resulting from sexual interactions between individuals in the group and deaths of those individuals) rather than external dynamics (immigration or emigration). This definition is a reformulation of definitions articulated by Cole (1957, Futuyma (1986) and Wells and Richmond (1995) and is more restrictive than those uses of 'population' that refer to groups of individuals that co-occur in space and time but do not have internal dynamics that determine whether the size of the group increases or decreases over time (see review by Wells and Richmond 1995). The definition we apply is important to section 7 consultations because such concepts as 'population decline,' 'population collapse,' 'population extinction,' and 'population recovery' apply to the restrictive definition of 'population' but do not explicitly apply to alternative definitions. As a result, we do not treat the different whale "stocks" recognized by the International Whaling Commission or other authorities as populations unless those distinctions were clearly based on demographic criteria. We do, however, acknowledge those "stock" distinctions in these narratives.

At least three subspecies of blue whales have been identified based on body size and geographic distribution (*B. musculus intermedia*, which occurs in the higher latitudes of the Southern Oceans, *B. m. musculus*, which occurs in the Northern Hemisphere, and *B. m. brevicauda* which occurs in the mid-latitude waters of the southern Indian Ocean and north of the Antarctic convergence), but this consultation will treat them as a single entity. Readers who are interested in these subspecies will find more information in Gilpatrick *et al.* (1997), Kato *et al.* (1995), Omura *et al.* (1970) and Ichihara (1966).

In addition to these subspecies, the International Whaling Commission's Scientific Committee has formally recognized one blue whale population in the North Pacific (Donovan 1991), although there is increasing evidence that more than there may be more than one blue whale population in the Pacific Ocean (Gilpatrick *et al.* 1997, Barlow *et al.* 1995, Mizroch *et al.* 1984a, Ohsumi and Wada 1974). For example, studies of the blue whales that winter off Baja California and in the Gulf of California suggest that these whales are morphologically distinct from blue whales of the western and central North Pacific (Gilpatrick *et al.* 1997), although these differences might result from differences in the productivity of their foraging areas more than genetic differences (the southern whales forage off California; Sears *et al.*1987; Barlow *et al.*1997; Calambokidis *et al.* 1990).

A population or "stock" of endangered blue whales occurs in waters surrounding the Hawai'ian archipelago (from the main Hawai'ian Islands west to at least Midway Island), although blue whales are rarely reported from Hawai'ian waters. The only reliable report of this species in the central North Pacific was a sighting made from a scientific research vessel about 400 km northeast of Hawai'i in January 1964 (NMFS 1998). However, acoustic monitoring has recorded blue whales off Oahu and the Midway Islands much more recently (Barlow *et al.* 1994, McDonald and Fox 1999, Northrop *et al.* 1971; Thompson and Friedl 1982).

The recordings made off Oahu showed bimodal peaks throughout the year, suggesting that the animals were migrating into the area during summer and winter (Thompson and Friedl 1982; McDonald and Fox 1999). Twelve aerial surveys were flown within 25 nm^2 of the main Hawai'ian Islands from 1993-1998 and no blue whales were sighted. Nevertheless, blue whale vocalizations that have been recorded in these waters suggest that the occurrence

of blue whales in these waters may be higher than blue whale sightings. There are no reports of blue whales strandings in Hawai'ian waters.

The International Whaling Commission also groups all of the blue whales in the North Atlantic Ocean into one "stock" and groups blue whales in the Southern Hemisphere into six "stocks" (Donovan 1991), which are presumed to follow the feeding distribution of the whales.

Threats to the Species

NATURAL THREATS. Natural causes of mortality in blue whales are largely unknown, but probably includes predation and disease (not necessarily in their order of importance). Blue whales are known to become infected with the nematode *Carricauda boopis* (Baylis 1920), which are believed to have caused fin whales to die as a result of renal failure (Lambertsen 1986; see additional discussion under *Fin whales*). Killer whales and sharks are also known to attack, injure, and kill very young or sick fin and humpback whale and probably hunt blue whales as well (Perry *et al.* 1999).

ANTHROPOGENIC THREATS. Two human activities are known to threaten blue whales: whaling and shipping. Historically, whaling represented the greatest threat to every population of blue whales and was ultimately responsible for listing blue whales as an endangered species. As early as the mid-seventeenth century, the Japanese were capturing blue, fin, 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. Before fin whales became the focus of whaling operations, populations of blue whales had already become commercially extinct (IWC 1995).

From 1889 to 1965, whalers killed about 5,761 blue whales in the North Pacific Ocean (NMFS 1998). Evidence of a population decline were evident in the catch data from Japan. In 1912, whalers captured 236 blue whales; in 1913, 58 blue whales; in 194, 123 blue whales; from 1915 to 1965, the number of blue whales captured declined continuously (Mizroch *et al.* 1984). In the eastern North Pacific, whalers killed 239 blue whales off the California coast in 1926. And, in the late 1950s and early 1960s, Japanese whalers killed 70 blue whales per year off the Aleutian Islands (Mizroch *et al.* 1984a).

Although the International Whaling Commission banned commercial whaling in the North Pacific in 1966, Soviet whaling fleets continued to hunt blue whales in the North Pacific for several years after the ban. Surveys conducted in these former-whaling areas in the 1980s and 1990s failed to find any blue whales (Forney and Brownell 1996). By 1967, Soviet scientists wrote that blue whales in the North Pacific Ocean (including the eastern Bering Sea and Prince William Sound) had been so overharvested by Soviet whaling fleets that some scientists concluded that any additional harvests were certain to cause the species to become extinct in the North Pacific (Latishev 2007). As its legacy, whaling has reduced blue whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push blue whales closer to extinction. Otherwise, whaling currently does not threaten blue whale populations.

In 1980, 1986, 1987, and 1993, ship strikes have been implicated in the deaths of blue whales off California (Barlow *et al.* 1997). In addition, several photo-identified blue whales from California waters were observed with large scars on their dorsal areas that may have been caused by ship strikes. Studies have shown that blue whales respond to approaching ships in a variety of ways, depending on the behavior of the animals at the time of approach, and speed and direction of the approaching vessel. While feeding, blue whales react less rapidly and with less obvious avoidance behavior than whales that are not feeding (Sears *et al.* 1983). Within the St. Lawrence Estuary, blue whales are believed to be affected by large amounts of recreational and commercial vessel traffic. Blue whales in the St. Lawrence appeared more likely to react to these vessels when boats made fast, erratic approaches or sudden changes in direction or speed (Edds and Macfarlane 1987, Macfarlane 1981). The number of blue whales struck and killed by ships is unknown because the whales do not always strand or examinations of blue whales that have stranded did not identify the traumas that could have been caused by ship collisions. In the California/Mexico stock, annual incidental mortality due to ship strikes averaged 0.2 whales during 1991 to 1995 and from 1998-2002 (Barlow *et al.* 1997).

In September 2007, three blue whale mortalities were confirmed to be caused by ship strikes in the Santa Barbara Channel off Southern California. These deaths were part of a larger Unusual Mortality Event, declared by the Working Group on Marine Mammal Unusual Mortality Events. There are no records of ship strikes for blue whales in the western North Pacific but any mortalities caused by ship strikes in that region are not likely to have been reported.

Status

Blue whales were listed as endangered under the ESA in 1973. Blue whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA. Critical habitat has not been designated for blue whales.

It is difficult to assess the current status of blue whales because (1) there is no general agreement on the size of the blue whale population prior to whaling and (2) estimates of the current size of the different blue whale populations vary widely. We may never know the size of the blue whale population prior to whaling, although some authors have concluded that their population numbers about 200,000 animals before whaling. Similarly, estimates of the global abundance of blue whales are uncertain. Since the cessation of whaling, the global population of blue whales has been estimated to range from 11,200 to 13,000 animals (Maser *et al.* 1981; U. S. Department of Commerce 1983). These estimates, however, are more than 20 years old.

A lot of uncertainty surrounds estimates of blue whale abundance in the North Pacific Ocean. Barlow (1994) estimated the North Pacific population of blue whales at between 1,400 to 1,900. Barlow and Calambokidis (1995) estimated the abundance of blue whales off California at 2,200 individuals. Wade and Gerrodette (1993) and Barlow *et al.* (1997) estimated there were a minimum of 3,300 blue whales in the North Pacific Ocean in the 1990s.

The size of the blue whale population in the north Atlantic is also uncertain. The population has been estimated to number from a few hundred individuals (Allen 1970; Mitchell 1974) to 1,000 to 2,000 individuals (Sigurjónsson

1995). Gambell (1976) estimated there were between 1,100 to 1,500 blue whales in the North Atlantic before whaling began and Braham (1991) estimated there were between 100 and 555 blue whales in the North Atlantic during the late 1980s and early 1990s. Sears *et al.* (1987) identified over 300 individual blue whales in the Gulf of St. Lawrence, which provides a minimum estimate for their population in the North Atlantic. Sigurjónsson and Gunnlaugson (1990) concluded that the blue whale population had been increasing since the late 1950s and argued that the blue whale population had increased at an annual rate of about 5 percent between 1979 and 1988, although the level of confidence we can place in these estimates is low.

Estimates of the number of blue whales in the Southern Hemisphere range from 5,000 to 6,000 (review by Yochem and Leatherwood 1985) with an average rate of increase that has been estimated at between 4 and 5 percent per year. Butterworth *et al.* (1993), however, estimated the Antarctic population at 710 individuals. More recently, Stern (2001) estimated the blue whale population in the Southern Ocean at between 400 and 1,400 animals (c.v. 0.4). The pygmy blue whale population has been estimated at 6,000 individuals (Yochem and Leatherwood 1985)

The information available on the status and trend of blue whales do not allow us to reach any conclusions about the extinction risks facing blue whales as a species, or particular populations of blue whales. With the limited data available on blue whales, we do not know whether these whales exist at population sizes large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself) or if blue whales might are threatened more by exogenous threats such as anthropogenic activities (primarily whaling, entanglement, and ship strikes) or natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate).

Diving and Social Behavior

Generally, blue whales make 5-20 shallow dives at 12-20 second intervals followed by a deep dive of 3-30 minutes (Mackintosh 1965; Leatherwood *et al.* 1976; Maser *et al.* 1981; Yochem and Leatherwood 1985; Strong 1990; Croll *et al.* 1999). Croll *et al.* (1999) found that the dive depths of blue whales foraging off the coast of California during the day averaged 132 m (433 ft) with a maximum recorded depth of 204 m (672 ft) and a mean dive duration of 7.2 minutes. Nighttime dives are generally less than 50 m (165 ft) in depth (Croll *et al.* 1999).

Blue whales are usually found swimming alone or in groups of two or three (Ruud 1956, Slijper 1962, Nemoto 1964, Mackintosh 1965, Pike and MacAskie 1969, Aguayo 1974). However, larger foraging aggregations and aggregations mixed with other species like fin whales are regularly reported (Schoenherr 1991, Fiedler *et al.* 1998). Little is known of the mating behavior of blue whales.

Vocalizations and Hearing

The vocalizations that have been identified for blue whales include a variety of sounds described as low frequency moans or long pulses (Cummings and Thompson 1971, 1977; Edds 1982, Thompson and Friedl 1982; Edds-Walton 1997). Blue whales produce a variety of low frequency sounds in the 10-100 Hz band (Cummings and Thompson 1971, Edds 1982, Thompson and Friedl 1982, McDonald *et al.* 1995, Clark and Fristrup 1997, Rivers 1997). The

most typical signals are very long, patterned sequences of tonal infrasonic sounds in the 15-40 Hz range. The sounds last several tens of seconds. Estimated source levels are as high as 180-190 dB (Cummings and Thompson 1971). Ketten (1997) reports the frequencies of maximum energy between 12 and 18 Hz. In temperate waters, intense bouts of long patterned sounds are very common from fall through spring, but these also occur to a lesser extent during the summer in high latitude feeding areas. Short sequences of rapid calls in the 30-90 Hz band are associated with animals in social groups. The seasonality and structure of long patterned sounds suggest that these sounds are male displays for attracting females, competing with other males, or both. The context for the 30-90 Hz calls suggests that they are communicative but not related to a reproductive function. Vocalizations attributed to blue whales have been recorded in presumed foraging areas, along migration routes, and during the presumed breeding season (Beamish and Mitchell 1971; Cummings and Thompson 1971, 1977, 1994; Cummings and Fish 1972; Thompson *et al.* 1996; Rivers 1997; Tyack and Clark 1997; Clark *et al.* 1998).

Blue whale moans within the low frequency range of 12.5-200 Hz, with pulse duration up to 36 seconds, have been recorded off Chile (Cummings and Thompson 1971). A short, 390 Hz pulse also is produced during the moan. One estimate of the overall source level was as high as 188 dB, with most energy in the 1/3-octave bands centered at 20, 25, and 31.5 Hz, and also included secondary components estimates near 50 and 63 Hz (Cummings and Thompson 1971).

As with other vocalizations produced by baleen whales, the function of blue whale vocalizations is unknown, although there are numerous hypotheses (which include include: maintenance of inter-individual distance, species and individual recognition, contextual information transmission, maintenance of social organization, location of topographic features, and location of prey resources; see the review by Thompson *et al.* 1992 for more information on these hypotheses). 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 blue whales can, in theory, travel long distances, and it is possible that such long-distance communication occurs (Payne and Webb 1971, Edds-Walton 1997). The long-range sounds may also be used for echolocation in orientation or navigation (Tyack 1999).

Cetaceans have an auditory anatomy that follows the basic mammalian pattern, with some modifications to adapt to the demands of hearing in the sea. The typical mammalian ear is divided into the outer ear, middle ear, and inner ear. The outer ear is separated from the inner ear by the tympanic membrane, or eardrum. In terrestrial mammals, the outer ear, eardrum, and middle ear function to transmit airborne sound to the inner ear, where the sound is detected in a fluid. Since cetaceans already live in a fluid medium, they do not require this matching, and thus do not have an air-filled external ear canal. The inner ear is where sound energy is converted into neural signals that are transmitted to the central nervous system via the auditory nerve. 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 (Tyack 1999). Baleen whales have inner ears that appear to be specialized for low-frequency hearing. In a study of the morphology of the mysticete auditory apparatus, Ketten (1997) hypothesized that large mysticetes have acute infrasonic hearing.

3.3.1 Fin whale

Distribution

Fin whales are distributed widely in every ocean except the Arctic Ocean. In the North Pacific Ocean, fin whales occur in summer foraging areas in the Chukchi Sea, the Sea of Okhotsk, around the Aleutian Islands, and the Gulf of Alaska; in the eastern Pacific, they occur south to California; in the western Pacific, they occur south to Japan. Fin whales in the eastern Pacific winter from California south; in the western Pacific, they winter from the Sea of Japan, the East China and Yellow Seas, and the Philippine Sea (Gambell 1985).

Aggregations of fin whales are found throughout the year off southern and central California (Dohl *et al*. 1983, Forney *et al*. 1995; Barlow 1997). In surveys conducted off San Clemente Island from 1998–1999, fin whales were the second most-common baleen whale that had been observed (after gray whales) and were most frequently observed during warm-water months (Carretta *et al*. 2000).

In the North Atlantic Ocean, fin whales occur in summer foraging areas from the coast of North America to the Arctic, around Greenland, Iceland, northern Norway, Jan Meyers, Spitzbergen, and the Barents Sea. In the western Atlantic, they winter from the edge of sea ice south to the Gulf of Mexico and the West Indies. In the eastern Atlantic, they winter from southern Norway, the Bay of Biscay, and Spain with some whales migrating into the Mediterranean Sea (Gambell 1985).

In the Southern Hemisphere, fin whales are distributed broadly south of 50° S in the summer and migrate into the Atlantic, Indian, and Pacific Oceans in the winter, along the coast of South America (as far north as Peru and Brazil), Africa, and the islands in Oceania north of Australia and New Zealand (Gambell 1985).

Fin whales are common off the Atlantic coast of the United States in waters immediately off the coast seaward to the continental shelf (about the 1,000-fathom contour). In this region, they are tend to occur north of Cape Hatteras where they accounted for about 46 percent of the large whales observed in surveys conducted between 1978 and 1982. During the summer months, fin whales in this region tend to congregate in feeding areas between 41°20'N and 51°00'N, from shore seaward to the 1,000-fathom contour.

In the Atlantic Ocean, Clark (1995) reported a general southward pattern of fin whale migration in the fall from the Labrador and Newfoundland region, south past Bermuda, and into the West Indies. The overall distribution may be based on prey availability, and fin whales are found throughout the action area for this consultation in most months of the year. This species preys opportunistically on both invertebrates and fish (Watkins *et al.* 1984). They feed by filtering large volumes of water for the associated prey. Fin whales are larger and faster than humpback and right whales and are less concentrated in nearshore environments.

Population Structure

Fin whales have two recognized subspecies: *Balaoptera physalus physalus* (Linnaeus 1758) occurs in the North Atlantic Ocean while *B. p. quoyi* (Fischer 1829) occurs in the Southern Ocean. Globally, fin whales are sub-divided into three major groups: Atlantic, Pacific, and Antarctic. Within these major areas, different organizations use different population structure.

In the North Atlantic Ocean, the International Whaling Commission recognizes seven management units or "stocks" of fin whales: (1) Nova Scotia, (2) Newfoundland-Labrador, (3) West Greenland, (4) East Greenland-Iceland, (5) North Norway, (6) West Norway-Faroe Islands, and (7) British Isles-Spain-Portugal. In addition, the population of fin whales that resides in the Ligurian Sea, in the northwestern Mediterranean Sea is believed to be genetically distinct from other fin whales populations (as used in this Opinion, "populations" are isolated demographically, meaning, they are driven more by internal dynamics — birth and death processes — than by the geographic redistribution of individuals through immigration or emigration. Some usages of the term "stock" are synonymous with this definition of "population" while other usages of "stock" do not).

In the North Pacific Ocean, the International Whaling Commission recognizes two "stocks": (1) East China Sea and (2) rest of the North Pacific (Donovan, 1991). However, Mizroch *et al.* (1984) concluded that there were five possible "stocks" of fin whales within the North Pacific based on histological analyses and tagging experiments: (1) East and West Pacific that intermingle around the Aleutian Islands; (2) East China Sea; (3) British Columbia; (4) Southern-Central California to Gulf of Alaska; and (5) Gulf of California. Based on genetic analyses, Berube *et al.* (1998) concluded that fin whales in the Sea of Cortez represent an isolated population that has very little genetic exchange with other populations in the North Pacific Ocean (although the geographic distribution of this population and other populations can overlap seasonally). They also concluded that fin whales in the Gulf of St. Lawrence and Gulf of Maine are distinct from fin whales found off Spain and in the Mediterranean Sea.

Regardless of how different authors structure the fin whale population, mark-recapture studies have demonstrate that individual fin whales migrate between management units (Mitchell 1974; Gunnlaugsson and Sigurjónsson 1989), which suggests that these management units are not geographically isolated populations.

Mizroch *et al.* (1984) identified five fin whale "feeding aggregations" in the Pacific Ocean: (1) eastern and western groups that move along the Aleutians (Berzin and Rovnin 1966; Nasu 1974); (2) an East China Sea group; (3) a group that moves north and south along the west coast of North America between California and the Gulf of Alaska (Rice 1974); and (4) a group centered in the Sea of Cortez (Gulf of California).

Hatch (2004) reported that fin whale vocalizations among five regions of the eastern North Pacific were heterogeneous: the Gulf of Alaska, the northeast North Pacific (Washington and British Columbia), the southeast North Pacific (California and northern Baja California), the Gulf of California, and the eastern tropical Pacific.

Sighting data show no evidence of migration between the Sea of Cortez and adjacent areas in the Pacific, but seasonal changes in abundance in the Sea of Cortez suggests that these fin whales might not be isolated (Tershy *et al.* 1993). Nevertheless, Bérubé *et al.* (2002) concluded that the Sea of Cortez fin whale population is genetically distinct from the oceanic population and have lower genetic diversity, which suggests that these fin whales might represent an isolated population.

In its draft recovery plan for fin whales, NMFS recognized three populations in U.S. Pacific waters: Alaska (Northeast Pacific), California/Oregon/Washington, and Hawai'i (Barlow *et al.* 1997; Hill *et al.* 1997). We assume that individuals from the latter "population" of fin whales are the whales that would be exposed to the activities considered in this consultation.

Threats to the Species

NATURAL THREATS. 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. Although these results are based on studies of fin whales in the northeast Atlantic, there are no comparable estimates for fin whales in the Pacific Ocean. 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 injure or kill very young or sick whales (Perry *et al.* 1999, Tomilin 1967).

ANTHROPOGENIC THREATS. Three human activities are known to threaten fin whales: whaling, commercial fishing, and shipping. Historically, whaling represented the greatest threat to every population of fin whales and was ultimately responsible for listing fin whales as an endangered species. As early as the mid-seventeenth century, the Japanese were capturing fin, blue (*Balaenoptera musculus*), 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. After blue whales were depleted in most areas, fin whales became the focus of whaling operations and more than 700,000 fin whales were landed in the Southern Hemisphere alone between 1904 and 1979 (IWC 1995).

As its legacy, whaling has reduced fin whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push fin whales closer to extinction. Otherwise, whaling currently does not threaten every fin whale population, although it may threaten specific populations.

From 1904 to 1975, the International Whaling Commission estimates that 703,693 fin whales captured and killed in Antarctic whaling operations (IWC 1990). Whaling in the Southern Oceans originally targeted humpback whales, but by 1913, those whales had became rare so whalers shifted their focus to fin and blue whales (Mizroch *et al.* 1984b). From 1911 to 1924, whalers killed 2,000–5,000 fin whales each year. After the introduction of factory whaling ships in 1925, the number of whales killed each year increased substantially: from 1931 to 1972, whalers killer about 511,574 fin whales (Kawamura 1994). In 1937 alone, whalers are reported to have killed more than 28,000 fin whales. From 1953 to 1961, the number of fin whales killed each year averaged around 25,000. In 1962, whalers appeared to shift their focus to sei whale as fin whales became scarce. By 1974, whalers killed fewer than 1,000 fin whales.

Recently released Soviet whaling records indicate a discrepancy between reported and actual fin whale catch numbers by whalers from the former USSR in southern waters between 1947 and 1980 (Zemsky *et al.* 1995). The former USSR previously reported 52,931 whales caught; however, the data that was released recently suggests that only 41,984 were killed.

In the Antarctic Ocean, fin whales are hunted by Japanese whalers who have been allowed to kill up to 10 fin whales each year for the 2005-2006 and 2006-2007 seasons under an Antarctic Special Permit. The Japanese whalers plan to kill 50 fin whales per year starting in the 2007-2008 season and continuing for the next 12 years.

Fin whales are also hunted in subsistence fisheries off West Greenland. In 2004, 5 males and 6 females were killed and landed; 2 other fin whales were struck and lost in the same year. In 2003 2 males and 4 females were landed and 2 other fin whales were struck and lost (IWC 2005). Between 2003 and 2007, the IWC set a catch limit of up to 19 fin whales in this subsistence fishery (IWC 2005), however, the IWC's Scientific Committee recommended limiting the number of fin whale killed in this fishery to 1 to 4 individuals until accurate population estimates are produced.

Despite anecdotal observations from fishermen which suggest that large whales swim through their nets rather than get caught in them (NMFS 2000), fin whales have been entangled by fishing gear off Newfoundland and Labrador in small numbers: a total of 14 fin whales are reported to have been captured in coastal fisheries in those two provinces between 1969 and 1990 (Lien 1994, Perkins and Beamish 1979). Of these 14 fin whales, 7 are known to have died as a result of that capture, although most of the animals that died were less than 15 meters in length (Lien 1994). Between 1999 and 2005, there were 10 confirmed reports of fin whales being entangled in fishing gear along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole *et al.* 2005, Nelson *et al.* 2007). Of these reports, Fin whales were injured in 1 of the entanglements and killed in 3 entanglements. These data suggest that, despite their size and strength, fin whales are likely to be entangled and, in some cases, killed by gear used in modern fisheries.

Fin whales are also killed and injured in collisions with vessels more frequently than any other whale. Of 92 fin whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, 31 (33%) showed evidence of collisions with ships (Laist *et al.* 2001). Between 1999 and 2005, there were 15 reports of fin whales being struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole *et al.* 2005, Nelson *et al.* 2007). Of these reports, 13 were confirmed as ship strikes which were reported as having resulted in the death of 11 fin whales.

Ship strikes were identified as a known or potential cause of death in 8 (20%) of 39 fin whales that stranded on the coast of Italy in the Mediterranean Sea between 1986 and 1997 (Laist *et al.* 2001). Throughout the Mediterranean Sea, 46 of the 287 fin whales that are recorded to have stranded between 1897 and 2001 were confirmed to died from injuries sustained by ship strikes (Panigada *et al.* 2006). Most of these fin whales (n = 43), were killed between 1972 and 2001 and the highest percentage (37 of 45 or ~82%) killed in the Ligurian Sea and adjacent waters, where the Pelagos Sanctuary for Marine Mammals was established. In addition to these ship strikes, there are numerous reports of fin whales being injured as result of ship strikes off the Atlantic coast of France and the United Kingdom (Jensen and Silber 2003).

Status

Fin whales were listed as endangered under the ESA in 1970. In 1976, the IWC protected fin whales from commercial whaling (Allen 1980). Fin whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA. Critical habitat has not been designated for fin whales.

It is difficult to assess the current status of fin whales because (1) there is no general agreement on the size of the fin whale population prior to whaling and (2) estimates of the current size of the different fin whale populations vary

widely (NMFS 2007). We may never know the size of the fin whale population prior to whaling. The most current estimate of the population size of fin whales in the Pacific Ocean is 85,200 (no coefficient of variance or confidence interval was provided) based on the history of catches and trends in catches per unit of effort (IWC 1979). Based on surveys conducted south of 30°S latitude between 1978 and 1988, fin whales in the Southern Ocean were estimated to number about 400,000 (IWC 1979; no coefficient of variance or confidence interval was provided).

Chapman (1976) estimated the "original" population size of fin whales off Nova Scotia as 1,200 and 2,400 off Newfoundland, although he offered no explanation or reasoning to support that estimate. Sergeant (1977) suggested that between 30,000 and 50,000 fin whales once populated the North Atlantic Ocean based on assumptions about catch levels during the whaling period. Sigurjónsson (1995) estimated that between 50,000 and 100,000 fin whales once populated the North Atlantic, although he provided no data or evidence to support that estimate. More recently, Palumbi and Roman (2006) estimated that about 360,000 fin whales (95% confidence interval = 249,000 - 481,000) populated the North Atlantic Ocean before whaling based on mutation rates and estimates of genetic diversity.

Similarly, estimates of the current size of the different fin whale populations and estimates of their global abundance also vary widely. The draft recovery plan for fin whales accepts a minimum population estimate of 2,362 fin whales for the North Atlantic Ocean (NMFS 2007); however, the recovery plan also states that this estimate, which is based on on shipboard and aerial surveys conducted in the Georges Bank and Gulf of St. Lawrence in 1999 is the "best" estimate of the size of this fin whale population (NMFS 2006, 2007). However, based on data produced by surveys conducted between 1978-1982 and other data gathered between 1966 and 1989, Hain *et al.* (1992) estimated that the population of fin whales in the western North Atlantic Ocean (specifically, between Cape Hatteras, North Carolina, and Nova Scotia) numbered about 1,500 whales in the winter and 5,000 whales in the spring and summer. Because authors do not always reconcile "new" estimates with earlier estimates, it is not clear whether the current "best" estimate represents a refinement of the estimate that was based on older data or whether the fin whale population in the North Atlantic has declined by about 50% since the early 1980s.

The East Greenland-Iceland fin whale population was estimated at 10,000 animals (95 % confidence interval = 7,600 - 14,200), based on surveys conducted in 1987 and 1989 (Buckland *et al.* 1992). The number of eastern Atlantic fin whales, which includes the British Isles-Spain-Portugal population, has been estimated at 17,000 animals (95% confidence interval = 10,400 -28,900; Buckland *et al.* 1992). These estimates are both more than 15 years old and the data available do not allow us to determine if they remain valid.

Forcada *et al.* (1996) estimated there were 3,583 fin whales in the western Mediterranean (standard error = 967; 95% confidence interval = 2,130 - 6,027), which is similar to an estimate published by Notarbartolo-di-Sciara *et al.* (2003). In the Mediterraneans' Ligurian Sea (which includes the Pelagos Whale Sanctuary and the Gulf of Lions), Forcada *et al.* (1995) estimated there were 901 fin whales (standard error = 196.1).

Regardless of which of these estimates, if any, come closest to actual population sizes, these estimates suggest that the global population of fin whales consists of tens of thousands of individuals. Based on ecological theory and demographic patterns derived from several hundred imperiled species and populations, fin whales appear to exist at population sizes that are large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as

demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself). As a result, we assume that fin whales are likely to be threatened more by exogenous threats such as anthropogenic activities (primarily whaling, entanglement, and ship strikes) or natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate) than endogenous threats caused by the small size of their population.

Nevertheless, based on the evidence available, the number of fin whales that are recorded to have been killed or injured in the past 20 years by human activities or natural phenomena, does not appear to be increasing the extinction probability of fin whales, although it may slow the rate at which they recover from population declines that were caused by commercial whaling.

Diving and Social Behavior

The percentage of time fin whales spend at the surface varies. Some authors have reported that fin whales make 5-20 shallow dives with each of these dive lasting 13-20 seconds followed by a deep dive lasting between 1.5 and 15 minutes (Gambell 1985). Other authors have reported that the fin whale's most common dives last between 2 and 6 minutes, with 2 to 8 blows between dives (Hain *et al.* 1992, Watkins 1981).

In waters off the Atlantic Coast of the U.S. individual fin whales or pairs represented about 75% of the fin whales observed during the Cetacean and Turtle Assessment Program (Hain *et al.* 1992). Individual whales or groups of less than five individuals represented about 90% of the observations (out of 2,065 observations of fin whales, the mean group size was 2.9, the modal value was 1, and the range was 1 – 65 individuals; Hain *et al.* 1992).

Vocalizations and Hearing

The sounds fin whales produce underwater are one of the most studied *Balaenoptera* sounds. Fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981; Watkins *et al.* 1987a; Edds 1988; Thompson *et al.* 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (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, Clark personal communication, McDonald personal communication). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999).

During the breeding season, fin whales produce a 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 authors feel there is geographic differences in the frequency, duration and repetition of the pulses (Thompson *et al.* 1992).

As with other vocalizations produced by baleen whales, the function of fin whale vocalizations is unknown, although there are numerous hypotheses (which include include: maintenance of inter-individual distance, species and

individual recognition, contextual information transmission, maintenance of social organization, location of topographic features, and location of prey resources; see the review by Thompson *et al.* 1992 for more information on these hypotheses). 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). Also, 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).

Cetaceans have an auditory anatomy that follows the basic mammalian pattern, with some modifications to adapt to the demands of hearing in the sea. The typical mammalian ear is divided into the outer ear, middle ear, and inner ear. The outer ear is separated from the inner ear by the tympanic membrane, or eardrum. In terrestrial mammals, the outer ear, eardrum, and middle ear function to transmit airborne sound to the inner ear, where the sound is detected in a fluid. Since cetaceans already live in a fluid medium, they do not require this matching, and thus do not have an air-filled external ear canal. The inner ear is where sound energy is converted into neural signals that are transmitted to the central nervous system via the auditory nerve. 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 (Tyack 1999). Baleen whales have inner ears that appear to be specialized for low-frequency hearing. In a study of the morphology of the mysticete auditory apparatus, Ketten (1997) hypothesized that large mysticetes have acute infrasonic hearing.

3.3.2 Humpback Whale

Distribution

Humpback whales are a cosmopolitan species that occur in the Atlantic, Indian, Pacific, and Southern Oceans. Humpback whales migrate seasonally between warmer, tropical or sub-tropical waters in winter months (where they reproduce and give birth to calves) and cooler, temperate or sub-Arctic waters in summer months (where they feed). In their summer foraging areas and winter calving areas, humpback whales tend to occupy shallower, coastal waters; during their seasonal migrations, however, humpback whales disperse widely in deep, pelagic waters and tend to avoid shallower coastal waters (Winn and Reichley 1985).

In the North Pacific Ocean, the summer range of humpback whales includes coastal and inland waters from Point Conception, California, north to the Gulf of Alaska and the Bering Sea, and west along the Aleutian Islands to the Kamchatka Peninsula and into the Sea of Okhotsk (Tomlin 1967, Nemoto 1957, Johnson and Wolman 1984 as cited in NMFS 1991b). These whales migrate to Hawai'i, southern Japan, the Mariana Islands, and Mexico during the winter.

A discrete feeding aggregation of humpback whales appears to occur off California, Oregon, and Washington State (Calambokidis *et al.* 1996, 2007). In waters off southern California, humpback whales are most commonly sighted north of the Channel Islands; their migration to northern feeding areas generally starts in March with a migration to

southern wintering areas bringing them through waters off southern California in November and December (Calambokidis et al. 2001, 2007).

In the Atlantic Ocean, humpback whales range from the mid-Atlantic bight, the Gulf of Maine, across the southern coast of Greenland and Iceland, and along coast of Norway in the Barents Sea. These humpback whales migrate to the western coast of Africa and the Caribbean Sea during the winter.

In the Southern Ocean, humpback whales occur in waters off Antarctica. These whales migrate to the waters off Venezuela, Brazil, southern Africa, western and eastern Australia, New Zealand, and islands in the southwest Pacific during the austral winter. A separate population of humpback whales appears to reside in the Arabian Sea in the Indian Ocean off the coasts of Oman, Pakistan, and India (Mikhalev 1997).

Population Structure

Descriptions of the population structure of humpback whales differ depending on whether an author focuses on where humpback whales winter or where they feed. During winter months in northern or southern hemispheres, adult humpback whales migrate to specific areas in warmer, tropical waters to reproduce and give birth to calves. During summer months, humpback whales migrate to specific areas in northern temperate or sub-arctic waters to forage. In summer months, humpback whales from different "reproductive areas" will congregate to feed; in the winter months, whales will migrate from different foraging areas to a single wintering area. In either case, humpback whales appear to form "open" populations; that is, populations that are connected through the movement of individual animals.

NORTH PACIFIC OCEAN. NMFS' Stock Assessment Reports recognize four "stocks" of humpback whales in the North Pacific Ocean, based on genetic and photo-identification studies: two Eastern North Pacific stocks, one Central North Pacific stock, and one Western Pacific stock (Hill and DeMaster 1998). The first two of these "stocks" are based on where these humpback whales winter: the central North Pacific "stock" winters in the waters around Hawai'i while the eastern North Pacific "stock" (also called the California-Oregon-Washington-Mexico stock) winters along coasts of Central America and Mexico. However, Calambokidis *et al.* (1997) identified humpback whales from Southeast Alaska (central North Pacific), the California-Oregon-Washington (eastern North Pacific), and Ogasawara Islands (Japan, Western Pacific) groups in the Hawai'ian Islands during the winter; humpback whales from the Kodiak Island, Southeast Alaska, and British Columbia groups in the Ogasawara Islands; and whales from the British Columbia, Southeast Alaska, Prince William Sound, and Shumagin-Aleutian Islands groups in Mexico.

Herman (1979), however, presented extensive evidence and various lines of reasoning to conclude that the humpback whales associated with the main Hawai'ian Islands immigrated to those waters only in the past 200 years. Winn and Reichley (1985) identified genetic exchange between the humpback whales that winter off Hawai'i and those that winter off Mexico (with further mixing on feeding areas in Alaska) and suggested that the humpback whales that winter in Hawai'i may have emigrated from wintering areas in Mexico. Based on these patterns of movement, we conclude that the various "stocks" of humpback whales are not true populations or, at least, they represent populations that experience substantial levels of immigration and emigration.

A "population" of humpback whales winters in an area extending from the South China Sea east through the Philippines, Ryukyu Retto, Ogasawara Gunto, Mariana Islands, and Marshall Islands (Rice 1998). Based on whaling records, humpback whales wintering in this area have also occurred in the southern Marianas through the month of May (Eldredge 1991). There are several recent records of humpback whales in the Mariana Islands, at Guam, Rota, and Saipan during January through March (Darling and Mori 1993; Eldredge 1991, 2003; Taitano 1991). During the summer, whales from this population migrate to the Kuril Islands, Bering Sea, Aleutian Islands, Kodiak, Southeast Alaska, and British Columbia to feed (Angliss and Outlaw 2007, Calambokidis 1997, 2001).

NORTH ATLANTIC OCEAN. In the Atlantic Ocean, humpback whales aggregate in four feeding areas in the summer months: (1) Gulf of Maine, eastern Canada, (2) west Greenland, (3) Iceland and (4) Norway (Katona and Beard 1990, Smith *et al.* 1999). The principal breeding range for these whales lies from the Antilles and northern Venezuela to Cuba (Winn *et al.* 1975, Balcomb and Nichols 1982, Whitehead and Moore 1982). The largest contemporary breeding aggregations occur off the Greater Antilles where humpback whales from all of the North Atlantic feeding areas have been identified from photographs (Katona and Beard 1990, Clapham *et al.* 1993b, Mattila *et al.* 1994, Palsbøll *et al.* 1997, Smith *et al.* 1999, Stevick *et al.* 2003a). Historically, an important breeding aggregation was located in the eastern Caribbean based on the important humpback whale fisheries this region supported (Mitchell and Reeves 1983, Reeves *et al.* 2001, Smith and Reeves 2003). Although sightings persist in those areas, modern humpback whale abundance appears to be low (Winn *et al.* 1975, Levenson and Leapley 1978, Swartz *et al.* 2003). Winter aggregations also occur at the Cape Verde Islands in the Eastern North Atlantic (Reiner *et al.* 1996, Reeves *et al.* 2002, Moore *et al.* 2003). In another example of the "open" structure of humpback whale populations, an individual humpback whale migrated from the Indian Ocean to the South Atlantic Ocean and demonstrated that individual whales may migrate from one ocean basin to another (Pomilla and Rosenbaum 2005).

INDIAN OCEAN. As discussed previously, a separate population of humpback whales appears to reside in the Arabian Sea in the Indian Ocean off the coasts of Oman, Pakistan, and India (Mikhalev 1997).

Threats to the Species

NATURAL THREATS. There is limited information on natural phenomena that kill or injure humpback whales. We know that humpback whales are killed by orcas (Dolphin 1989, Florez-González *et al.* 1984, Whitehead and Glass 1985) and are probably killed by false killer whales and sharks. Because 7 female and 7 male humpback whales stranded on the beaches of Cape Cod and had died from toxin produced by dinoflagellates between November 1987 and January 1988, we also know that adult and juvenile humpback whales are killed by naturally-produced biotoxins (Geraci *et al.* 1989).

Other natural sources of mortality, however, remain largely unknown. Similarly, we do not know whether and to what degree natural mortality limits or restricts patterns of growth or variability in humpback whale populations.

ANTHROPOGENIC THREATS. Three human activities are known to threaten humpback whales: whaling, commercial fishing, and shipping. Historically, whaling represented the greatest threat to every population of humpback whales and was ultimately responsible for listing humpback whales as an endangered species. From 1900 to 1965, nearly 30,000 whales were taken in modern whaling operations of the Pacific Ocean. Prior to that, an unknown number of

humpback whales were taken (Perry *et al.* 1999). In 1965, the International Whaling Commission banned commercial hunting of humpback whales in the Pacific Ocean. As its legacy, whaling has reduced humpback whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push these whales closer to extinction.

Humpback whales are also killed or injured during interactions with commercial fishing gear. Like fin whales, humpback whales have been entangled by fishing gear off Newfoundland and Labrador, Canada: a total of 595 humpback whales are reported to have been captured in coastal fisheries in those two provinces between 1969 and 1990 (Lien 1994, Perkins and Beamish 1979). Of these whales, 94 are known to have died as a result of that capture, although, like fin whales, most of the animals that died were smaller: less than 12 meters in length (Lien 1994). These data suggest that, despite their size and strength, humpback whales are likely to be entangled and, in some cases, killed by gear used in modern fisheries.

There are also reports of entangled humpback whales from the Hawai'ian Islands. In 1991, a humpback whale was observed entangled in longline gear and released alive (Hill *et al.* 1997). In 1995, a humpback whale in Maui waters was found trailing numerous lines (not fishery-related) and entangled in mooring lines. The whale was successfully released, but subsequently stranded and was attacked and killed by tiger sharks in the surf zone. Also in 1996, a vessel from Pacific Missile Range Facility in Hawai'i rescued an entangled humpback, removing two crab pot floats from the whale. From 2001 through 2006, there were 23 reports of entangled humpback whales in Hawai'ian waters; 16 of these reports were from 2005 and 2006.

Many of the entangled humpback whales observed in Hawai'ian waters brought the gear with them from higher latitude feeding grounds; for example, the whale the U.S. Navy rescued in 1996 had been entangled in gear that was traced to a recreational fisherman in southeast Alaska. Thus far, 6 of the entangled humpback whales observed in the Hawai'ian Islands have been confirmed to have been entangled in gear from Alaska. Nevertheless, humpback whales are also entangled in fishing gear in the Hawai'ian Islands. Since 2001, there have been 5 observed interactions between humpback whales and gear associated with the Hawai'i-based longline fisheries (NMFS 2008). In each instance, however, all of the whales were disentangled and released or they were able to break free from the gear without reports of impairment of the animal's ability to swim or feed.

Along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada, there were 160 reports of humpback whales being entangled in fishing gear between 1999 and 2005 (Cole *et al.* 2005, Nelson *et al.* 2007). Of these reports, 95 entanglements were confirmed resulting in the injury of 11 humpback whales and the death of 9 whales. No information is available on the number of humpback whales that have been killed or seriously injured by interactions with fishing fleets outside of U.S. waters.

The number of humpback whales killed by ship strikes is exceeded only by fin whales (Jensen and Silber 2003). On the Pacific coast, a humpback whale is killed about every other year by ship strikes (Barlow *et al.* 1997). The humpback whale calf that was found stranded on Oahu with evidence of vessel collision (propeller cuts) in 1996 suggests that ship collisions might kill adults, juvenile, and calves (NMFS unpublished data). Of 123 humpback whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, 10 (8.1%) showed evidence of collisions with ships (Laist *et al.* 2001). Between 1999 and 2005, there were 18 reports of humpback whales being

struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole *et al.* 2005, Nelson *et al.* 2007). Of these reports, 13 were confirmed as ship strikes which were reported as having resulted in the death of 7 humpback whales. Despite several literature searches, we did not identify information on the number of humpback whales killed or seriously injured by ship strikes outside of U.S. waters.

In addition to ship strikes in North America and Hawai'i, there are several reports of humpback whales being injured as result of ship strikes off the Antarctic Peninsula, in the Caribbean Sea, the Mediterranean Sea, off Australia, Bay of Bengal (Indian Ocean), Brazil, New Zealand, Peru, South Africa,

Status

Humpback whales were listed as endangered under the ESA in 1973. Humpback whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA. Critical habitat has not been designated for humpback whales.

It is difficult to assess the current status of humpback whales for the same reasons that it is difficult to assess the status of fin whales: (1) there is no general agreement on the size of the humpback whale population prior to whaling and (2) estimates of the current size of the different humpback whale populations vary widely and produce estimates that are not always comparable to one another, although robust estimates of humpback whale populations in the western North Atlantic have been published. We may never know the size of the humpback whale population prior to whaling.

Winn and Reichley (1985) argued that the global population of humpback whales consisted of at least 150,000 whales in the early 1900s, with the largest population historically occurring in the Southern Ocean. Based on analyses of mutation rates and estimates of genetic diversity, Palumbi and Roman (2006) concluded that there may have been as many as 240,000 (95% confidence interval = 156,000 – 401,000) humpback whales in the North Atlantic before whaling began. In the western North Atlantic between Davis Strait, Iceland and the West Indies, Mitchell and Reeves (1983) estimated there were at least 4,685 humpback whales in 1865 based on available whaling records (although the authors note that this does not represent a "pre-exploitation estimate" because whalers from Greenland, the Gulf of St. Lawrence, New England, and the Caribbean Sea had been hunting humpback whales before 1865).

Estimates of the number of humpback whales occurring in the different populations that inhabit the Northern Pacific population have risen over time. In the 1980s, the size of the North Pacific humpback whale population was estimated to range from 1,407 to 2,100 (Baker 1985; Darling and Morowitz 1986; Baker and Herman 1987). By the mid-1990s, the population was estimated to consist of about 6,000 whales (standard error = 474) in the North Pacific (Calambokidis *et al.* 1997; Cerchio 1998; Mobley *et al.* 1999).

As discussed previously, between 2004 and 2006, an international group of whale researchers coordinated their surveys to conduct a comprehensive assessment of the population structure, levels of abundance, and status of humpback whales in the North Pacific (Calambokidis *et al.* 2008). That effort identified a total of 7,971 unique

individuals from photographs taken during close approaches. Of this total,, 4,516 individuals were identified at wintering regions in at least one of the three seasons in which the study surveyed wintering area and 4,328 individuals were identified at least once at feeding areas in one of the two years in which the study surveyed feeding areas. Based on the results of that effort, Calambokidis *et al.* (2008) estimated that the current population of humpback whales in the North Pacific Ocean consisted of about 18,300 whales, not counting calves. Almost half of the humpback whales that were estimated to occur in wintering areas, or about 8,000 humpback whales, occupy the Hawai'ian Islands during the winter months.

In the North Atlantic, Stevick *et al.* (2003) estimated the size of the humpback whale population between 1979 and 1993 by applying statistical analyses that are commonly used in capture-recapture studies to individual humpback whales that were identified based on natural markings. Between 1979 and 1993, they estimated that the North Atlantic populations (what they call the "West Indies breeding population") consisted of between 5,930 and 12,580 individual whales. The best estimate they produced (11,570; 95% confidence interval = 10,290 -13,390) was based on samples from 1992 and 1993. If we assume that this population has grown according to the instantaneous rate of increase Stevick *et al.* (2003) estimated for this population (r = 0.0311), this would lead us to estimate that this population might consist of about 18,400 individual whales in 2007-2008.

Regardless of which of these estimates, if any, most closely correspond to the actual size and trend of the humpback whale population, all of these estimates suggest that the global population of humpback whales consists of tens of thousands of individuals, that the North Atlantic population consists of at least 2,000 individuals and the North Pacific population consists of about 18,000 individuals. Based on ecological theory and demographic patterns derived from several hundred imperiled species and populations, humpback whales appear to exist at population sizes that are large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself). As a result, we assume that humpback whales will have elevated extinction probabilities because of exogenous threats caused by anthropogenic activities (primarily whaling, entanglement, and ship strikes) and natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate) rather than endogenous threats caused by the small size of their population.

Diving and Social Behavior

In Hawai'ian waters, humpback whales remain almost exclusively within the 1820 m isobath and usually within waters depths less than 182 meters. Maximum diving depths are approximately 150 m (492 ft) (but usually <60 m [197 ft]), with a very deep dive (240 m [787 ft]) recorded off Bermuda (Hamilton *et al.* 1997). They may remain submerged for up to 21 min (Dolphin 1987). Dives on feeding grounds ranged from 2.1-5.1 min in the north Atlantic (Goodyear unpublished manuscript). In southeast Alaska average dive times were 2.8 min for feeding whales, 3.0min for non-feeding whales, and 4.3 min for resting whales (Dolphin 1987). In the Gulf of California humpback whale dive times averaged 3.5 min (Strong 1989). Because most humpback prey is likely found above 300 m depths most humpback dives are probably relatively shallow.

In a review of the social behavior of humpback whales, Clapham (1986) reported that they form small, unstable social groups during the breeding season. During the feeding season they form small groups that occasionally aggregate on concentrations of food. Feeding groups are sometimes stable for long-periods of times. There is good evidence of some territoriality on feeding (Clapham 1994, 1996), and calving areas (Tyack 1981). In calving areas, males sing long complex songs directed towards females, other males or both. The breeding season can best be described as a floating lek or male dominance polygyny (Clapham 1996). Intermale competition for proximity to females can be intense as expected by the sex ratio on the breeding grounds which may be as high as 2.4:1.

Vocalizations and Hearing

Humpback whales produce at least three kinds of vocalization: (1) complex songs with components ranging from at least 20Hz B 4 kHz with estimated source levels from 144 B 174 dB, which are mostly produced by males on breeding areas (Payne 1970, Winn *et al.* 1970, Richardson *et al.* 1995); (2) social sounds in breeding areas that extend from 50 Hz B more than 10 kHz with most energy below 3 kHz (Tyack and Whitehead 1983, Richardson *et al.* 1995); and (3) vocalizations in foraging areas that are less frequent, but tend to be 20Hz B 2 kHz with estimated sources levels in excess of 175 dB re 1 μPa-m (Thompson *et al.* 1986, Richardson *et al.* 1995). Sounds that investigators associate with aggressive behavior in male humpback whales are very different from songs; they extend from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz (Tyack 1983, Silber 1986). These sounds appear to have an effective range of up to 9 kilometers (Tyack and Whitehead 1983). A general description of the anatomy of the ear for cetaceans is provided in the description of the fin whale above; that description is also applicable to humpback whales.

In summary, humpback whales produce at least three kinds of sounds:

1. Complex songs with components ranging from at least 20 Hz–4 kHz with estimated source levels from 144 – 174 dB; these are mostly sung by males on the breeding grounds (Frazer and Mercado 2000; U.S. Navy 2006a; Payne 1970; Winn *et al.* 1970a; Richardson *et al.* 1995)
2. Social sounds in the breeding areas that extend from 50Hz – more than 10 kHz with most energy below 3 kHz (Tyack and Whitehead 1983, Richardson *et al.* 1995); and
3 Feeding area vocalizations that are less frequent, but tend to be 20 Hz–2 kHz with estimated sources levels in excess of 175 dB re 1 μPa-m (Thompson *et al.* 1986; Richardson *et al.* 1995).

Helwig *et al.* (2000) produced a mathematical model of a humpback whale's hearing sensitivity based on the anatomy of the whale's ear. Based on that model, they concluded that humpback whales would be sensitive to sound in frequencies ranging from 0.7kHz to 10kHz, with a maximum sensitivity between 2 and 6kHz.

3.3.3 Sei Whale

Distribution

Sei whales occur in every ocean except the Arctic Ocean. The migratory pattern of this species is thought to encompass long distances from high-latitude feeding areas in summer to low-latitude breeding areas in winter; however, the location of winter areas remains largely unknown (Perry *et al.* 1999). Sei whales are often associated

with deeper waters and areas along the continental shelf edge (Hain *et al.* 1985); however, this general offshore pattern of sei whale distribution is disrupted during occasional incursions into more shallow and inshore waters (Waring *et al.* 2004).

In the western Atlantic Ocean, sei whales occur from Labrador, Nova Scotia,and Labrador in the summer months and migrate south to Florida, the Gulf of Mexico, and the northern Caribbean (Gambell 1985, Mead 1977). In the eastern Atlantic Ocean, sei whales occur in the Norwegian Sea (as far north as Finnmark in northeastern Norway), occasionally occurring as far north as Spitsbergen Island, and migrate south to Spain, Portugal, and northwest Africa (Jonsgård and Darling 1974, Gambell 1985).

In the north Pacific Ocean, sei whales occur from the Bering Sea south to California (on the east) and the coasts of Japan and Korea (on the west). During the winter, sei whales are found from 20°-23°N (Masaki 1977; Gambell 1985). Horwood (1987) reported that 75 - 85% of the North Pacific population of sei whales resides east of 180° longitude.

Sei whales occur throughout the Southern Ocean during the summer months, although they do not migrate as far south to feed as blue or fin whales. During the austral winter, sei whales occur off Brazil and the western and eastern coasts of Southern Africa and Australia.

Population Structure

The population structure of sei whales is largely unknown because there are so few data on this species. The International Whaling Commission's Scientific Committee groups all of the sei whales in the entire North Pacific Ocean into one population (Donovan 1991). However, some mark-recapture, catch distribution, and morphological research suggest more than one "stock" of sei whales may exist in the Pacific: one between 175°W and 155°W longitude, and another east of 155°W longitude (Masaki 1977); however, the amount of movement between these "stocks" suggests that they probably do not represent demographically-isolated populations as we use this concept in this Opinion.

Mitchell and Chapman (1977) divided sei whales in the western North Atlantic in two populations, one that occupies the Nova Scotian Shelf and a second that occupies the Labrador Sea. Sei whales are most common on Georges Bank and into the Gulf of Maine and the Bay of Fundy during spring and summer, primarily in deeper waters. There are occasional influxes of sei whales further into Gulf of Maine waters, presumably in conjunction with years of high copepod abundance inshore. Sei whales are occasionally seen feeding in association with right whales in the southern Gulf of Maine and in the Bay of Fundy.

Threats to the Species

NATURAL THREATS. Sei whales appear to compete with blue, fin, and right whales for prey and that competition may limit the total abundance of each of the species (Rice 1974, Scarff 1986). As discussed previously in the narratives for fin and right whales, the foraging areas of right and sei whales in the western north Atlantic Ocean overlap and both whales feed preferentially on copepods (Mitchell 1975).

ANTHROPOGENIC THREATS. Two human activities are known to threaten sei whales: whaling and shipping. Historically, whaling represented the greatest threat to every population of sei whales and was ultimately responsible for listing sei whales as an endangered species. From 1910 to 1975, approximately 74,215 sei whales were caught in the entire North Pacific Ocean (Horwood 1987, Perry *et al.* 1999). From the early 1900s, Japanese whaling operations consisted of a large proportion of sei whales: 300 - 600 sei whales were killed per year from 1911 to 1955. The sei whale catch peaked in 1959, when 1,340 sei whales were killed. In 1971, after a decade of high sei whale catch numbers, sei whales were scarce in Japanese waters.

In the North Atlantic Ocean, sei whales were hunted from land stations in Norway and Iceland in the early- to mid-1880s, when blue whales started to become more scarce. In the late 1890s, whalers began hunting sei whales in Davis Strait and off the coasts of Newfoundland. In the early 1900s, whalers from land stations on the Outer Hebrides and Shetland Islands started to hunt sei whales. Between 1966 and 1972, whalers from land stations on the east coast of Nova Scotia engaged in extensive hunts of sei whales on the Nova Scotia shelf, killing about 825 sei whales (Mitchell and Chapman 1977).

Sei whales are occasionally killed in collisions with vessels. Of 3 sei whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, 2 showed evidence of collisions with ships (Laist *et al.* 2001). Between 1999 and 2005, there were 3 reports of sei whales being struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole *et al.* 2005, Nelson *et al.* 2007). Two of these ship strikes were reported as having resulted in the death of the sei whale.

Status

Sei whales were listed as endangered under the ESA in 1973. In the North Pacific, the International Whaling Commission began management of commercial taking of sei whales in 1970, and fin whales were given full protection in 1976 (Allen 1980). Sei whales are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the Marine Mammal Protection Act. They are listed as endangered under the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). Critical habitat has not been designated for sei whales.

Prior to commercial whaling, sei whales in the north Pacific are estimated to have numbered 42,000 individuals (Tillman 1977), although Ohsumi and Fukuda (1975) estimated that sei whales in the north Pacific numbered about 49,000 whales in 1963, had been reduced to 37,000 or 38,000 whales by 1967, and reduced again to 20,600 to 23,700 whales by 1973. Japanese and Soviet catches of sei whales in the North Pacific and Bering Sea increased from 260 whales in 1962 to over 4,500 in 1968 and 1969, after which the sei whale population declined rapidly (Mizroch *et al.* 1984). When commercial whaling for sei whales ended in 1974, the population of sei whales in the North Pacific had been reduced to between 7,260 and 12,620 animals (Tillman 1977). In the same year, the north Atlantic population of sei whales was estimated to number about 2,078 individuals, including 965 whales in the Labrador Sea group and 870 whales in the Nova Scotia group (IWC 1977, Mitchell and Chapman 1977).

About 50 sei whales are estimated to occur in the North Pacific "stock" with another 77 sei whales in the Hawai'ian "stock" (Lowry *et al.* 2007). The abundance of sei whales in the Atlantic Ocean remains unknown (Lowry *et al.*

2007). In California waters, only one confirmed and five possible sei whale sightings were recorded during 1991, 1992, and 1993 aerial and ship surveys (Carretta and Forney 1993, Mangels and Gerrodette 1994). No sightings were confirmed off Washington and Oregon during recent aerial surveys. Several researchers have suggested that the recovery of right whales in the northern hemisphere has been slowed by other whales that compete with right whales for food. Mitchell (1975) analyzed trophic interactions among baleen whales in the western north Atlantic and noted that the foraging grounds of right whales overlapped with the foraging grounds of sei whales and both preferentially feed on copepods.

Like blue whales, the information available on the status and trend of sei whales do not allow us to reach any conclusions about the extinction risks facing sei whales as a species, or particular populations of sei whales. With the limited data available on sei whales, we do not know whether these whales exist at population sizes large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself) or if sei whales might are threatened more by exogenous threats such as anthropogenic activities (primarily whaling, entanglement, and ship strikes) or natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate). However, sei whales have historically exhibited sudden increases in abundance in particular areas followed by sudden decreases in number. Several authors have reported "invasion years" in which large numbers of sei whales appeared off areas like Norway and Scotland, followed the next year by sudden decreases in population numbers (Jonsgård and Darling 1974).

With the evidence available, we do not know if this year-to-year variation still occurs in sei whales. However, if sei whales exist as a fraction of their historic population sizes, large amounts of variation in their abundance would increase the extinction probabilities of individual populations (Fagan and Holmes 2006, Fagan *et al.* 1999, 2001).

Diving and Social Behavior

Generally, sei whales make 5-20 shallow dives of 20-30 sec duration followed by a deep dive of up to 15 min (Gambell 1985). The depths of sei whale dives have not been studied, however the composition of their diet suggests that they do not perform dives in excess of 300 meters. Sei whales are usually found in small groups of up to 6 individuals, but they commonly form larger groupings when they are on feeding grounds (Gambell 1985).

Vocalizations and Hearing

There is a limited amount of information on the vocal behavior of sei whales. McDonald *et al.* (2005) recorded sei whale vocalizations off the Antarctic Peninsula that included broadband sounds in the 100-600 Hz range with 1.5 second duration and tonal and upsweep call in the 200-600 Hz range 1-3 second duration. McDonald et al. (2005) also reported broadband "growls" and "whooshes" at frequency of 433 ±192 Hz and source level of 156 ±3.6 dB re 1 μPa at 1 meter. Sei whale vocalizations consist of paired sequences (0.5 to 0.8 seconds [sec], separated by 0.4 to 1.0 sec) of 7 to 20 short (4 milliseconds) frequency-modulated sweeps between 1.5 and 3.5 kHz (Richardson *et al.* 1995).

During visual and acoustic surveys conducted in the Hawai'ian Islands in 2002, Rankin and Barlow (2007) recorded 107 sei whale vocalizations, which they classified as two variations of low-frequency downswept calls. The first variation consisted of sweeps from 100 Hz to 44 Hz, over 1.0 seconds. The second variation, which was more common (105 out of 107) consisted of low frequency calls which swept from 39 Hz to 21 Hz over 1.3 seconds. These vocalization are different from sounds attributed to sei whales in the Atlantic and Southern Oceans but are similar to sounds that had previously been attributed to fin whales in Hawai'ian waters. Sei whale calls recorded off the Hawaiian Islands consisted of downsweeps from 100 Hz to 44 Hz over 1.0 sec and low-frequency calls with downsweeps from 39 Hz to 21 Hz over 1.3 seconds (Rankin and Barlow 2007a). Sei whales off the east coast of the United States produced single calls that ranged from 82 to 34 Hz over 1.4 s period (Baumgartner *et al*. 2001)

A general description of the anatomy of the ear for cetaceans is provided in the preceding description of the fin whale.

3.3.4 Sperm Whale

Distribution

Sperm whales occur in every ocean except the Arctic Ocean. 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.

In the western Atlantic Ocean, sperm whales are distributed in a distinct seasonal cycle, concentrated east-northeast of Cape Hatteras in winter and shifting northward in spring when whales are found throughout the Mid-Atlantic Bight. Distribution extends further northward to areas north of Georges Bank and the Northeast Channel region in summer and then south of New England in fall, back to the Mid-Atlantic Bight.

In the eastern Atlantic Ocean, mature male sperm whales have been recorded as far north as Spitsbergen (Oien, 1990). Recent observations of sperm whales and stranding events involving sperm whales from the eastern North Atlantic suggest that solitary and paired mature male sperm whales predominantly occur in waters off Iceland, the Faroe Islands, and the Norwegian Sea (Gunnlaugsson and Sigurjonsson 1990, Oien 1990, Christensen *et al.* 1992).

In the Mediterranean Sea sperm whales are found from the Alboran Sea to the Levant Basin, mostly over steep slope and deep offshore waters. Sperm whales are rarely sighted in the Sicilian Channel, and are vagrant in the northern Adriatic and Aegean Seas (Notarbartolo di Sciara and Demma 1997). In the Italian seas sperm whales are more frequently associated with the continental slope off western Liguria, western Sardinia, northern and eastern Sicily, and both coasts of Calabria.

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Sperm whales are found year-round in waters off California, with peak in their abundance from April through mid-June and from the end of August to mid-November (NMFS 2006). Sperm whales are reported to be relatively rare over the continental shelf in southern California, but relatively abundant in deeper waters offshore (Appler et al. 2004, Bonnell and Dailey 1993, Carretta et al. 2000, Forney 2007).

Sperm whales commonly concentrate around oceanic islands in areas of upwelling, and along the outer continental shelf and mid-ocean waters. Because they inhabit deeper pelagic waters, their distribution does not include the broad continental shelf of the Eastern Bering Sea and these whales generally remain offshore in the eastern Aleutian Islands, Gulf of Alaska, and the Bering Sea.

Sperm whales have a strong preference for the 3,280 feet (1,000 meters) depth contour and seaward. Berzin (1971) reported that they are restricted to waters deeper than 300 meters (984 feet), while Watkins (1977) and Reeves and Whitehead (1997) reported that they are usually not found in waters less than 1,000 meters (3,281 feet) deep. While deep water is their typical habitat, sperm whales have been observed near Long Island, New York, in water between 41-55 meters (135-180 feet; Scott and Sadove 1997). When they are found relatively close to shore, sperm whales are usually associated with sharp increases in bottom depth where upwelling occurs and biological production is high, implying the presence of a good food supply (Clarke 1956).

Population Structure

The population structure of sperm whales is largely unknown. Lyrholm and Gyllenstein (1998) reported moderate, but statistically significant, differences in sperm whale mitochondrial (mtDNA) between ocean basins, although sperm whales throughout the world appear to be homogenous genetically (Whitehead 2003). Genetic studies also suggest that sperm whales of both genders commonly move across over ocean basins and that males, but not females, often breed in ocean basins that are different from the one in which they were born (Whitehead, 2003).

Sperm whales may not form “populations” as that term is normally conceived. Jaquet (1996) outlined a hierarchical social and spatial structure that includes temporary clusters of animals, family units of 10 or 12 females and their young, groups of about 20 animals that remain together for hours or days, “aggregations” and “super-aggregations” of 40 or more whales, and “concentrations” that include 1,000 or more animals (Peterson 1986, Whitehead and Wiegart 1990, Whitehead *et al.* 1991). The “family unit” forms the foundation for sperm whale society and most females probably spend their entire life in the same family unit (Whitehead 2002). The dynamic nature of these relationships and the large spatial areas they are believed to occupy might complicate or preclude attempts to apply traditional population concepts, which tend to rely on group fidelity to geographic distributions that are relatively static over time.

Atlantic Ocean

Based on harvests of tagged sperm whales or sperm whales with other distinctive marking, sperm whales in the North Atlantic Ocean appear to represent a single population, with the possible exception of the sperm whales that appear to reside in the Gulf of Mexico. Mitchell (1975) reported one sperm whale that was tagged on the Scotian Shelf and killed about 7 years later off Spain. Donovan (1991) reported five to six handheld harpoons from the Azore sperm whale fishery that were recovered from whales killed off northwest Spain, with another Azorean harpoon recovered from a male sperm whale killed off Iceland (Martin 1982). These patterns suggest that at least some sperm whales migrate across the North Atlantic Ocean.

Female and immature animals stay in Atlantic temperate or tropical waters year round. In the western North Atlantic, groups of female and immature sperm whales concentrate in the Caribbean Sea (Gosho *et al.* 1984) and south of New England in continental-slope and deep-ocean waters along the eastern United States (Blaylock *et al.* 1995). In eastern Atlantic waters, groups of female and immature sperm whales aggregate in waters off the Azores, Madeira, Canary, and Cape Verde Islands (Tomilin 1967).

Several investigators have suggested that the sperm whales that occupy the northern Gulf of Mexico are distinct from sperm whales elsewhere in the North Atlantic Ocean (Schmidly 1981, Fritts 1983, and Hansen *et al.* 1995), although the International Whaling Commission groups does not treat these sperm whales as a separate population or "stock."

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Bayed and Beaubrun (1987) suggested that the frequent observation of neonates in the Mediterranean Sea and the scarcity of sperm whale sightings from the Gibraltar area may be evidence of a resident population of sperm whales in the Mediterranean.

Indian Ocean

In the Northern Indian Ocean the International Whaling Commission recognized differences between sperm whales in the northern and southern Indian Ocean (Donovan 1991). Little is known about the Northern Indian Ocean population of sperm whales (Perry *et al.* 1999).

Pacific Ocean

Several authors 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. For stock assessment purposes, NMFS recognizes three discrete population centers of sperm whales in the Pacific: (1) Alaska, (2) California-Oregon-Washington, and (3) Hawai'i.

Sperm whales are widely distributed throughout the Hawai'ian Islands throughout the year and are the most abundanct large whale in waters off Hawai'i during the summer and fall (Rice 1960, Shallenberger 1981, Lee 1993, and Mobley *et al.* 2000). Sperm whale clicks recorded from hydrophones off Oahu confirm the presence of sperm whales near the Hawai'ian Islands throughout the year (Thompson and Friedl 1982). The primary area of occurrence for the sperm whale is seaward of the shelf break in the Hawai'ian Islands.

Sperm whales have been sighted in the Kauai Channel, the Alenuihaha Channel between Maui and the island of Hawai'i, and off the island of Hawai'i (Lee 1993, Mobley *et al.*1999, Forney *et al.* 2000). Additionally, the sounds of sperm whales have been recorded throughout the year off Oahu (Thompson and Friedl 1982). Twenty-one sperm whales were sighted during aerial surveys conducted in Hawai'ian waters conducted from 1993 through 1998. Sperm whales sighted during the survey tended to be on the outer edge of a 50 - 70 km distance from the Hawai'ian Islands, indicating that presence may increase with distance from shore. However, from the results of these surveys, NMFS has calculated a minimum abundance of sperm whales within 46 km of Hawai'i to be 43 individuals (Forney *et al.* 2000).

Southern Ocean

Sperm whales south of the equator are generally treated as a single "population," although the International Whaling Commission divides these whales into nine different divisions that are based more on evaluations of whaling captures than the biology of sperm whales (Donovan 1991). Several authors, however, have argued that the sperm whales that occur off the Galapagos Islands, mainland Ecuador, and northern Peru are geographically distinct from other sperm whales in the Southern Hemisphere (Rice 1977, Wade and Gerrodette 1993, and Dufault and Whitehead 1995).

Threats to the Species

NATURAL THREATS. Sperm whales are hunted by killer whales (*Orcinus orca*), false killer whales (*Pseudorca crassidens*), and short-finned pilot whales (*Globicephala melas*; Arnbom *et al.* 1987, Palacios and Mate 1996, Rice 1989, Weller *et al.* 1996, Whitehead 1995). Sperm whales have been observed with bleeding wounds their heads and tail flukes after attacks by these species (Arnbom *et al.* 1987, Dufault and Whitehead 1995). In October 1997, 25 killer whales were documented to have attacked a group of mature sperm whales off Point Conception, California (personal communication from K Roberts cited in Perry *et al.* 1999) and successfully killing one of these mature sperm whales. Sperm whales have also been reported to have papilloma virus (Lambertson *et al.* 1987).

Studies on sperm whales in the North Pacific and North Atlantic Oceans have demonstrated that sperm whales are infected by calciviruses and papillomavirus (Smith and Latham 1978, Lambertsen *et al.* 1987). In some instances, these diseases have been demonstrated to affect 10 percent of the sperm whales sampled (Lambertsen *et al.* 1987).

ANTHROPOGENIC THREATS. Three human activities are known to threaten sperm whales: whaling, entanglement in fishing gear, and shipping. Historically, whaling represented the greatest threat to every population of sperm whales and was ultimately responsible for listing sperm whales as an endangered species. Sperm whales were hunted all over the world during the 1800s, largely for its spermaceti oil and ambergris. Harvesting of sperm whales subsided by 1880 when petroleum replaced the need for sperm whale oil (Whitehead 2003).

The actual number of sperm whales killed by whalers remains unknown and some of the estimates of harvest numbers are contradictory. Between 1800 and 1900, the International Whaling Commission estimated that nearly 250,000 sperm whales were killed globally by whalers. From 1910 to 1982, another 700,000 sperm whales were killed globally by whalers (IWC Statistics 1959-1983). These estimates are substantially higher than a more recent estimate produced by Caretta *et al.* (2005), however, who estimated that at least 436,000 sperm whales were killed by whalers between 1800 and 1987. Hill and DeMaster (1999) concluded that about 258,000 sperm whales were harvested in the North Pacific between 1947 and 1987 by commercial whalers. They reported that catches in the North Pacific increased until 1968, when 16,357 sperm whales were harvested, then declined after 1968 because of harvest limits imposed by the IWC. Perry *et al.* (1999) estimated that, on average, more than 20,000 sperm whales were harvested in the Southern Hemisphere each year between 1956 and 1976.

These reports probably underestimate the actual number of sperm whales that were killed by whalers, particularly because they could not have incorporated realistic estimates of the number of sperm whales killed by Soviet whaling fleets, which often went unreported. Between 1947 and 1973, Soviet whaling fleets engaged in illegal whaling in the Indian, North Pacific, and southern Oceans. In the Southern Hemisphere, these whalers killed an estimated 100,000 whales that they did not report to the International Whaling Commission (Yablokov *et al.* 1998). Illegal catches in the Northern Hemisphere (primarily in the North Pacific) were smaller but still caused sperm whales to disappear from large areas of the North Pacific Ocean (Yablokov and Zemsky 2000).

In addition to large and illegal harvests of sperm whales, Soviet whalers had disproportionate effect on sperm whale populations because they commonly killed adult females in any reproductive condition (pregnant or lactating) as well as immature sperm whales of either gender.

When the International Whaling Commission introduced the International Observer Scheme in 1972, the IWC relaxed regulations that limited the minimum length of sperm whales that could be caught from 11.6 meters to 9.2 meters out of a concern that too many male sperm whales were being caught so reducing this size limit would encourage fleets to catch more females. Unfortunately, the IWC's decision had been based on data from the Soviet fleets who commonly reported female sperm whales as males. As a result, the new regulations allowed the Soviet whalers to continue their harvests of female and immature sperm whales legally, with substantial consequences for sperm whale populations. Berzin noted in a report he wrote in 1977, "the result of this was that some breeding areas for sperm whales became deserts" (Berzin 2007).

Although the International Whaling Commission protected sperm whales from commercial harvest in 1981, whaling operations along the Japanese coast continued to hunt sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). More recently, the Japanese Whaling Association began hunting sperm whales for research. In 2000, the Japanese Whaling Association announced that it planned to kill 10 sperm whales in the Pacific Ocean for research, which was the first time sperm whales have been hunted since the international ban on commercial whaling. 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 5 sperm whales were killed for research in 2002 – 2003. The consequences of these deaths on the status and trend of sperm whales remains uncertain, given that they probably have not recovered from the legacy of whaling; however, the renewal of a program that intentionally

targets and kills sperm whales before we can be certain they recovered from a history of over-harvest places this species at risk in the foreseeable future.

Sperm whales are still hunted for subsistence purposes by whalers from Lamalera, Indonesia, which is on the south coast of the island of Lembata and from Lamakera on the islands of Solor. These whalers hunt in a traditional manner: with bamboo spears and using small wooden outriggers, 10–12 m long and 2 m wide, constructed without nails and with sails woven from palm fronds. The animals are killed by the harpooner leaping onto the back of the animal from the boat to drive in the harpoon. The maximum number of sperm whales killed by these hunters in any given year was 56 sperm whales killed in 1969.

In U.S. waters in the Pacific Ocean, sperm whales are known to have been incidentally captured only in drift gillnet operations, which killed or seriously injured an average of 9 sperm whales per year from 1991 - 1995 (Barlow *et al.* 1997). 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 fish caught in longline gear in the Gulf of Alaska. 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.

Sperm whales are also killed by ship strikes. In May 1994 a sperm whale that had been struck by a ship was observed south of Nova Scotia (Reeves and Whitehead 1997) and in May 2000 a merchant ship reported a strike in Block Canyon (NMFS, unpublished data), which is a major pathway for sperm whales entering southern New England continental shelf waters in pursuit of migrating squid (CeTAP 1982, Scott and Sadove 1997).

Status

Sperm whales were listed as endangered under the ESA in 1973. Sperm whales have been protected from commercial harvest by the International Whaling Commission since 1981, although the Japanese continued to harvest sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). They are also protected by the Convention on International Trade in Endangered Species of Wild Flora and Fauna and the MMPA. Critical habitat has not been designated for sperm whales.

The status and trend of sperm whales at the time of this summary is largely unknown. Hill and DeMaster (1999) and Angliss and Lodge (2004) reported that estimates for population abundance, status, and trends for sperm whales off the coast of Alaska were not available when they prepared the Stock Assessment Report for marine mammals off Alaska. Similarly, No information was available to support estimates of sperm whales status and trends in the western North Atlantic Ocean (Waring *et al.* 2004), the Indian Ocean (Perry *et al.* 1999), or the Mediterranean Sea.

Nevertheless, several authors and organizations have published "best estimates" of the global abundance of sperm whales or their abundance in different geographic areas. Based on historic whaling data,190,000 sperm whales were estimated to have been in the entire North Atlantic, but the IWC considers data that produced this estimate unreliable

(Perry *et al.* 1999). Whitehead (2002) estimated that prior to whaling sperm whales numbered around 1,110,000 and that the current global abundance of sperm whales is around 360,000 (coefficient of variation = 0.36) whales. Whitehead's current population estimate (2002) is about 20% of past global abundance estimates which were based on historic whaling data.

Waring *et al.* (2007) concluded that the best estimate of the number of sperm whales along the Atlantic coast of the U.S. was 4,029 (coefficient of variation = 0.38) in 1998 and 4,804 (coefficient of variation = 0.38) in 2004, with a minimum estimate of 3,539 sperm whales in the western North Atlantic Ocean.

Barlow and Taylor (2005) derived two estimates of sperm whale abundance in a 7.8 million km^2 study area in the northeastern temperate Pacific: when they used acoustic detection methods they produced an estimate of 32,100 sperm whales (coefficient of variation = 0.36); when they used visual surveys, they produced an estimate of 26,300 sperm whales (coefficient of variation = 0.81). Caretta *et al.* (2005) concluded that the most precise estimate of sperm whale abundance off California, Oregon, and Washington was 1,233 (coefficient of variation = 0.41; based on ship surveys conducted in the summer and fall of 1996 and 2001). Their best estimate of the abundance of sperm whales in Hawai'i was 7,082 sperm whales (coefficient of variation = 0.30) based on ship-board surveys conducted in 2002.

Mark and recapture data from sperm whales led Whitehead and his co-workers to conclude that sperm whale numbers off the Galapagos Islands decreased by about 20% a year between 1985 and 1995 (Whitehead *et al.* 1997). In 1985 Whitehead *et al.* (1997) estimated there were about 4,000 female and immature sperm whales, whereas in 1995 they estimated that there were only a few hundred. They suggested that sperm whales migrated to waters off the Central and South American mainland to feed in productive waters of the Humboldt Current, which had been depopulated of sperm whales as a result of intensive whaling.

The information available on the status and trend of sperm whales do not allow us to make definitive statement about the extinction risks facing sperm whales as a species or particular populations of sperm whales. However, the evidence available suggests that sperm whale populations probably exhibit the dynamics of small populations, causing their population dynamics to become a threat in and of itself. The number of sperm whales killed by Soviet whaling fleets in the 1960s and 1970s would have substantial and adverse consequence for sperm whale populations and their ability to recover from the effects of whaling on their population. The number of adult female killed by Soviet whaling fleets, including pregnant and lactating females whose death would also have resulted in the death of their calves, would have had a devastating effect on sperm whale populations. In addition to decimating their population size, whaling would have skewed sex ratios in their populations, created gaps in the age structure of their populations, and would have had lasting and adverse effect on the ability of these populations to recover (for example, see Whitehead 2003).

Populations of sperm whales could not have recovered from the overharvests of adult females and immature whales in the 30 to 40 years that have passed since the end of whaling, but the information available does not allow us to determine whether and to what degree those populations might have stabilized or whether they have begun the process of recovering from the effects of whaling. Absent information to the contrary, we assume that sperm whales will have elevated extinction probabilities because of both exogenous threats caused by anthropogenic activities

(primarily whaling, entanglement, and ship strikes) and natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate) as well as endogenous threats caused by the legacy of overharvests of adult females and immature whales on their populations (that is, a population with a disproportion of adult males and older animals coupled with a small percentage of juvenile whales that recruit into the adult population).

Diving and Social Behavior

Sperm whales are probably the deepest and longest diving mammal: they can dive to depths of at least 2000 meters (6562 ft), and may remain submerged for an hour or more (Watkins *et al.* 1993). Typical foraging dives last 40 min and descend to about 400 m followed by about 8 min of resting at the surface (Gordon 1987; Papastavrou *et al.* 1989). However, dives of over 2 hr and as deep as 3,000 m have been recorded (Clarke 1976; Watkins *et al.* 1985). Descent rates recorded from echo-sounders were approximately 1.7m/sec and nearly vertical (Goold and Jones 1995). There are no data on diurnal differences in dive depths in sperm whales. However, like most diving vertebrates for which there are data (e.g. rorqual whales, fur seals, chinstrap penguins), sperm whales probably make relatively shallow dives at night when organisms from the ocean's deep scattering layers move toward the ocean's surface.

The groups of closely related females and their offspring develop dialects specific to the group (Weilgart and Whitehead 1997) and females other than birth mothers will guard young at the surface (Whitehead 1996) and will nurse young calves (Reeves and Whitehead 1997).

Vocalizations and Hearing

Sperm whales produce loud broad-band clicks from about 0.1 to 20 kHz (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). These have source levels estimated at 171 dB re 1 μPa (Levenson 1974). Current evidence suggests that the disproportionately large head of the sperm whale is an adaptation to produce these vocalizations (Norris and Harvey 1972; Cranford 1992; but see Clarke 1979). This suggests that the production of these loud low frequency clicks is extremely important to the survival of individual sperm whales. The function of these vocalizations is relatively well-studied (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). Long series of monotonous regularly spaced clicks are associated with feeding and are thought to be produced for echolocation. Distinctive, short, patterned series of clicks, called codas, are associated with social behavior and intragroup interactions; they are thought to facilitate intra-specific communication, perhaps to maintain social cohesion with the group (Weilgart and Whitehead 1993).

A general description of the anatomy of the ear for cetaceans is provided in the description of the blue whale above. The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1990). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz. 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). Sperm whales have moved out of areas after the start of air gun seismic testing (Davis *et al.*

1995). Seismic air guns produce loud, broadband, impulsive noise (source levels are on the order of 250 dB) with "shots" every 15 seconds, 240 shots per hour, 24 hours per day during active tests. Because they spend large amounts of time at depth and use low frequency sound sperm whales are likely to be susceptible to low frequency sound in the ocean (Croll *et al* 1999). Furthermore, because of their apparent role as important predators of mesopelagic squid and fish, changing the abundance of sperm whales should affect the distribution and abundance of other marine species.

3.3.5 Guadalupe fur seal

Distribution

Guadalupe fur seals are found on Guadalupe Island (Mexico) in the eastern Pacific Ocean off Mexico; a few individuals have been known to range as far north as Sonoma County, California, south to Los Islotes Islands in Baja California, Mexico. A few Guadalupe fur seals occupy California sea lion rookeries in the Channel Islands of California (Stewart *et al.* 1987 in Reeves *et al.* 1992).

Population Structure

The population is considered a single stock because all are recent descendents from one breeding colony at Isla Guadalupe, Mexico.

Threats to the Species

NATURAL THREATS. Guadalupe fur seals are known to be hunted by sharks and killer whales (Gallo-Reynosoand Figueroa-Carranza. 1992), although the potential effects of predation on this population is not known.

ANTHROPOGENIC THREATS. The size of the population prior to the commercial harvests of the 19th century is not known, but estimates range from 20,000 to 100,000 animals (Wedgeforth 1928; Hubbs 1956; Fleischer 1987).Commercial sealing during the 19th century reduced the once-abundant Guadalupe fur seal to near extinction in 1894. Sealing on the California coast was first recorded in 1805 and Native Americans left the remains of Guadalupe fur seals in their middens (Bonner 1994). The species was evidently exterminated from southern California waters by 1825. Commercial sealing continued, although with declining returns, in Mexican waters through 1894. Incomplete sealing records suggest that perhaps as many as 52,000 fur seals were killed on Mexican islands between 1806 and 1890, mostly before 1848; from 1877 to 1984, only some 6,600 fur seals were harvested (Reeves *et al.* 1992).

Due to its full protection in Mexico and in the U.S., it is presumed that Guadalupe fur seals are not presently hunted.

Status

Guadalupe fur seals were listed as threatened under the Endangered Species Preservation Act of 1966 on March 11, 1967. This listing was extended in 1973 under the Endangered Species Act of 1973. In the U.S., Guadalupe fur seals *(Arctocephalus townsendi)* were listed as threatened under the ESA in 1985. The State of California lists the Guadalupe fur seal as a fully protected mammal in the Fish and Game Code of California (Chapter 8, Section 4700,

d), and it is also listed as a threatened species in the California Fish and Game Commission Code of Regulations (Title 14, Section 670.5, b, 6, H). The Guadalupe fur seal is also protected under CITES and is fully protected under Mexican law.

Guadalupe Island was declared a pinniped sanctuary by the Mexican government in 1975. Critical habitat has not been designated for this species in the U.S.

By 1897, the Guadalupe fur seal was believed to be extinct. None was seen until a fisherman found slightly more than two dozen at Guadalupe Island in 1926. Counts of Guadalupe fur seals have been made sporadically since 1954. A few of these counts were made during the breeding season, but the majority was made at other times of the year. Documented seal counts in the literature generally provide only the total of all Guadalupe fur seals counted (*i.e.*, the counts are not separated by age/sex class). The counts made during the breeding season, when the maximum number of animals occur on the rookery, were used to examine population growth. The natural logarithm of the counts was regressed against a year to calculate the growth rate of the population. These data indicate that the population of Guadalupe fur seals is increasing exponentially at an average annual growth rate of 13.7 percent. Subsampling of the rookery indicate that only 47-55 percent of the seals present (*i.e.*, hauled out) were counted during the census (Gallo 1994). The minimum size of the population in Mexico can be estimated as the actual count of 3,028 hauled out seals [The actual count data were not reported by Gallo (1994); this number was derived by multiplying the estimated number hauled out by 47 percent, the minimum estimate of the percent counted] (Carretta *et al.* 2006). In the United States, a few Guadalupe fur seals are known to inhabit California sea lion rookeries in the Channel Islands (Stewart *et al.* 1997).

Strandings of Guadalupe fur seals have occurred along the central and northern California coast, suggesting that the seal may be expanding its range (Hanni *et al.* 1997). The severe reduction of the Guadalupe fur seals has evidently had a less substantial effect on its gene pool, when compared to other similarly depleted pinniped species, as relatively high levels of genetic variability have been reported (Reeves *et al.* 2002).

Diving and Social Behavior

Guadalupe fur seals are shallow divers that forage in the upper 20 to 30 meters of the water column. They have mean dive depths of about 17 meters (for lactating females), with modal depths of 3.1 meters (Gallo-Reynoso 1994). The mean duration of their dives was 2.6 minutes. Like other otariids, Guadalupe fur seals are social breeders: a single male will breed with several females.

Vocalizations and Hearing

Like most pinnipeds, Guadalupe fur seals produce a variety of in-air sounds that include barks, roars, coughs (Peterson *et al.* 1968). Many of these sounds consist of multiple harmonics with frequencies less than 7 kHz and dominant frequencies below 1 kHz (Peterson *et al*. 1968). Male Guadalupe fur seals vocalize frequency during the breeding season and produce four different call types, especially when during male-male interactions (Croxall and Gentry 1987). Females produce a pup attraction call and female attraction calls, each seemingly pulsed with the fundamental frequency below ~2 kHz (Croxall and Gentry 1987). Other call types include a boundary bluff, a bark, and a growl which seem correlated to some form of territorial behavior. Females produce a pup attraction call and

female attraction calls, each seemingly pulsed with the fundamental frequency below ~2 kHz (Croxall and Gentry 1987).

There is no published information on the hearing range of Guadalupe fur seals, although it is most likely similar to other fur seals. Northern fur seals produce underwater clicks, and in-air barking, coughing, and roaring sounds (Schusterman 1978; Richardson et al. 1995). The underwater hearing range of the northern fur seal ranges from 0.5Hz to 40 kHz (Moore and Schusterman 1987; Babushina *et al.* 1991) and the threshold is 50 to 60 dB re 1 μPa-m (Moore and Schusterman 1987). The best underwater hearing occurs between 4 and 17 to 28 kHz (Moore and Schisterman 1987; Babushina *et al.* 1991). The maximum sensitivity in air is at 3 to 5 kHz for northern fur seals (Babushina *et al.* 1991), after which there is anomalous hearing loss at around 4 to 5 kHz (Moore and Schusterman 1987; Babushina 1999).

3.3.6 Green Sea Turtle

Distribution

Green turtles are found in the Pacific Ocean, Atlantic Ocean, Indian Ocean, Carribean Sea, and Mediterranean Sea, primarily in tropical or, to a lesser extent, subtropical waters. These regions can be further divided into nesting aggregations within the eastern, central, and western Pacific Ocean; the western, northern, and eastern Indian Ocean; Mediterranean Sea; and eastern, southern, and western Atlantic Ocean, including the Carribean Sea.

Green turtles appear to prefer waters that usually remain around 20°C in the coldest month. During warm spells (e.g., El Niño), green turtles may be found considerably north of their normal distribution. Stinson (1984) found green turtles to appear most frequently in U.S. coastal waters with temperatures exceeding 18°C. An east Pacific green turtle equipped with a satellite transmitter was tracked along the California coast and showed a distinct preference for waters with temperatures above 20°C (Eckert, unpublished data).

Further, green sea turtles seem to occur preferentially in drift lines or surface current convergences, probably because of the prevalence of cover and higher densities of their food items associated with these oceanic phenomena. For example, in the western Atlantic Ocean, drift lines commonly contain floating *Sargassum* capable of providing small turtles with shelter and sufficient buoyancy to raft upon (NMFS and USFWS 1998). Underwater resting sites include coral recesses, the underside of ledges, and sand bottom areas that are relatively free of strong currents and disturbance from natural predators and humans. Available information indicates that green turtle resting areas are in proximity to their feeding pastures (NMFS 2000).

Population Structure

The population dynamics of green sea turtles and all of the other sea turtles we consider in this Opinion are usually described based on the distribution and habit of nesting females, rather than their male counterparts. The spatial structure of male sea turtles and their fidelity to specific coastal areas is unknown; however, we describe sea turtle populations based on the nesting beaches that female sea turtles return to when they mature. Because the patterns of increase or decrease in the abundance of sea turtle nests over time are determined by internal dynamics rather than

external dynamics, we make inferences about the growth or decline of sea turtle populations based on the status and trend of their nests.

Primary nesting aggregations of green turtles (i.e. sites with greater than 500 nesting females per year) include: Ascension Island (south Atlantic Ocean), Australia, Brazil, Comoros Islands, Costa Rica, Ecuador (Galapagos Archipelago), Equatorial Guinea (Bioko Island), Guinea-Gissau (Bijagos Archipelago), Iles Eparses Islands (Tromelin Island, Europa Island), Indonesia, Malaysia, Myanmar, Oman, Philippines, Saudi Arabia, Seychelles Islands, Suriname, and United States (Florida; Seminoff 2002, NMFS and USFWS 1998a).

Smaller nesting aggregations include: Angola, Bangladesh, Bikar Atoll, Brazil, Chagos Archipelago, China, Costa Rica, Cuba, Cyprus, Democratic Republic of Yemen, Dominican Republic, d'Entrecasteaux Reef, French Guiana, Ghana, Guyana, India, Iran, Japan, Kenya, Madagascar, Maldives Islands, Mayotte Archipelago, Mexico, Micronesia, Pakistan, Palmerston Atoll, Papua New Guinea, Primieras Islands, Sao Tome é Principe, Sierra Leone, Solomon Islands, Somalia, Sri Lanka, Taiwan, Tanzania, Thailand, Turkey, Scilly Atoll, United States (Hawai'i), Venezuela, and Vietnam (Seminoff 2002).

Molecular genetic techniques have helped researchers gain insight into the distribution and ecology of migrating and nesting green turtles. In the Pacific Ocean, green sea turtles group into two distinct regional clades: (1) western Pacific and South Pacific islands, and (2) eastern Pacific and central Pacific, including the rookery at French Frigate Shoals, Hawai'i. In the eastern Pacific, greens forage coastally from San Diego Bay, California in the north to Mejillones, Chile in the South. Based on mtDNA analyses, green turtles found on foraging grounds along Chile's coast originate from the Galapagos nesting beaches, while those greens foraging in the Gulf of California originate primarily from the Michoacan nesting stock. Green turtles foraging in San Diego Bay and along the Pacific coast of Baja California originate primarily from rookeries of the Islas Revillagigedos (Dutton 2003).

Threats to the Species

NATURAL THREATS. The various habitat types green sea turtles occupy throughout their lives exposes these sea turtles to a wide variety of natural threats. The beaches on which green sea turtles nest and the nests themselves are threatened by hurricanes and tropical storms as well as the storm surges, sand accretion, and rainfall that are associated with hurricanes. Hatchlings are hunted by predators like herons, gulls, dogfish, and sharks. Larger green sea turtles, including adults, are also killed by sharks and other large, marine predators.

Green turtles in the northwest Hawai'ian Islands are afflicted with a tumor disease, fibropapilloma, which is of an unknown etiology and often fatal, as well as spirochidiasis, both of which are the major causes of strandings of this species. The presence of fibropapillomatosis among stranded turtles has increased significantly over the past 17 years, ranging from 47-69 percent during the past decade (Murakawa *et al.* 2000). Green turtles captured off Molokai from 1982-96 showed a massive increase in the disease over this period, peaking at 61% prevalence in 1995 (Balazs *et al.* 1998). Preliminary evidence suggests an association between the distribution of fibropapillomatosis in the Hawai'ian Islands and the distribution of toxic benthic dinoflagellates (*Prorocentrum* spp.) known to produce a tumor promoter, okadaic acid (Landsberg *et al.* 1999). Fibropapillomatosis is considered to decrease growth rates in afflicted turtles and may inhibit the growth rate of Hawai'ian green turtle populations (Balazs *et al.* 1998).

ANTHROPOGENIC THREATS. Three human activities are known to threaten green sea turtles: overharvests of individual animals, incidental capture in commercial fisheries, and human development of coastlines. Historically, the primary cause of the global decline of green sea turtles populations were the number of eggs and adults captured and killed on nesting beaches in combination with the number of juveniles and adults captured and killed in coastal feeding areas. Some population of green sea turtles still lose large number of eggs, juveniles, and adults to subsistence hunters, local communities that have a tradition of harvesting sea turtles, and poachers in search of turtle eggs and meat.

Directed harvests of eggs and other life stages of green sea turtles were identified as a "major problem" in American Samoa, Guam, Palau, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Republic of the Marshall Islands, and the Unincorporated Islands (Wake, Johnston, Kingman, Palmyra, Jarvis, Howland, Baker, and Midway). In the Atlantic, green sea turtles are captured and killed in turtle fisheries in Colombia, Grenada, the Lesser Antilles, Nicaragua, St. Vincent and the Grenadines (Bräutigam and Eckert 2006); the turtle fishery along the Caribbean coast of Nicaragua, by itself, captures more than 11,000 green sea turtles each year for the past 10 years (Bräutigam and Eckert 2006, Lagueux 1998).

Severe overharvests have resulted from a number of factors in modern times: (1) the loss of traditional restrictions limiting the number of turtles taken by island residents; (2) modernized hunting gear; (3) easier boat access to remote islands; (4) extensive commercial exploitation for turtle products in both domestic markets and international trade; (5) loss of the spiritual significance of turtles; (6) inadequate regulations; and (7) lack of enforcement (NMFS and USFWS 1998a).

Green sea turtles are also captured and killed in commercial fisheries. Gillnets account for the highest number of green sea turtles that are captured and killed, but they are also captured and killed in trawls, traps and pots, longlines, and dredges. Along the Atlantic coast of the U.S., NMFS estimated that almost 19,000 green sea turtles are captured in shrimp trawl fisheries each year in the Gulf of Mexico, with 514 of those sea turtles dying as a result of their capture (see Table X). Each year, several hundred green sea turtles are captured in herring fisheries; mackerel, squid, and butterfish fisheries; monkfish fisheries; pound net fisheries, summer flounder and scup fisheries; Atlantic pelagic longline fisheries; and gillnet fisheries in Pamlico Sound. Although most of these turtles are released alive, these fisheries are expected to kill almost 100 green sea turtles each year; the health effects of being captured on the sea turtles that survive remain unknown.

Green sea turtles are also threatened by domestic or domesticated animals which prey on their nests; artificial lighting that disorients adult female and hatchling sea turtles, which can dramatically increase the mortality rates of hatchling sea turtles; beach replenishment; ingestion and entanglement in marine debris; and environmental contaminants.

Status

Green turtles are listed as threatened under the ESA, except for breeding populations found in Florida and the Pacific coast of Mexico, which are listed as endangered. Using a precautionary approach, Seminoff (2002) estimates that the global green turtle population has declined by 34% to 58% over the last three generations (approximately 150 years)

although actual declines may be closer to 70% to 80%. Causes for this decline include harvest of eggs, subadults and adults, incidental capture by fisheries, loss of habitat, and disease.

While some nesting populations of green turtles appear to be stable or increasing in the Atlantic Ocean (e.g. Bujigos Archipelago (Guinea-Bissau), Ascension Island, Tortuguero (Costa Rica), Yucatan Peninsula (Mexico), and Florida), declines of over 50% have been documented in the eastern (Bioko Island, Equatorial Guinea) and western Atlantic (Aves Island, Venezuela). Nesting populations in Turkey (Mediterranean Sea) have declined between 42% and 88% since the late 1970s. Population trend variations also appear in the Indian Ocean. Declines greater than 50% have been documented at Sharma (Republic of Yemen) and Assumption and Aldabra (Seychelles), while no changes have occurred at Karan Island (Saudi Arabia) or at Ras al Hadd (Oman). The number of females nesting annually in the Indian Ocean has increased at the Comoros Islands, Tromelin and maybe Europa Island (Iles Esparses; Seminoff 2002).

Green turtles are thought to be declining throughout the Pacific Ocean, with the exception of Hawai'i, as a direct consequence of a historical combination of overexploitation and habitat loss (Eckert 1993, Seminoff 2002). They are also thought to be declining in the Atlantic Ocean. However, like several of the species we have already discussed, the information available on the status and trend of green sea turtles do not allow us to make definitive statement about the global extinction risks facing these sea turtles or risks facing particular populations (nesting aggregations) of these turtles. With the limited data available on green sea turtles, we do not know whether green sea turtles exist at population sizes large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself) or if green sea turtles might are threatened more by exogenous threats such as anthropogenic activities (entanglement, habitat loss, overharvests, etc.) or natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate). Nevertheless, with the exception of the Hawai'ian nesting aggregations, we assume that green sea turtles are endangered because of both anthropogenic and natural threats as well as changes in their population dynamics.

Diving and Social Behavior

Based on the behavior of post-hatchlings and juvenile green turtles raised in captivity, it is presumed that those in pelagic habitats live and feed at or near the ocean surface, and that their dives do not normally exceed several meters in depth (NMFS and USFWS 1998). The maximum recorded dive depth for an adult green turtle was 110 meters (Berkson 1967 *in* Lutcavage and Lutz 1997), while subadults routinely dive 20 meters for 9-23 minutes, with a maximum recorded dive of 66 minutes (Brill *et al.* 1995 *in* Lutcavage and Lutz 1997).

Vocalizations and Hearing

The information on green turtle hearing is very limited. Ridgway *et al.* (1969) studied the auditory evoked potentials of three green sea turtles (in air and through mechanical stimulation of the ear) and concluded that their maximum sensitivity occurred from 300 to 400 Hz with rapid declines for tones at lower and higher frequencies. They reported an upper limit for cochlear potentials without injury of 2000 Hz and a practical limit of about 1000 Hz. This is

similar to estimates for loggerhead sea turtles, which had most sensitive hearing between 250 and 1000 Hz, with rapid decline above 1000 Hz (Bartol *et al.* 1999).

In a study of the auditory brainstem responses of subadult green sea turtles, Bartol and Ketten (2006) reported responses to frequencies between 100 and 500 Hz; with highest sensitivity between 200 and 400 Hz. They reported that two juvenile green turtles had hearing sensitivities that were slightly broader in range: they responded to sounds at freqnencies from 100 to 800 Hz, with highest hearing sensitivities from 600 to 700 Hz.

These hearing sensitivities are similar to the hearing sensitivities reported for two terrestrial species: pond turtles (*Pseudemys scripta*) and wood turtles (*Chrysemys inscuplta*). Pond turtles are reported to have best hearing responsiveness between 200 and 700 Hz, with slow declines below 100 Hz and rapid declines above 700 Hz and almost no sensitivity above 3000 Hz (Wever and Vernon 1956) the latter has sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Peterson 1966).

3.3.7 Leatherback Sea Turtle

Distribution

Leatherback turtles are widely distributed throughout the oceans of the world. The species is found in four main regions of the world: the Pacific, Atlantic, and Indian Oceans, and the Caribbean Sea. Leatherbacks also occur in the Mediterranean Sea, although they are not known to nest there. The four main regional areas may further be divided into nesting aggregations. Leatherback turtles are found on the western and eastern coasts of the Pacific Ocean, with nesting aggregations in Mexico and Costa Rica (eastern Pacific) and Malaysia, Indonesia, Australia, the Solomon Islands, Papua New Guinea, Thailand, and Fiji (western Pacific). In the Atlantic Ocean, leatherback nesting aggregations have been documented in Gabon, Sao Tome and Principe, French Guiana, Suriname, and Florida. In the Caribbean, leatherbacks nest in the U.S. Virgin Islands and Puerto Rico. In the Indian Ocean, leatherback nesting aggregations are reported in India and Sri Lanka.

Leatherback sea turtles are highly migratory, exploiting convergence zones and upwelling areas in the open ocean, along continental margins, and in archipelagic waters (Morreale *et al.* 1994, Eckert 1998, Eckert 1999a). In a single year, a leatherback may swim more than 10,000 kilometers (Eckert 1998). In the North Atlantic Ocean, leatherback turtles regularly occur in deep waters (>328 ft), and an aerial survey study in the north Atlantic sighted leatherback turtles in water depths ranging from 3 to 13,618 ft, with a median sighting depth of 131.6 ft (CeTAP 1982). This same study found leatherbacks in waters ranging from 7 to 27.2°C. In the Pacific Ocean, leatherback turtles have the most extensive range of any living reptile and have been reported in all pelagic waters of the Pacific between 71°N and 47°S latitude and in all other major pelagic ocean habitats (NMFS and USFWS 1998). Leatherback turtles lead a completely pelagic existence, foraging widely in temperate waters except during the nesting season, when gravid females return to tropical beaches to lay eggs. Males are rarely observed near nesting areas, and it has been hypothesized that leatherback sea turtles probably mate outside of tropical waters, before females swim to their nesting beaches (Eckert and Eckert 1988).

Leatherback turtles are uncommon in the insular Pacific Ocean, but individual leatherback turtles are sometimes encountered in deep water and prominent archipelagoes. To a large extent, the oceanic distribution of leatherback

turtles may reflect the distribution and abundance of their macroplanktonic prey, which includes medusae, siphonophores, and salpae in temperate and boreal latitudes (NMFS and USFWS 1996). There is little information available on their diet in subarctic waters.

Population Structure

Leatherback turtles are widely distributed throughout the oceans of the world. The species is divided into four main populations in the Pacific, Atlantic, and Indian Oceans, and the Caribbean Sea. Leatherbacks also occur in the Mediterranean Sea, although they are not known to nest there. The four main populations are further divided into nesting aggregations. Leatherback turtles are found on the western and eastern coasts of the Pacific Ocean, with nesting aggregations in Mexico and Costa Rica (eastern Pacific) and Malaysia, Indonesia, Australia, the Solomon Islands, Papua New Guinea, Thailand, and Fiji (western Pacific). In the Atlantic Ocean, leatherback nesting aggregations have been documented in Gabon, Sao Tome and Principe, French Guiana, Suriname, and Florida. In the Caribbean, leatherbacks nest in the U.S. Virgin Islands and Puerto Rico. In the Indian Ocean, leatherback nesting aggregations are reported in India, Sri Lanka, and the Andaman and Nicobar Islands.

Threats to the Species

NATURAL THREATS. The various habitat types leatherback sea turtles occupy throughout their lives exposes these sea turtles to a wide variety of natural threats. The beaches on which leatherback sea turtles nest and the nests themselves are threatened by hurricanes and tropical storms as well as the storm surges, sand accretion, and rainfall that are associated with hurricanes. Hatchlings are hunted by predators like herons, gulls, dogfish, and sharks. Larger leatherback sea turtles, including adults, are also killed by sharks and other large, marine predators.

ANTHROPOGENIC THREATS. Leatherback sea turtles are endangered by several human activities, including fisheries interactions, entanglement in fishing gear (e.g., gillnets, longlines, lobster pots, weirs), direct harvest, egg collection, the destruction and degradation of nesting and coastal habitat, boat collisions, and ingestion of marine debris (NMFS and USFWS 1997).

The foremost threat is the number of leatherback turtles killed or injured in fisheries. Spotila (2000) concluded that a conservative estimate of annual leatherback fishery-related mortality (from longlines, trawls and gillnets) in the Pacific Ocean during the 1990s is 1,500 animals. He estimates that this represented about a 23% mortality rate (or 33% if most mortality was focused on the East Pacific population). Spotila (2000) asserts that most of the mortality associated with the Playa Grande nesting site was fishery related.

Leatherback sea turtles are exposed to commercial fisheries in many areas of the Atlantic Ocean. For example, leatherback entanglements in fishing gear are common in Canadian waters where Goff and Lien (1988) reported that 14 of 20 leatherbacks encountered off the coast of Newfoundland and Labrador were entangled in fishing gear including salmon net, herring net, gillnet, trawl line and crab pot line. Leatherbacks are reported taken by the many other nations that participate in Atlantic pelagic longline fisheries (see NMFS 2001, for a complete description of take records), including Taiwan, Brazil, Trinidad, Morocco, Cyprus, Venezuela, Korea, Mexico, Cuba, U.K., Bermuda, People's Republic of China, Grenada, Canada, Belize, France, and Ireland.

In the Pacific Ocean, between 1,000 and 1,300 leatherback sea turtles are estimated to have been captured and killed in longline fisheries in 2000 (Lewison *et al.* 2004). Shallow-set longline fisheries based out of Hawai'i are estimated to have captured and killed several hundred leatherback sea turtles before they were closed in 2001. When they were re-opened in 2004, with substantial modifications to protect sea turtles, these fisheries were estimated to have captured and killed about 1 or 2 leatherback sea turtles each year. Between 2004 and 2008, shallow-set fisheries based out of Hawai'i are estimated to have captured about 19 leatherback sea turtles, killing about 5 of these sea turtles. A recent biological opinion on these fisheries expected this rate of interaction and deaths to continue into the foreseeable future (NMFS 2008). Leatherback sea turtles have also been and are expected to continue to be captured and killed in the deep-set based longline fisheries based out of Hawai'i and American Samoa.

Shrimp trawls in the Gulf of Mexico capture the largest number of leatherback sea turtles: each year, they have been estimated to capture about 3,000 leatherback sea turtles with 80 of those sea turtles dying as a result. Along the Atlantic coast of the U.S., NMFS estimated that about 800 leatherback sea turtles are captured in pelagic longline fisheries, bottom longline and drift gillnet fisheries for sharks as well as lobster, deep-sea red crab, Jonah crab, dolphin fish and wahoo, and Pamlico Sound gillnet fisheries. Although most of these turtles are released alive, these fisheries are combine to kill about 300 leatherback sea turtles each year; the health effects of being captured on the sea turtles that survive remain unknown.

Leatherback sea turtles are known to drown in fish nets set in coastal waters of Sao Tome, West Africa (Castroviejo *et al.* 1994; Graff 1995). Gillnets are one of the suspected causes for the decline in the leatherback turtle population in French Guiana (Chevalier *et al.* 1999), and gillnets targeting green and hawksbill turtles in the waters of coastal Nicaragua also incidentally catch leatherback turtles (Lagueux *et al.* 1998). Observers on shrimp trawlers operating in the northeastern region of Venezuela documented the capture of six leatherbacks from 13,600 trawls (Marcano and Alio, 2000). An estimated 1,000 mature female leatherback turtles are caught annually off of Trinidad and Tobago with mortality estimated to be between 50-95% (Eckert and Lien, 1999). However, many of the turtles do not die as a result of drowning, but rather because the fishermen butcher them in order to get them out of their nets (NMFS 2001). There are known to be many sizeable populations of leatherbacks nesting in West Africa, possibly as many as 20,000 females nesting annually (Fretey 2001). In Ghana, nearly two thirds of the leatherback turtles that come up to nest on the beach are killed by local fishermen.

On some beaches, nearly 100% of the eggs laid have been harvested. Eckert (1996) and Spotila *et al.* (1996) note that adult mortality has also increased significantly, particularly as a result of driftnet and longline fisheries. Like green sea turtles, leatherback sea turtles are threatened by domestic or domesticated animals that prey on their nests; artificial lighting that disorients adult female and hatchling sea turtles, which can dramatically increase the mortality rates of hatchling sea turtles; beach replenishment; ingestion and entanglement in marine debris; and environmental contaminants.

Status

The leatherback turtle is listed as endangered under the ESA throughout its global range. Increases in the number of nesting females have been noted at some sites in the Atlantic Ocean, but these are far outweighed by local extinctions, especially of island populations, and the demise of populations throughout the Pacific, such as in

Malaysia and Mexico. Spotila *et al.* (1996) estimated the global population of female leatherback turtles to be only 34,500 (confidence limits: 26,200 to 42,900) nesting females; however, the eastern Pacific population has continued to decline since that estimate, leading some researchers to conclude that the leatherback is now on the verge of extinction in the Pacific Ocean (e.g. Spotila *et al.* 1996, Spotila, *et al.* 2000).

Globally, leatherback turtle populations have been decimated worldwide. In 1980, the global leatherback population was estimated at approximately 115,000 adult females (Pritchard 1982). By 1995, this global population (of adult females) is estimated to have declined to 34,500 (Spotila *et al.* 1996). Populations have declined in Mexico, Costa Rica, Malaysia, India, Sri Lanka, Thailand, Trinidad, Tobago, and Papua New Guinea. Throughout the Pacific, leatherbacks are seriously declining at all major nesting beaches.

In the Atlantic and Caribbean, the largest nesting assemblages of leatherbacks are found in the U.S. Virgin Islands, Puerto Rico, and Florida. Since the early 1980s, nesting data has been collected at these locations. Populations in the eastern Atlantic (*i.e.* off Africa) and Caribbean appear to be stable; however, information regarding the status of the entire leatherback population in the Atlantic is lacking and it is certain that some nesting populations (*e.g.*, St. John and St. Thomas, U.S. Virgin Islands) have been extirpated (NMFS and USFWS 1995). Data collected in southeast Florida clearly indicate increasing numbers of nests for the past twenty years (9.1-11.5% increase), although it is critical to note that there was also an increase in the survey area in Florida over time (NMFS 2001). However, the largest leatherback rookery in the western North Atlantic remains along the northern coast of South America in French Guiana and Suriname. Recent information suggests that Western Atlantic populations declined from 18,800 nesting females in 1996 (Spotila *et al.* 1996) to 15,000 nesting females by 2000 (Spotila, personal communication *cited in* NMFS 2001). The nesting population of leatherback turtles in the Suriname-French Guiana trans-boundary region has been declining since 1992 (Chevalier and Girondot, 1998). Poaching and fishing gear interactions are believed to be the major contributors to the decline of leatherbacks in the area.

Leatherback sea turtles appear to be in a critical state of decline in the North Pacific Ocean. The leatherback population that nests along the east Pacific Ocean was estimated to be over 91,000 adults in 1980 (Spotila 1996), but is now estimated to number less than 3,000 total adult and subadult animals (Spotila 2000). Leatherback turtles have experienced major declines at all major Pacific basin rookeries. At Mexiquillo, Michoacan, Mexico, Sarti *et al.* (1996) reported an average annual decline in nesting of about 23% between 1984 and 1996. The total number of females nesting on the Pacific coast of Mexico during the 1995-1996 season was estimated at fewer than 1,000. Less than 700 females are estimated for Central America (Spotila 2000). In the western Pacific, the decline is equally severe. Current nestings at Terengganu, Malaysia represent 1% of the levels recorded in the 1950s (Chan and Liew 1996).

While Spotila *et al.* (1996) indicated that turtles may have been shifting their nesting from French Guiana to Suriname due to beach erosion, analyses show that the overall area trend in number of nests has been negative since 1987 at a rate of 15.0 -17.3 % per year (NMFS 2001). If turtles are not nesting elsewhere, it appears that the Western Atlantic portion of the population is being subjected to mortality beyond sustainable levels, resulting in a continued decline in numbers of nesting females.

Based on published estimates of nesting female abundance, leatherback populations are declining at all major Pacific basin nesting beaches, particularly in the last two decades (Spotila *et al.* 1996, NMFS and USFWS 1998, Spotila *et al.* 2000). Declines in nesting populations have been documented through systematic beach counts or surveys in Malaysia (Rantau Abang, Terengganu), Mexico and Costa Rica. In other leatherback nesting areas, such as Papua New Guinea, Indonesia, and the Solomon Islands, there have been no systematic consistent nesting surveys, so it is difficult to assess the status and trends of leatherback turtles at these beaches. In all areas where leatherback nesting has been documented, however, current nesting populations are reported by scientists, government officials, and local observers to be well below abundance levels of several decades ago. The collapse of these nesting populations was most likely precipitated by a tremendous overharvest of eggs coupled with incidental mortality from fishing (Sarti *et al.* 1996, Eckert, 1997).

Based on recent modeling efforts, some authors concluded that leatherback turtle populations cannot withstand more than a 1% human-related mortality level which translates to 150 nesting females (Spotila *et al.* 1996). As noted previously, there are many human-related sources of mortality to leatherbacks; every year, 1,800 leatherback turtles are expected to be captured or killed as a result of federally-managed activities in the U.S. (this total includes both lethal and non-lethal take). An unknown number of leatherbacks are captured or killed in fisheries managed by states. Spotila *et al.* (1996) recommended not only reducing fishery-related mortalities, but also advocated protecting eggs and hatchlings. Zug and Parham (1996) point out that a combination of the loss of long-lived adults in fishery-related mortalities and a lack of recruitment stemming from elimination of annual influxes of hatchlings because of intense egg harvesting has caused the sharp decline in leatherback populations.

For several years, NMFS' biological opinions have established that leatherback populations currently face high probabilities of extinction as a result of both environmental and demographic stochasticity. Demographic stochasticity, which is chance variation in the birth or death of an individual of the population, is facilitated by the increases in mortality rates of leatherback populations resulting from the premature deaths of individual sea turtles associated with human activities (either removal of eggs or adult females that are killed on nesting beaches or that die as a result of being captured in fisheries) or incidental capture and mortality of individuals in various fisheries.

In the Pacific Ocean, leatherback sea turtles are critically endangered as a direct consequence of a historical combination of overexploitation and habitat loss. The information available suggests that leatherback sea turtles have high probabilities of becoming extinct in the Pacific Ocean unless they are protected from the combined threats of entanglements in fishing gear, overharvests, and loss of their nesting habitat. The limited data available suggests that leatherback sea turtles exist at population sizes small enough to be calssified as "small" populations (that is, populations that exhibit population dynamics that increase the extinction probabilities of the species or several of its populations) as evidenced by biases in the male to female ratios in the Pacific. The status of leatherback sea turtles in the Atlantic Ocean remains uncertain.

Diving and Social Behavior

The maximum dive depths for post-nesting female leatherbacks in the Caribbean have been recorded at 475 meters and over 1,000 meters, with routine dives recorded at between 50 and 84 meters. The maximum dive length recorded for such female leatherback turtles was 37.4 minutes, while routine dives ranged from 4 -14.5 minutes (*in* Lutcavage

and Lutz 1997). Leatherback turtles also appear to spend almost the entire portion of each dive traveling to and from maximum depth, suggesting that maximum exploitation of the water column is of paramount importance to the leatherback (Eckert *et al.* 1989).

A total of six adult female leatherback turtles from Playa Grande, Costa Rica were monitored at sea during their internesting intervals and during the 1995 through 1998 nesting seasons. The turtles dived continuously for the majority of their time at sea, spending 57 - 68% of their time submerged. Mean dive depth was 19 ± 1 meters and the mean dive duration was 7.4 ± 0.6 minutes (Southwood *et al.* 1999). Similarly, Eckert (1999) placed transmitters on nine leatherback females nesting at Mexiquillo Beach and recorded dive behavior during the nesting season. The majority of the dives were less than 150 meters depth, although maximum depths ranged from 132 meters to over 750 meters. Although the dive durations varied between individuals, the majority of them made a large proportion of very short dives (less than two minutes), although Eckert (1999) speculates that these short duration dives most likely represent just surfacing activity after each dive. Excluding these short dives, five of the turtles had dive durations greater than 24 minutes, while three others had dive durations between 12 - 16 minutes.

Migrating leatherback turtles also spend a majority of time at sea submerged, and they display a pattern of continual diving (Standora *et al.* 1984, *cited in* Southwood *et al.* 1999). Based on depth profiles of four leatherbacks tagged and tracked from Monterey Bay, California in 2000 and 2001, using satellite-linked dive recorders, most of the dives were to depths of less than 100 meters and most of the time was spent shallower than 80 meters. Based on preliminary analyses of the data, 75-90% of the time the leatherback turtles were at depths less than 80 meters.

Vocalizations and Hearing

There is no information on the vocalizations or hearing of leatherback sea turtles. However, we assume that their hearing sensitivities will be similar to those of green and loggerhead sea turtle: their best hearing sensitivity will be in the low frequency range: from 200 to 400 Hz with rapid declines for tones at lower and higher frequencies. Their hearing will probably have a practical upper limit of about 1000 Hz (Bartol *et al.* 1999, Ridgway *et al.* 1969).

These hearing sensitivities are similar to the hearing sensitivities reported for two terrestrial species: pond turtles (*Pseudemys scripta*) and wood turtles (*Chrysemys inscuplta*). Pond turtles are reported to have best hearing responsiveness between 200 and 700 Hz, with slow declines below 100 Hz and rapid declines above 700 Hz and almost no sensitivity above 3000 Hz (Wever and Vernon 1956) the latter has sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Peterson 1966).

3.3.8 Loggerhead Sea Turtle

Distribution

Loggerheads are circumglobal, inhabiting continental shelves, bays, estuaries, and lagoons in temperate, subtropical, and tropical waters. Major nesting grounds are generally located in temperate and subtropical regions, with scattered nesting in the tropics (*in* NMFS and USFWS 1998).

Population Structure

Loggerhead sea turtles, like other sea turtles, are divided into regional groupings that represent major oceans or seas: the Atlantic Ocean, Pacific Ocean, Indian Ocean, Caribbean Sea and Mediterranean Sea. In these regions, the population structure of loggerhead turtles are usually based on the distribution of their nesting aggregations (see Table 5). In the Pacific Ocean, loggerhead turtles are represented by a northwestern Pacific nesting aggregation (located in Japan) which may be comprised of separate nesting groups (Hatase *et al.* 2002) and a smaller southwestern nesting aggregation that occurs in Australia (Great Barrier Reef and Queensland), New Caledonia, New Zealand, Indonesia, and Papua New Guinea. One of the largest loggerhead nesting aggregations in the world is found in Oman, in the Indian Ocean.

Based on genetic analyses of loggerhead sea turtles captured in pelagic longline fisheries in the same general area as that of the proposed action, loogerhead sea turtles along the southeastern coast of the United States might originate from one of the five major nesting aggregations in the western North Atlantic: (1) a northern nesting aggregation that occurs from North Carolina to northeast Florida, about 29°N; (2) a south Florida nesting aggregation, occurring from 29°N on the east coast to Sarasota on the west coast; (3) a Florida panhandle nesting aggregation, occurring at Eglin Air Force Base and the beaches near Panama City, Florida; (4) a Yucatán nesting aggregation, occurring on the eastern Yucatán Peninsula, Mexico; and (5) a Dry Tortugas nesting aggregation that occurs in the islands of the Dry Tortugas near Key West, Florida (NMFS 2001).

Loggerhead sea turtles from the northern nesting aggregation, which represents about 9% of the loggerhead nests in the western North Atlantic, comprise more between 25 and 59% of the loggerhead sea turtles captured in foraging areas from Georgia to waters of the northeastern United States (Bass *et al.* 1998, Norrgard 1995, Rankin-Baransky 1997, Sears 1994, Sears *et al.* 1995). About 10% of the loggerhead sea turtles in foraging areas off the Atlantic coast of central Florida will have originated from the northern nesting aggregation (Witzell 1999). Loggerhead sea turtles associated with the South Florida nesting aggregation, in contrast, occur in higher frequencies in the Gulf of Mexico (where they represent about 10% of the loggerhead sea turtles captured) and the Mediterranean Sea (where they represent about 45-47% of the loggerhead sea turtles captured).

Threats to the Species

NATURAL THREATS. The various habitat types loggerhead sea turtles occupy throughout their lives exposes these sea turtles to a wide variety of natural and anthropogenic threats. The beaches on which loggerhead sea turtles nest and the nests themselves are threatened by hurricanes and tropical storms as well as the storm surges, sand accretion, and rainfall that are associated with hurricanes. For example, in 1992, all of the eggs over a 90-mile length of coastal Florida were destroyed by storm surges on beaches that were closest to the eye of Hurricane Andrew (Milton *et al.* 1994). Hatchlings are hunted by predators like herons, gulls, dogfish, and sharks. Adult loggerhead sea turtles are also killed by sharks and other large, marine predators. Loggerhead sea turtles are also killed by cold stunning, exposure to biotoxins, sharks and other large, marine predators.

Table 5. Nesting populations of loggerhead sea turtles that have been identified using molecular genetics (after Hutchinson and Dutton 2007)

Ocean Basin	Population

Atlantic (eastern) (the Cape Verde rookeries appear to be genetically distinct, the other rookeries listed have not been evaluated)	
1	Cape Verde
2	Greece
3	Libya
4	Turkey
5	West African coast
Atlantic (western) and Caribbean	
6	Northern (U.S.) including rookeries from southern Virginia south to Florida
7	Florida peninsula which includes rookeries from the northeastern border of Florida south to southwestern Florida
8	Dry Tortugas, which includes the islands of Key West
9	Northern Gulf of Mexico, which extends from northwestern Florida into Texas
10	Cay Sal bank in thee western Bahamas
11	Quintana Roo, which includes all rookeries on Mexico's Yucatan Peninsula
12	Brazil
13	Additional rookeries in Caribbean Central America, the Bahamian Archipelago, Cuba, Colombia, Venezuela, and the eastern Caribbean Islands have not been classified
Indian Ocean (none of these rookeries have been evaluated genetically)	
14	Oman
15	Yemen
16	Sri Lanka
17	Madagascar
18	South Africa and (possibly) Mozambique
Pacific Ocean	
19	Western Australia
20	Eastern Australia, which may include rookeries from New Caledonia
21	North Pacific or Japan, which includes all rookeries in the Japanese Archipelago
22	Solomon Islands

ANTHROPOGENIC THREATS. A wide variety of human activities adversely affect hatchlings and adult female turtles when they are on land, including beach erosion, beach armoring and nourishment; artificial lighting; beach cleaning; human presence on nesting beaches; beach driving; coastal construction and fishing piers that alter patterns of erosion and accretion on nesting beaches; exotic dune and beach vegetation; and poaching. As the size of the human population in coastal areas increases, that population brings with it secondary threats such as exotic fire ants, feral hogs, dogs, and the growth of populations native species that tolerate human presence (*e.g.*, raccoons, armadillos, and opossums) and which feed on turtle eggs.

When they are in coastal or marine waters, loggerhead turtles are affected by a completely different set of human activities that include discharges of toxic chemicals and other pollutants into the marine ecosystem; underwater explosions; hopper dredging, offshore artificial lighting; entrainment or impingement in power plants; entanglement in marine debris; ingestion of marine debris; boat collisions; poaching, and interactions with commercial fisheries. Of these, interactions with fisheries represents a primary threat because of number of individuals that are captured and killed in fishing gear each year.

Loggerhead sea turtles are also captured and killed in commercial fisheries. In the Pacific Ocean, between 2,600 and 6,000 loggerhead sea turtles are estimated to have been captured and killed in longline fisheries in 2000 (Lewison *et al.* 2004). Shallow-set Hawai'i based longline fisheries are estimated to have captured and killed several hundred loggerhead sea turtles before they were closed in 2001. When they were re-opened in 2004, with substantial modifications to protect sea turtles, these fisheries were estimated to have captured and killed about fewer than 5 loggerhead sea turtles each year. Between 2004 and 2008, shallow-set fisheries based out of Hawai'i are estimated to have captured about 45 loggerhead sea turtles, killing about 10 of these sea turtles. A recent biological opinion on these fisheries expected this rate of interaction and deaths to continue into the foreseeable future (NMFS 2008). Loggerhead sea turtles have also been and are expected to continue to be captured and killed in the deep-set based longline fisheries based out of Hawai'i and American Samoa.

Shrimp trawl fisheries account for the highest number of loggerhead sea turtles that are captured and killed, but they are also captured and killed in trawls, traps and pots, longlines, and dredges. Along the Atlantic coast of the U.S., NMFS estimated that almost 163,000 loggerhead sea turtles are captured in shrimp trawl fisheries each year in the Gulf of Mexico, with 3,948 of those sea turtles dying as a result of their capture. Each year, several hundred loggerhead sea turtles are also captured in herring fisheries; mackerel, squid, and butterfish fisheries; monkfish fisheries; pound net fisheries, summer flounder and scup fisheries; Atlantic pelagic longline fisheries; and gillnet fisheries in Pamlico Sound. Although most of these turtles are released alive, these fisheries are combine to capture about 2,000 loggehead sea turtles each year, killing almost 700; the health effects of being captured on the sea turtles that survive remain unknown.

In the pelagic environment, loggerhead sea turtles are exposed to a series of longline fisheries that include the U.S. Atlantic tuna and swordfish longline fisheries, an Azorean longline fleet, a Spanish longline fleet, and various fleets in the Mediterranean Sea (Aguilar *et al.* 1995, Bolten *et al.* 1994, Crouse 1999). In the benthic environment in waters off the coastal U.S., loggerheads are exposed to a suite of fisheries in federal and state waters including trawl, purse seine, hook and line, gillnet, pound net, longline, dredge, and trap fisheries.

Like all of the other sea turtles we have discussed, loggerhead sea turtles are threatened by domestic or domesticated animals that prey on their nests; artificial lighting that disorients adult female and hatchling sea turtles, which can dramatically increase the mortality rates of hatchling sea turtles; beach replenishment; ingestion and entanglement in marine debris; and environmental contaminants.

Status

The most recent reviews show that only two loggerhead nesting beaches have greater than 10,000 females nesting per year: South Florida (U.S.) and Masirah Island (Oman). The status of the Oman nesting colony has not been evaluated recently so the current size of this population and its trend are unknown. Nesting colonies in the U.S. have been reported to produce 68,000 to 90,000 nests per year. Recent analyses of nesting data from southeast Florida nesting colonies, which are the largest nesting colonies in the western Atlantic Ocean, suggest that this nesting population is declining. Long-term nesting data suggest similar declines in loggerhead nesting in North Carolina, South Carolina, and Georgia.

In the Eastern Atlantic, the Cape Verde Islands support an intermediately-sized loggerhead nesting colony. In 2000, researchers tagged over 1,000 nesting females on just 5 km (3.1 mi) of beach on Boavista Island (Ehrhart *et al.* 2003). In the Western Atlantic (excluding the U.S.), Brazil supports an intermediately-sized loggerhead nesting assemblage. Published and unpublished reports provide an estimate of about 4,000 nests per year in Brazil (Ehrhart *et al.* 2003). Loggerhead nesting throughout the Caribbean is sparse.

In the Mediterranean, loggerhead nesting is confined almost exclusively to the eastern portion of the Mediterranean Sea. The main nesting assemblages occur in Cyprus, Greece, and Turkey. However, small numbers of loggerhead nests have been recorded in Egypt, Israel, Italy, Libya, Syria, and Tunisia. Based on the recorded number of nests per year in Cyprus, Greece, Israel, Tunisia, and Turkey, loggerhead nesting in the Mediterranean ranges from about 3,300 to 7,000 nests per season (Margaritoulis *et al.* 2003). Loggerheads nest throughout the Indian Ocean and, with the exception of Oman, the number of nesting females is small. Most trends in loggerhead nesting populations in the Indian Ocean are unknown.

Loggerhead populations in Honduras, Mexico, Colombia, Israel, Turkey, Bahamas, Cuba, Greece, Japan, and Panama have been declining. Balazs and Wetherall (1991) speculated that 2,000 to 3,000 female loggerheads may nest annually in all of Japan; however, more recent data suggest that only approximately 1,000 female loggerhead turtles may nest there (Bolten *et al.* 1996; Sea Turtle Association of Japan 2002). Monitoring of nesting beaches at Gamoda (Tokushima Prefecture) has been ongoing since 1954. Surveys at this site showed a marked decline in the number of nests between 1960 and the mid-1970s. Since then, the number of nests has fluctuated, but has been downward since 1985 (Bolten *et al.* 1996; Sea Turtle Association of Japan 2002). Monitoring on several other nesting beaches, surveyed since the mid-1970s, revealed increased nesting during the 1980s before declining during the early 1990s. The number of nests at Gamoda remains very small, fluctuating between near zero (1999) to about 50 nests (1996 and 1998; Kamezaki *et al.* 2003).

Scattered nesting has also been reported on Papua New Guinea, New Zealand, Indonesia, and New Caledonia; however, population sizes on these islands have not been ascertained. Survey data are not available for other nesting assemblages in the south Pacific (NMFS and USFWS 1998). In addition, loggerheads are not commonly found in U.S. Pacific waters, and there have been no documented strandings of loggerheads off the Hawai'ian Islands in nearly 20 years (1982-1999 stranding data, G. Balazs, NMFS, personal communication, 2000). There are very few records of loggerheads nesting on any of the many islands of the central Pacific, and the species is considered rare or vagrant on islands in this region (NMFS and USFWS 1998).

For several years, NMFS' biological opinions have established that most loggerhead sea turtles populations face high probabilities of extinction as a result of both environmental and demographic stochasticity. Demographic stochasticity, which is chance variation in the birth or death of an individual of the population, is facilitated by the increases in mortality rates of loggerhead populations resulting from the premature deaths of individual sea turtles associated with human activities (either removal of eggs or adult females that are killed on nesting beaches or that die as a result of being captured in fisheries) or incidental capture and mortality of individuals in various fisheries.

The information available suggests that loggerhead sea turtles have high probabilities of becoming extinct in the Pacific Ocean unless they are protected from the combined threats of entanglements in fishing gear, overharvests,

and loss of their nesting habitat. The limited data available suggests that nesting aggregations of loggerhead sea turtles in the Pacific Ocean exist at sizes small enough to be classified as "small" populations (that is, populations that exhibit population dynamics that increase the extinction probabilities of the species or several of its populations) as evidenced by biases in the male to female ratios in the Pacific. These small sizes would increase the extinction probability of these nesting aggregations.

The status of loggerhead sea turtles in the Atlantic Ocean remains uncertain and controversial. For years, the south Florida nesting aggregation, which is the only major nesting aggregation in the western Atlantic Ocean, had been assumed to be stable or increasing. However, more recent data demonstrate that this nesting population is currently declining and probably has been declining for several years. Between 1998 and 2007, nest counts of loggerhead sea turtles in the State of Florida have declined by almost 50 percent to the lowest levels in the 19 years of Florida's monitoring program (Fish and Wildlife Research Institute 2007). Given that (1) the nesting aggregations that account for almost 90 percent of loggerhead nesting in the western Atlantic Ocean are declining, (2) the other nesting aggregations in the western Atlantic Ocean are substantially much smaller, and (3) large numbers of sea turtles from these smaller populations are captured or killed in commercial and other fisheries in the United States each year, we suspect that the extinction probabilities of loggerhead sea turtle populations in the Atlantic Ocean are only slightly lower than those of populations in the Pacific Ocean. The principle difference between the Atlantic and the Pacific may be this: loggerhead sea turtle populations in the Atlantic Ocean may currently be large enough to avoid the small population dynamics we have discussed previously, but the intensity of the anthropogenic pressure on their populations (in the form of numbers captured and killed in fisheries alone) appear to be large enough to accelerate the extinction probabilities of these populations.

Diving and Social Behavior

Studies of loggerhead diving behavior indicate varying mean depths and surface intervals, depending on whether they were located in shallow coastal areas (short surface intervals) or in deeper, offshore areas (longer surface intervals). The maximum recorded dive depth for a post-nesting female was 211-233 meters, while mean dive depths for both a post-nesting female and a subadult were 9-22 meters. Routine dive times for a post-nesting female were between 15 and 30 minutes, and for a subadult, between 19 and 30 minutes (Sakamoto *et al.* 1990 *cited in* Lutcavage and Lutz 1997). Two loggerheads tagged by Hawai'i-based longline observers in the North Pacific and attached with satellite-linked dive recorders were tracked for about 5 months. Analysis of the dive data indicate that most of the dives were very shallow - 70% of the dives were no deeper than 5 meters. In addition, the loggerheads spent approximately 40% of their time in the top meter and nearly all of their time at depths shallower than 100 meters. On 5% of the days, the turtles dove deeper than 100 meters; the deepest daily dive recorded was 178 meters (Polovina *et al.* 2003).

Polovina *et al.* (2004) reported that tagged turtles spent 40 percent of their time at the surface and 90 percent of their time at depths shallower than 40 meters. On only five percent of recorded dive days loggerheads dove to depths greater than 100 meters at least once. In the areas that the loggerheads were diving, there was a shallow thermocline at 50 meters. There were also several strong surface temperature fronts the turtles were associated with, one of 20°C at 28°N latitude and another of 17°C at 32°N latitude.

Vocalizations and Hearing

The information on loggerhead turtle hearing is very limited. Bartol *et al.* (1999) studied the auditory evoked potential of loggerhead sea turtles that had been captured in pound nets in tributaries to the Chesapeake Bay in Maryland and Virginia and concluded that loggerhead sea turtles had most sensitive hearing between 250 and 1000 Hz, with rapid decline above 1000 Hz (Bartol *et al.* 1999). This is similar to the results produced by Ridgway *et al.* (1969) who studied the auditory evoked potentials of three green sea turtles (in air and through mechanical stimulation of the ear). They concluded that the maximum sensitivity of green sea turtles occurred from 300 to 400 Hz with rapid declines for tones at lower and higher frequencies. They reported an upper limit for cochlear potentials without injury of 2000 Hz and a practical limit of about 1000 Hz.

These hearing sensitivities are similar to the hearing sensitivities reported for two terrestrial species: pond turtles (*Pseudemys scripta*) and wood turtles (*Chrysemys inscuplta*). Pond turtles are reported to have best hearing responsiveness between 200 and 700 Hz, with slow declines below 100 Hz and rapid declines above 700 Hz and almost no sensitivity above 3000 Hz (Wever and Vernon 1956) the latter has sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Peterson 1966).

Olive ridley Sea Turtle

Distribution

Olive ridley turtles occur in the tropical waters of the Pacific and Indian Oceans from Micronesia, Japan, India, and Arabia south to northern Australia and southern Africa. In the Atlantic Ocean, they occur off the western coast of Africa and the coasts of northern Brazil, French Guiana, Surinam, Guyana, and Venezuela in South America, and occasionally in the Caribbean Sea as far north as Puerto Rico. In the eastern Pacific Ocean, Olive ridley turtles are found from the Galapagos Islands north to California. While Olive ridley turtles have a generally tropical to subtropical range, individual turtles have been reported as far as the Gulf of Alaska (Hodge and Wing, 2000).

Olive ridley turtles nest along continental margins and oceanic islands. The largest nesting aggregation in the world occurs in the Indian Ocean along the northeast coast of India where more than 600,000 Olive ridley turtles nested in a single week in 1991 (Mrosovsky 1993). The second most important nesting area occurs in the eastern Pacific along the west coast of Mexico and Central America. Olive ridley turtles also nest along the Atlantic coast of South America, western Africa, and the western Pacific (Sternberg 1981, Groombridge 1982).

In the eastern Pacific, Olive ridley turtles nest along the Mexico and Central American coast, with large nesting aggregations occurring at a few select beaches located in Mexico and Costa Rica. Few turtles nest as far north as southern Baja California, Mexico (Fritts *et al*. 1982) or as far south as Peru (Brown and Brown 1982). The post-nesting migration routes of Olive ridleys traversed thousands of kilometers of deep oceanic waters, ranging from Mexico to Peru, and more than 3,000 kilometers out into the central Pacific (Plotkin, *et al*. 1993). Although they are the most abundant north Pacific sea turtle, surprisingly little is known of the oceanic distribution and critical foraging areas of Olive ridley turtles.

Most records of Olive ridley turtles are from protected, relative shallow marine waters. Deraniyagalia (1939) described the habitat of Olive ridley turtles as shallow waters between reefs and shore, larger bays, and lagoons.

Nevertheless, Olive ridley turtles have also been observed in the open ocean. Since, Olive ridley turtles throughout the eastern Pacific Ocean depend on rich upwelling areas off South America for food, Olive ridley turtles sighted offshore may have been foraging..

Population Structure

Olive ridley sea turtles exist as two separate populations: one that occurs in the western Pacific and Indian Ocean (northern Australia, Malaysia, Thailand, and the State of Orissa in India) and another than occurs along the Pacific coast of the Americas from Mexico to Columbia (Chaloupka *et al*. 2004).

Threats to the Species

NATURAL THREATS. The various habitat types Olive ridley sea turtles occupy throughout their lives exposes these sea turtles to a wide variety of natural threats. The beaches on which Olive ridley sea turtles nest and the nests themselves are threatened by hurricanes and tropical storms as well as the storm surges, sand accretion, and rainfall that are associated with hurricanes. Hatchlings are hunted by predators like herons, gulls, dogfish, and sharks. Adult Olive ridley sea turtles are also killed by sharks and other large, marine predators.

ANTHROPOGENIC THREATS. In India, uncontrolled mechanized fishing in areas of high sea turtle concentration, primarily illegally operated trawl fisheries, has resulted in large scale mortality of adult Olive ridley turtles during the last two decades. Since 1993, more than 50,000 Olive ridleys have stranded along the coast, at least partially because of near-shore shrimp fishing (Shanker and Mohanty 1999). Fishing in coastal waters off Gahirmatha was restricted in 1993 and completely banned in 1997 with the formation of a marine sanctuary around the rookery. However, mortality due to shrimp trawling reached a record high of 13,575 ridleys during the 1997-1998 season and none of the approximately 3,000 trawlers operating off the Orissa coast use turtle excluder devices in their nets despite mandatory requirements passed in 1997 (Pandav and Choudhury 1999).

Historically, an estimated 10 million Olive ridleys inhabited the waters in the eastern Pacific off Mexico (Cliffton *et al*. 1982 in NMFS and USFWS 1998). However, human-induced mortality caused this population to decline. From the 1960s to the 1970s, several million adult Olive ridleys were harvested by Mexico for commercial trade with Europe and Japan. (NMFS and USFWS 1998). Although Olive ridley meat is palatable, it was not widely sought after; its eggs, however, are considered a delicacy. Fisheries for Olive ridley turtles were also established in Ecuador during the 1960s and 1970s to supply Europe with leather. (Green and Ortiz-Crespo 1982).

The nationwide ban on commercial harvest of sea turtles in Mexico, enacted in 1990, has improved the situation for the Olive ridley. Surveys of important Olive ridley nesting beaches in Mexico indicate increasing numbers of nesting females in recent years (Marquez *et al*. 1995; Arenas *et al*. 2000). Annual nesting at the principal beach, Escobilla Beach, Oaxaca, Mexico, averaged 138,000 nests prior to the ban, and since the ban on harvest in 1990, annual nesting has increased to an average of 525,000 nests (Salazar *et al*. in press). At a smaller Olive ridley nesting beach in central Mexico, Playon de Mismalayo, nest and egg protection efforts have resulted in more hatchlings, but the population is still seriously decremented and is threatened with extinction (Silva-Batiz *et al*. 1996). Nevertheless some authors have suggested that Olive ridley turtles in Mexico should be considered recovered (Arenas *et al*. 2000).

The main threats to turtles in Thailand include egg poaching, harvest and subsequent consumption or trade of adults or their parts (i.e. carapace), indirect capture in fishing gear, and loss of nesting beaches through development (Aureggi *et al*. 1999). During the 1996-97 survey, only six Olive ridley nests were recorded, and of these, half were poached, and one was predated by feral dogs. During the 1997-98 survey, only three nests were recorded.

Olive ridley nests in Indonesia are subject to extensive hunting and egg collection. In combination with rapid rural and urban development, these activities have reduced the size of the nesting population in the region as well as their nesting success.

Status of the Species

Olive ridley turtle populations on the Pacific coast of Mexico are listed as endangered under the ESA; all other populations are listed as threatened. The International Union for Conservation of Nature and Natural Resources has classified the Kemp's ridley turtle as "endangered" (IUCN Red List 2000).

Where population densities are high enough, nesting takes place in synchronized aggregations known as arribadas. The largest known arribadas in the eastern Pacific are off the coast of Costa Rica (~475,000 - 650,000 females estimated nesting annually) and in southern Mexico (~800,000 nests per year at La Escobilla, in Oaxaca, Mexico (Millá án 2000)). In Costa Rica, 25,000 to 50,000 Olive ridleys nest at Playa Nancite and 450,000 to 600,000 turtles nest at Playa Ostional each year (NMFS and USFWS 1998d). In an 11-year review of the nesting at Playa Ostional, (Ballestero *et al*. 2000) report that the data on numbers of nests deposited is too limited for a statistically valid determination of a trend; although the number of nesting turtles has appeared to decline over a six-year period.

At a nesting site in Costa Rica, an estimated 0.2 percent of 11.5 million eggs laid during a single arribada produced hatchlings (in NMFS and USFWS 1998d). In addition, some female Olive ridleys nesting in Costa Rica have been found afflicted with the fibropapilloma disease (Aguirre, *et al*. 1999). At Playa La Flor, the second most important nesting beach for Olive ridleys on Nicaragua, Ruiz (1994) documented 6 arribadas (defined as 50 or more females resting simultaneously). The main egg predators were domestic dogs and vultures (*Coragyps atratus* and *Cathartes aura*).

In the western Pacific, information on the size of Olive ridley nesting aggregations are limited although they do not appear to be recovering (with the exception of the nesting aggregation at Orissa, India). There are a few sightings of Olive ridleys from Japan, but no report of egg-laying. Similarly, there are no nesting records from China, Korea, the Philippines, Taiwan, Viet Nam, or Kampuchea and nesting records in Indonesia are not sufficient to assess population trends (Eckert 1993, Suwelo 1999). In Thailand, Olive ridleys occur along the southwest coast, on the Surin and Similan islands, and in the Andaman Sea. On Phra Thong Island, on the west coast of Thailand, the number of nesting turtles have declined markedly from 1979 to 1990.

Olive ridley turtles have been observed in Indonesia and surrounding waters, and some Olive ridley turtles have been documented as nesting in this region recently. On Jamursba-Medi beach, on the northern coast of Irian Jaya, 77 Olive ridley nests were documented from May to October, 1999 (Teguh 2000 in Putrawidjaja 2000).

Olive ridley turtles nest on the eastern and western coasts of peninsular Malaysia; however, nesting has declined rapidly in the past decade. The highest density of nesting was reported to be in Terengganu, Malaysia, and at one time yielded 240,000 eggs (2,400 nests, with approximately 100 eggs per nest; see Siow and Moll 1982, in Eckert 1993), while only 187 nests were reported from the area in 1990 (Eckert 1993). In eastern Malaysia, Olive ridleys nest very rarely in Sabah and only a few records are available from Sarak (in Eckert 1993).

Olive ridleys are the most common species found along the east coast of India, migrating every winter to nest en-masse at three major rookeries in the state of Orissa, Gahirmatha, Robert Island, and Rushikulya (Pandav and Choudhury 1999). According to Pandav and Choudhury (1999), the number of nesting females at Gahirmatha has declined in recent years, although after three years of low nestings, the 1998-1999 season showed an increasing trend (Noronha *Environmental News Service*, April 14, 1999), and the 1999-2000 season had the largest recorded number of Olive ridleys nesting in 15 years (*The Hindu*, March 27, 2000; *The Times of India*, November 15, 2000). During the 1996-1997 and 1997-98 seasons, there were no mass nestings of Olive ridleys. During the 1998-1999 nesting season, around 230,000 females nested during the first arribada, lasting approximately a week (Pandav and Kar 2000); unfortunately, 80% of the eggs were lost due to inundation and erosion (B. Pandav, personal communication, in Shanker and Mohanty 1999). During 1999-2000, over 700,000 Olive ridleys nested at Nasi islands and Babubali island, in the Gahirmatha coast.

Diving and Social Behavior

Although Olive ridley turtles are probably surface feeders, they have been caught in trawls at depths of 80-110 meters (NMFS and USFWS 1998), and a post-nesting female reportedly dove to a maximum depth of 290 meters. The average dive length for an adult female and adult male is reported to be 54.3 and 28.5 minutes, respectively (Plotkin 1994, in Lutcavage and Lutz 1997).

Vocalizations and Hearing

There is no information on Olive ridley sea turtle vocalizations or hearing. However, we assume that their hearing sensitivities will be similar to those of green and loggerhead sea turtle: their best hearing sensitivity will be in the low frequency range: from 200 to 400 Hz with rapid declines for tones at lower and higher frequencies. Their hearing will probably have a practical upper limit of about 1000 Hz (Bartol *et al*. 1999, Ridgway *et al*. 1969).

These hearing sensitivities are similar to the hearing sensitivities reported for two terrestrial species: pond turtles (*Pseudemys scripta*) and wood turtles (*Chrysemys inscuplta*). Pond turtles are reported to have best hearing responsiveness between 200 and 700 Hz, with slow declines below 100 Hz and rapid declines above 700 Hz and almost no sensitivity above 3000 Hz (Wever and Vernon 1956) the latter has sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Peterson 1966).

4.0 Environmental Baseline

By regulation, environmental baselines for biological opinions include the past and present impacts of all state, Federal or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR 402.02). The environmental baseline for this biological opinion includes the effects of several activities that affect the survival and recovery of endangered whales in the action area.

A number of human activities have contributed to the current status of populations of large whales in the action area. Some of those activities, most notably commercial whaling, occurred extensively in the past, ended, and no longer appear to affect these whale populations, although the effects of these reductions likely persist today. Other human activities are ongoing and appear to continue to affect whale populations. The following discussion summarizes the principal phenomena that are known to affect the likelihood that these endangered whales will survive and recover in the wild.

Natural Mortality

Natural mortality rates in cetaceans, especially large whale species, are largely unknown. Although cannot identify the specific natural phenomena that result in the death of endangered and threatened species in the action area, we assume those phenomena include parasites, predation, red tide toxins and ice entrapment. For example, the giant spirurid nematode (*Crassicauda boopis*) has been attributed to congestive kidney failure and death in some large whale species (Lambertson *et al.* 1986). A well-documented observation of killer whales attacking a blue whale off Baja, California, demonstrates that blue whales are at least occasionally vulnerable to these predators (Tarpy 1979). Evidence of ice entrapment and predation by killer whales has been documented in almost every population of bowhead whales although the percentage of whales entrapped in ice is considered to be small in this strongly ice-associated species (Tomilin 1957; Mitchell and Reeves 1982; Nerini *et al.* 1984; Philo *et al.* 1993). Other stochastic events, such as fluctuations in weather and ocean temperature affecting prey availability, may also contribute to large whale natural mortality. Whales also appear to strand from natural (as compared with anthropogenic) causes.

Human-Induced Mortality

Commercial Whaling and Subsistence Hunting

Large whale population numbers in the proposed action areas have historically been impacted by commercial exploitation, mainly in the form of whaling. Prior to current prohibitions on whaling, such as the International Whaling Commission's 1966 moratorium, most large whale species had been depleted to the extent it was necessary

to list them as endangered under the ESA of 1966. For example, from 1900 to 1965 nearly 30,000 humpback whales were taken in the Pacific Ocean with an unknown number of additional animals taken prior to 1900 (Perry *et al.* 1999). Sei whales are estimated to have been reduced to 20% (8,600 out of 42,000) of their pre-whaling abundance in the North Pacific (Tillman 1977). In addition, 9,500 blue whales were reported killed by commercial whalers in the North Pacific between 1910-1965 (Ohsumi and Wada 1972); 46,000 fin whales between 1947-1987 (Rice 1984); and 25,800 sperm whales (Barlow *et al* 1997). North Pacific right whales once numbered 11,000 animals but commercial whaling has now reduced their population to 29-100 animals (Wada 1973). Although commercial whaling no longer targets the large, endangered whales in the proposed action areas, historical whaling may have altered the age structure and social cohesion of these species in ways that continue to influence them.

Entrapment and Entanglement in Commercial Fishing Gear

Entrapment and entanglement in commercial fishing gear is one of the most frequently documented sources of human-caused mortality in large whale species. For example, an estimated 78 rorquals were killed annually in the offshore southern California drift gillnet fishery during the 1980s (Heyning and Lewis 1990). From 1996-2000, 22 humpback whales of the Central North Pacific population were found entangled in fishing gear (Angliss *et al.* 2002). From 1998 to 2005, five fin whales, 12 humpback whales, and 6 sperm whales were either seriously injured or killed in fisheries off the mainland west coast of the U.S. (California Marine Mammal Stranding Network Database 2006). To date, there are no reports of sei whales having been killed in interactions with any eastern North Pacific fisheries, although the absence of reports does not mean that no sei whales have interacted with fisheries or died as a result of any interactions.

Several fisheries in the action area capture and kill sea turtles. In a biological opinion on the California-Oregon draft gillnet fisheries that NMFS issued on 30 September 1997, NMFS concluded that this fishery would capture 30 leatherback sea turtles and 18 loggerhead turtles each year. Of these, NMFS concluded that 19 leatherback sea turtles and three loggerhead sea turtles would die each year as a result of their capture. In an 8 December 1999 biological opinion on the Eastern Tropical Pacific U.S. tuna purse seine fishery on listed species, NMFS concluded that 35 green sea turtles and 133 olive ridley sea turtles would be captured each year in this fishery between 2000 and 2010; two leatherback sea turtles would be captured roughly every ten years; three loggerhead sea turtles would be captured every seven years (NMFS 1999). Ses turtles are also captured and killed in the California set gillnet fisheries for halibut and angel shark and the California-based longline fisheries.

Ship Strikes

Collisions with commercial ships are an increasing threat to many large whale species, particularly as shipping lanes cross important large whale breeding and feeding habitats or migratory routes. We struggle to estimate the number of whales that are killed or seriously injured in ship strikes within the U.S. Exclusive Economic Zone and have virtually no information on interactions between ships and commercial vessels outside of U.S. waters in the North Pacific Ocean. With the information available, we know those interactions occur but we cannot estimate their significance to the different species of whales in the Southern California Range Complex.

Habitat Degradation

Chronic exposure to the neurotoxins associated with paralytic shellfish poisoning from zooplankton prey has been shown to have detrimental effects on marine mammals. Estimated ingestion rates are sufficiently high to suggest that the PSP toxins are affecting marine mammals, possibly resulting in lower respiratory function, changes in feeding behavior and a lower reproduction fitness (Durbin *et al.* 2002). Other human activities, including discharges from wastewater systems, dredging, ocean dumping and disposal, aquaculture and additional impacts from coastal development are also known to impact marine mammals and their habitat. In the North Pacific, undersea exploitation and development of mineral deposits, as well as dredging of major shipping channels pose a continued threat to the coastal habitat of right whales. Point-source pollutants from coastal runoff, offshore mineral and gravel mining, at-sea disposal of dredged materials and sewage effluent, potential oil spills, as well as substantial commercial vessel traffic, and the impact of trawling and other fishing gear on the ocean floor are continued threats to marine mammals in the proposed action area.

The impacts from these activities are difficult to measure. However, some researchers have correlated contaminant exposure to possible adverse health effects in marine mammals. Studies of captive harbor seals have demonstrated a link between exposure to organochlorines (*e.g.*, DDT, PCB, and polyaromatic hydrocarbons) and immunosuppression (Ross *et al.* 1995, Harder *et al.* 1992, De Swart *et al.* 1996). Organochlorines are chemicals that tend to bioaccumulate through the food chain, thereby increasing the potential of indirect exposure to a marine mammal via its food source. During pregnancy and nursing, some of these contaminants can be passed from the mother to developing offspring. Contaminants like 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).

Anthropogenic Noise. The marine mammals that occur in the action area are regularly exposed to several sources of natural and anthropogenic sounds. Anthropogenic noises that could affect ambient noise arise from the following general types of activities in and near the sea, any combination of which can contribute to the total noise at any one place and time. These noises include transportation, dredging, construction; oil, gas, and mineral exploration in offshore areas; geophysical (seismic) surveys; sonars; explosions; and ocean research activities (Richardson *et al.* 1995).

Noise in the marine environment has received a lot of attention in recent years and is likely to continue to receive attention in the foreseeable future. Several investigators have argued that anthropogenic sources of noise have increased ambient noise levels in the ocean over the last 50 years (Jasny *et al.* 2005; NRC 1994, 1996, 2000, 2003, 2005; Richardson *et al.* 1995). Much of this increase is due to increased shipping as ships become more numerous and of larger tonnage (NRC 2003). Commercial fishing vessels, cruise ships, transport boats, airplanes, helicopters and recreational boats all contribute sound into the ocean (NRC 2003). The military uses sound to test the construction of new vessels as well as for naval operations. In some areas where oil and gas production takes place, noise originates from the drilling and production platforms, tankers, vessel and aircraft support, seismic surveys, and the explosive removal of platforms (NRC 2003). Many researchers have described behavioral responses of marine mammals to the sounds produced by helicopters and fixed-wing aircraft, boats and ships, as well as dredging, construction, geological explorations, etc. (Richardson *et al.* 1995). Most observations have been limited to short-

term behavioral responses, which included cessation of feeding, resting, or social interactions. Several studies have demonstrated short-term effects of disturbance on humpback whale behavior (Baker *et al.* 1983, Bauer and Herman 1986, Hall 1982, Krieger and Wing 1984), but the long-term effects, if any, are unclear or not detectable. Carretta *et al.* (2001) and Jasny *et al.* (2005) identified the increasing levels of anthropogenic noise as a habitat concern for whales and other cetaceans because of its potential effect on their ability to communicate.

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans (Simmonds and Hutchinson 1996). 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 at sea at any one time (U.S. Navy 2001). The radiated noise spectrum of merchant ships ranges from 20 to 500 Hz and peaks at approximately 60 Hz. Ross (1976) has estimated that between 1950 and 1975 shipping had caused a rise in ambient ocean noise levels of 10 dB. He predicted that this would increase by another 5 dB by the beginning of the 21st century. NRC (1997) estimated that the background ocean noise level at 100 Hz has been increasing by about 1.5 dB per decade since the advent of propeller-driven ships.

Michel *et al.* (2001) suggested an association between long-term exposure to low frequency sounds from shipping and an increased incidence of marine mammal mortalities caused by collisions with shipping. At lower frequencies, the dominant source of this noise is the cumulative effect of ships that are too far away to be heard individually, but because of their great number, contribute substantially to the average noise background.

US Navy Activities in the Southern California Range Complex. The U.S. Navy has been conducting training and other activities in the Southern California Range Complex for more than 70 years. This training, which includes anti-submarine warfare exercises, anti-air warfare exercises, anti-surface warfare exercises, and amphibious warfare exercises, exists as major training events, coordinated training events, unit-level training, and research, development, test, and evaluation. The U.S. Navy estimates that it currently conducts about 8 major training exercises, seven integrated exercises, and numerous unit-level training and maintenance exercise in the Southern California Range Complex each year. In total, training activities in the Southern California Range Complex produces an estimated 3,010 hours of mid-frequency active sonar each year from several sources (see Table 2-10 of the U.S. Navy's Final EIS for the Southern California Range Complex; U.S. Navy 2008).

Although the U.S. Navy did not estimate the number of times different endangered or threatened species might be exposed to mid-frequency active sonar during these training activities, we would expect about 14,000 instances in which endangered or threatened marine mammals would be exposed to Navy training activities during the cold season and another 3,600 exposure events during the warm season. The largest number of exposure events (about 70 percent or about 9,900 exposure events during the cold season and about 1,891 exposure events during the warm season) would involve blue whales, with 2,100 exposure events involving sperm whales (about 15 percent of the exposure events), and 1,900 exposure events involving fin whales (about 13.7 percent of the exposures)

Of this total number of exposure events involving mid-frequency active sonar, the U.S. Navy estimated that blue whales would experience behavioral harassment in about 480 exposure events each year, fin whales would behavioral harassment in about 135 exposure events, sperm whales would experience behavioral harassment in about 120 exposure events, and Guadalupe fur seals would experience behavioral harassment in about 772 exposure

events. Because blue whales are low-frequency hearing specialists who are not likely to to devote attentional resources to stimuli in this frequency range, so we assume that blue whales that experienced changes in behavior would respond more to vessel traffic or other cues associated with an exercise rather than the active sonar itself.

Further, the U.S. Navy estimated that three blue whales would have been behaviorally harassed each year as a result of being exposed to underwater detonations associated with training activities in the Southern California Range Complex and another two blue whales would have experienced temporary losses in hearing sensitivity as a result of being exposed to those detonations. Two fin whales would have been behaviorally harassed each year as a result of being exposed to underwater detonations associated with training activities in the Southern California Range Complex and another fin whale would have experienced temporary losses in hearing sensitivity as a result of being exposed to those detonations. Two sperm whales would have would have been behaviorally harassed each year as a result of being exposed to underwater detonations associated with training activities in the Southern California Range Complex and another two sperm whales would have experienced temporary losses in hearing sensitivity as a result of being exposed to those detonations. Two Guadalupe fur seals would have would have been behaviorally harassed each year as a result of being exposed to underwater detonations associated with training activities in the Southern California Range Complex and another two fur seals would have experienced temporary losses in hearing sensitivity as a result of being exposed to those detonations.

Shallow Water Ambient Noise. In contrast to deep water, ambient noise levels in shallow waters (i.e., coastal areas, bays, harbors, etc.) are subject to wide variations in level and frequency depending on time and location. The primary sources of noise include distant shipping and industrial activities, wind and waves, and marine animals (Urick 1983). At any given time and place, the ambient noise level is a mixture of these noise types. 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 sound levels tend to be higher than when the bottom is absorptive.

Commercial and Private Marine Mammal Watching

In addition to the federal vessel operations, private and commercial shipping vessels, vessels (both commercial and private) engaged in marine mammal watching also have the potential to impact whales in the proposed action area. A recent study of whale watch activities worldwide has found that the business of viewing whales and dolphins in their natural habitat has grown rapidly over the past decade into a billion dollar ($US) industry involving over 80 countries and territories and over 9 million participants (Hoyt 2001). In 1988, a workshop sponsored by the Center for Marine Conservation and the NMFS was held in Monterey, California to review and evaluate whale watching programs and management needs (CMC and NMFS 1988). That workshop produced several recommendations for addressing potential harassment of marine mammals during wildlife viewing activities that include developing regulations to restrict operating thrill craft near cetaceans, swimming and diving with the animals, and feeding cetaceans in the wild.

Since then, NMFS has promulgated regulations at 50 CFR 224.103 that specifically prohibit: (1) the negligent or intentional operation of an aircraft or vessel, or the doing of any other negligent or intentional act which results in disturbing or molesting a marine mammal; (2) feeding or attempting to feed a marine mammal in the wild; and (3)

approaching humpback whales in Hawai'i and Alaska waters closer than 100 yards (91.4 m). In addition, NMFS launched an education and outreach campaign to provide commercial operators and the general public with responsible marine mammal viewing guidelines which in part state that viewers should: (1) remain at least 50 yards from dolphins, porpoise, seals, sea lions and sea turtles and 100 yards from large whales; (2) limit observation time to 30 minutes; (3) never encircle, chase or entrap animals with boats; (4) place boat engine in neutral if approached by a wild marine mammal; (5) leave the water if approached while swimming; and (6) never feed wild marine mammals. In January 2002, NMFS also published an official policy on human interactions with wild marine mammals which states that: "*NOAA Fisheries cannot support, condone, approve or authorize activities that involve closely approaching, interacting or attempting to interact with whales, dolphins, porpoises, seals or sea lions in the wild. This includes attempting to swim with, pet, touch or elicit a reaction from the animals.*"

Although considered by many to be a non-consumptive use of marine mammals with economic, recreational, educational and scientific benefits, marine mammal watching is not without potential negative impacts. One concern is that animals may become more vulnerable to vessel strikes once they habituate to vessel traffic (Swingle *et al.* 1993; Wiley *et al.* 1995). Another concern is that preferred habitats may be abandoned if disturbance levels are too high.

Several investigators have studied the effects of whale watch vessels on marine mammals (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães *et al.* 2002, Richter *et al.* 2003, Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams *et al.* 2002). The whale's behavioral responses to whale watching vessels depended on the distance of the vessel from the whale, vessel speed, vessel direction, vessel noise, and the number of vessels. The whales' responses changed with these different variables and, in some circumstances, the whales did not respond to the vessels, but in other circumstances, whales changed their vocalizations, surface time, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions.

Scientific Research

Marine mammals have been the subject of field studies for decades. The primary objective of most of these studies has generally been monitoring populations or gathering data for behavioral and ecological studies. Over time, NMFS has issued dozens of permits for various non-lethal forms of "take" of marine mammals in the proposed action area from a variety of activities, including aerial and vessel surveys, photo-identification, remote biopsy sampling, and attachment of scientific instruments.

Table 6 identifies the total number of interactions currently authorized by various permits that NOAA has issued for various studies and research. For example, existing permits authorized different investigators to harass, pursue, shoot, and wound about 400 endangered North Pacific right whales each year for photo-identification and behavioral observation; harass, pursue, and shoot up to 60 of these right whales per year to place tags; harass, pursue, shoot, andwound 15 cows and calves to take biopsy samples; and harass and pursue 2,300 of these whales incidental to other activities. Since the right whale population in the North Pacific has been estimated to consist of between 29 and 100 individuals (less than 30 individual whales have been identified since the 1950s), existing permits allow investigators to harass each of these endangered whales several times for different research purposes.

Existing permits authorize investigators to make close approaches of other endangered whales species for photographic identification, behavioral observations, passive acoustic recording, aerial photogrammetry, and underwater observation.

BLUE WHALES. Existing permits authorize blue whales to be behaviorally harassed (as that term is defined for the purposes of the Marine Mammal Protection Act) in 6,885 instances in the eastern or central Pacific Ocean and harassed during close approaches for biopsy samples in 1,040 instances (with an additional 35 blue whale calves harassed during close approaches for biopsy samples as well).

FIN WHALES. Existing permits authorize fin whales to be behaviorally harassed (as that term is defined for the purposes of the Marine Mammal Protection Act) in 13,745 instances in the eastern or central Pacific Ocean and harassed during close approaches for biopsy samples in 2,025 instances (with an additional 80 fin whale calves harassed during close approaches for biopsy samples as well).

HUMPBACK WHALES. Existing permits authorize humpback whales to be behaviorally harassed (as that term is defined for the purposes of the Marine Mammal Protection Act) in 29,115 instances in the eastern or central Pacific Ocean and harassed during close approaches for biopsy samples in 4,250 instances (with an additional 525 humpback whale calves harassed during close approaches for biopsy samples as well).

SEI WHALES. Existing permits authorize sei whales to be behaviorally harassed (as that term is defined for the purposes of the Marine Mammal Protection Act) in 3,500 instances in the eastern or central Pacific Ocean and harassed during close approaches for biopsy samples in 457 instances (with an additional 8 sei whale calves harassed during close approaches for biopsy samples as well).

SPERM WHALES. Existing permits authorize sperm whales to be behaviorally harassed (as that term is defined for the purposes of the Marine Mammal Protection Act) in 17,750 instances in the eastern or central Pacific Ocean and harassed during close approaches for biopsy samples in 905 instances (with an additional 75 sperm whale calves harassed during close approaches for biopsy samples as well).

The actual number of close approaches does not appear to have closely approximated the number of close approaches authorized by existing permits. Nevertheless, because existing permits authorize the number of close approaches discussed in the preceding paragraphs, nothing prevents the different whale species from being exposed to those levels of close approaches by different investigators each year.

After decades of this research, the consequences of these levels of close approaches on the population ecology of endangered whales remains unknown (Moore and Clarke 2002). This is particularly problematic because so much research occurs in areas that are critical to the population ecology of whales, such as the calving areas in Hawai'i and feeding areas off California and Alaska. Events or activities that disrupt the behavior of animals in these critical areas could have substantial, long-term consequences for their ecology.

The Impact of the Baseline on Listed Resources

Although listed resources are exposed to a wide variety of past and present state, Federal or private actions and other human activities that have already occurred or continue to occur in the action area as well as Federal projects in the action area that have already undergone formal or early section 7 consultation, and State or private actions that are contemporaneous with this consultation, the impact of those activities on the status, trend, or the demographic processes of threatened and endangered species remains largely unknown.

Historically, commercial whaling had occurred in the action area and had caused all of the large whales to decline to the point where the whales faced risks of extinction that were high enough to list them as endangered species. Since the end of commercial whaling, the primary threat to these species has been eliminated. However, all of the whale species have not recovered from those historic declines and scientists cannot determine if those initial declines continue to influence current populations of most large whale species. Species like Pacific right whales have not begun to recover from the effects of commercial whaling on their populations and continue to face very high risks of extinction in the foreseeable future because of their small population sizes (on the order of 50 individuals) and low population growth rates. Relationships between potential stressors in the marine environments and the responses of these species that may keep their populations depressed are unknown.

Recent attention has focused on the emergence of a wide number of anthropogenic sound sources in the Southern California Range Complex and their role as an pollutant in the marine environment. Relationships between specific sound sources, or anthropogenic sound generally, and the responses of marine mammals to those sources are still subject to extensive scientific research and public inquiry but no clear patterns have emerged. In contrast the individual and cumulative impacts of human activities in Southern California have only been subjected to limited levels of scientific investigation. As a result, the potential consequences of these activities on threatened and endangered marine mammals remains uncertain.

Few of the anthropogenic phenomena in the Southern California Range Complex that represent potential risks to endangered whales in those water seem likely to kill whales. Instead, most of these phenomena — close approaches by whale-watching and research vessels, anthropogenic sound sources, pollution, and many fishery interactions — would affect the behavioral, physiological, or social ecology of whales in these waters. The second line of evidence consists of reports that suggest that the response of whales to many of the anthropogenic activities in the Southern California Range Complex are probably short-lived, which suggests that the responses would not be expected to affect the fitness of individual whales. Most of these reports relate to humpback whales during their winter, breeding season; there are very few reports of the behavioral responses of other whales species to human activity in the action area. For example, annual reports from the North Gulf Oceanic Society and two other investigators reported that most whales did not react to approaches by their vessels or only small numbers of whales reacted. That is, in their 1999 report on their research activities, the North Gulf Oceanic Society reported observing signs that whales were "disturbed" in only 3 out of 51 encounters with whales and that the whales' behavioral responses consisted of breaching, slapping tail and pectoral fin, and diving away from research vessels.

Gauthier and Sears (1999), Weinrich *et al.* (1991, 1992), Clapham and Mattila (1993), Clapham *et al.* (1993) concluded that close approaches for biopsy samples or tagging did cause humpback whales to respond or caused them to exhibit "minimal" responses when approaches were "slow and careful." This caveat is important and is

based on studies conducted by Clapham and Mattila (1993) of the reactions of humpback whales to biopsy sampling in breeding areas in the Caribbean Sea. These investigators concluded that the way a vessel approaches a group of whales had a major influence on the whale's response to the approach; particularly cow and calf pairs. Based on their experiments with different approach strategies, they concluded that experienced, trained personnel approaching humpback whales slowly would result in fewer whales exhibiting responses that might indicate stress.

At the same time, several lines of evidence suggest that these human activities might be greater consequences for individual whales (if not for whale populations). Several investigators reported behavioral responses to close approaches that suggest that individual whales might experience stress responses. Baker *et al.* (1983) described two responses of whales to vessels, including: (1) "horizontal avoidance" of vessels 2,000 to 4,000 meters away characterized by faster swimming and fewer long dives; and (2) "vertical avoidance" of vessels from 0 to 2,000 meters away during which whales swam more slowly, but spent more time submerged. Watkins *et al.* (1981) found that both fin and humpback whales appeared to react to vessel approach by increasing swim speed, exhibiting a startled reaction, and moving away from the vessel with strong fluke motions.

Bauer (1986) and Bauer and Herman (1986) studied the potential consequences of vessel disturbance on humpback whales wintering off Hawai'i. They noted changes in respiration, diving, swimming speed, social exchanges, and other behavior correlated with the number, speed, direction, and proximity of vessels. Results were different depending on the social status of the whales being observed (single males when compared with cows and calves), but humpback whales generally tried to avoid vessels when the vessels were 0.5 to 1.0 kilometer from the whale. Smaller pods of whales and pods with calves seemed more responsive to approaching vessels.

Baker *et al.* (1983) and Baker and Herman (1987) summarized the response of humpback whales to vessels in their summering areas and reached conclusions similar to those reached by Bauer and Herman (1986): these stimuli are probably stressful to the humpback whales in the action area, but the consequences of this stress on the individual whales remains unknown. Studies of other baleen whales, specifically bowhead and gray whales document similar patterns of short-term, behavioral disturbance in response to a variety of actual and simulated vessel activity and noise (Richardson et. al, 1985; Malme *et al.* 1983). For example, studies of bowhead whales revealed that these whales oriented themselves in relation to a vessel when the engine was on, and exhibited significant avoidance responses when the vessel's engine was turned on even at distance of approximately 3,000 ft (900 m). Weinrich *et al.* (1992) associated "moderate" and "strong" behavioral responses with alarm reactions and stress responses, respectively.

Jahoda *et al.* (2003) studied the response of 25 fin whales in feeding areas in the Ligurian Sea to close approaches by inflatable vessels and to biopsy samples. They concluded that close vessel approaches caused these whales to stop feeding and swim away from the approaching vessel. The whales also tended to reduce the time they spent at surface and increase their blow rates, suggesting an increase in metabolic rates that might indicate a stress response to the approach. In their study, whales that had been disturbed while feeding remained disturbed for hours after the exposure ended. They recommended keeping vessels more than 200 meters from whales and having approaching vessels move a low speeds to reduce visible reactions in these whales.

Beale and Monaghan (2004) concluded that the significance of disturbance was a function of the distance of humans to the animals, the number of humans making the close approach, and the frequency of the approaches. These results would suggest that the cumulative effects of the various human activities in the action area would be greater than the effects of the individual activity. None of the existing studies examined the potential effects of numerous close approaches on whales or gathered information of levels of stress-related hormones in blood samples that are more definitive indicators of stress (or its absence) in animals.

There is mounting evidence that wild animals respond to human disturbance in the same way that they respond to predators (Beale and Monaghan 2004, Frid 2003, Frid and Dill 2002, Gill *et al.* 2000, Gill and Sutherland 2001, Harrington and Veitch 1992, Lima 1998, Romero 2004). These responses manifest themselves as stress responses (in which an animal perceives human activity as a potential threat and undergoes physiological changes to prepare for a flight or fight response or more serious physiological changes with chronic exposure to stressors), interruptions of essential behavioral or physiological events, alteration of an animal's time budget, or some combinations of these responses (Frid and Dill 2002, Romero 2004, Sapolsky *et al.* 2000, Walker *et al.* 2005). These responses have been associated with abandonment of sites (Sutherland and Crockford 1993), reduced reproductive success (Giese 1996, Mullner *et al.* 2004), and the death of individual animals (Daan *et al.* 1996, Feare 1976, Waunters *et al.* 1997).

The strongest evidence that of the probable impact of the Environmental Baseline on humpback whales consists of the estimated growth rate of the humpback whale population in the North Pacific Ocean. In the 1980s, the size of the North Pacific humpback whale population was estimated to range from 1,407 to 2,100 (Baker 1985; Darling and Morowitz 1986; Baker and Herman 1987). By the mid-1990s, the population was estimated to consist of about 6,000 whales (standard error = 474) in the North Pacific (Calambokidis *et al.* 1997; Cerchio 1998; Mobley *et al.* 1999). The most recent estimate places the current population of humpback whales in the North Pacific Ocean consisted of about 18,300 whales, not counting calves (Calambokidis *et al.* 2008).

The stress regime created by the activities discussed in this *Environmental Baseline* continues to have a serious and adverse impact on leatherback and loggerhead sea turtles. For several years, NMFS' biological opinions have established that the leatherback and loggerhead sea turtles populations in the Pacific Ocean face high probabilities of extinction as a result of both environmental and demographic stochasticity. Demographic stochasticity, or chance variation in the birth or death of an individual of the population, is facilitated by the increases in mortality rates of loggerhead populations resulting from the premature deaths of individual sea turtles associated with human activities (either removal of eggs or adult females that are killed on nesting beaches or that die as a result of being captured in fisheries) or incidental capture and mortality of individuals in various fisheries.

The information available suggests that leatherback and loggerhead sea turtles have high probabilities of becoming extinct in the Pacific Ocean unless they are protected from the combined threats of entanglements in fishing gear, overharvests, and loss of their nesting habitat. The limited data available suggests that leatherback and loggerhead sea turtles in the Pacific Ocean exist at population sizes small enough to be classified as "small" populations (that is, populations that exhibit population dynamics that increase the extinction probabilities of the species or several of its populations) as evidenced by biases in the male to female ratios in the Pacific. The number of individuals of borh

species that continue to be captured and killed in fisheries in the action area contributes to the increased extinction risk of both of these species.

5.0 Effects of the Proposed Action

In *Effects of the Action* sections of Opinions, NMFS presents the results of its assessment of the probable direct and indirect effects of federal actions that the subject of a consultation as well as the direct and indirect effects of interrelated, and interdependent actions on threatened and endangered species and designated critical habitat. As we described in the *Approach to the Assessment* section of this Opinion, we organize our effects' analyses using an stressor identification - exposure – response – risk assessment framework; we conclude this section with an *Integration and Synthesis of Effects* that integrates information we presented in the *Status of the Species* and *Environmental Base* sections of this Opinion with the results of our exposure and response analyses to estimate the probable risks the proposed action poses to endangered and threatened species. Because this Opinion has previously concluded that the proposed action is not likely to adversely affect critical habitat that has been designated for listed species, critical habitat is not considered in the analyses that follow.

Before we begin, we need to address a few definitions. The Endangered Species Act does not define "harassment" nor has NMFS defined this term, pursuant to the ESA, through regulation. However, the Marine Mammal Protection Act of 1972, as amended, defines "harassment" as "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild or has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" [16 U.S.C. 1362(18)(A)]. For military readiness activities, this definition of "harassment" has been amended to mean "any act that disrupts 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" (Public Law 106-136, 2004). The latter portion of these definitions (that is, "...causing disruption of behavioral patterns including... migration, breathing, nursing, breeding, feeding, or sheltering") is almost identical to the U.S. Fish and Wildlife Service's regulatory definition of harass.[3]

For this Opinion, we define "harassment" similarly: "an intentional or unintentional human act or omission that creates the probability of injury to an individual animal by disrupting one or more behavioral patterns that are essential to the animal's life history or its contribution to the population the animal represents." We are particularly concerned about changes in animal behavioral that is likely to result in animals that fail to feed, fail to breed

[3] An intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.4)

successfully, or fail to complete their life history because those changes may have adverse consequences for populations of those species.

5.1 Potential Stressors

There are several potential stressors associated with the proposed U.S. Navy training exercises in the Southern California Range Complex (Table). This listing is not exhaustive; however, it represents the stressors for which some information is available. Further, the stressors on this list are not mutually exclusive because some sources of stressors may produce multiple stressors. For example, surface vessels represent one stressor because of their weight and speed (risk of potential collisions), a second form of stressor because of the sounds associated with their passage (bow wave and engine noise), and a third form of stressor when they engage their active sonar systems; further, these stressors might interact to create a suite of environmental cues that represents a unique environmental stimulus that is different from each individual cue.

The U.S. Navy has conducted training exercises in the Southern California Range Complex (the Action Area) for several decades and these potential stressors have been associated with most, if not all, of those exercises. As a result, it is more accurate to say that the U.S. Navy proposes to continue to conduct training exercises in the Southern California Range Complex and the potential stressors listed in Table 7 would continue to be associated with those exercises.

Table 7. Potential stressors associated with the activities the U.S. Navy proposes to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009

	Potential Stressor	Proposed Activity			
		COMPTUEX/JTFEX	Coordinated Training	Unit-Level Training	RDT&E
1	Surface vessel traffic	X	X	X	X
2	Aircraft traffic	X	X	X	X
3	High-frequency active sonar	X	X	X	X
4	Mid-frequency active sonar	X	X	X	X
5	Pressure waves associated with explosions	X	X	X	X
6	Sound fields produced by explosions	X	X	X	X
7	Transmitted sounds from in-air explosions	X	X	X	X
8	Disturbance associated with human presence on beaches (during amphibious exercises)	X	X	X	-
9	Parachutes released during deployment of sonobuoys	X	X	X	X

This list of potential stressors assumes that the direct and indirect effects of the West Coast Shallow Water Training Range the U.s. Navy plans to establish in the Southern California Range Complex would primarily result from the process of laying cable, including cutting a 300-foot long furrow that is 4 inches (10 cm) wide by up to 36 inches deep using equipment (tracked vehicle or towed plow) would be deployed from a surface vessel. We assume that the U.S. Navy will fulfill its commitment to avoid rocky substrate, which would eliminate the likelihood that this activity would create new or additional potential stressors for endangered or threatened species (the stressors

associated with vessel traffic and active sonar training in this area are considered separately). We also assume that expanding the shallow water minefield by positioning mine shapes that are about 30 to 35 in (76 to 89 cm) in size and spaced about 500 to 700 yds (457 to 640 m) from one another, and are either weighed down with cement or moored to the bottom would not create additional stressors that are not considered elsewhere in this analysis of effects.

What follows is a more detailed description of the stressors listed in Table 7 in greater detail. Following those descriptions, we present the results of our exposure analyses, followed by the results of our response analyses. As outlined in the introductory paragraph of this section, we conclude our effects analyses with an *Integration and Synthesis* that presents the results of our risk analyses.

5.1.1 Surface Vessel Traffic

Most of the activities the U.S. Navy proposes to conduct in the Southern California Range Complex involve some level of activity from surface vessels, submarines, or both. Under the baseline condition, Carrier Strike Groups include one aircraft carrier, one carrier air wing, four strike fighter squadrons, one electronic combat squadron, one airborne early warning squadron, two combat helicopter squadrons, two logistics aircraft, five surface combatant ships (guided missile cruisers, destroyers, and frigates), one attack submarine, and one logistics support ship. Under the baseline condition, Expeditionary Strike Groups include three amphibious ships, landing craft – utility, landing craft - air cushioned, amphibious assault vehicle or expeditionary fighting vehicle, three surface combatant ships, three combat helicopter detachments, one attack submarine, one marine expeditionary unit (Special Operations Capable) of 2,200 Marines, ground combat and combat logistics elements, and composite aviation squadron of fixed-wing aircraft and helicopters. Under the baseline condition, Surface Strike Groups include three surface ships, surface combatants, amphibious ships, one combat helicopter detachment, and one attack submarine. An expeditionary strike force and combine more than one carrier strike group, expeditionary strike group, or surface strike group.

Vessel traffic associated with the proposed training exercises actually represents a suite of stressors or stress regimes that pose several potential hazards to endangered and threatened species in the Southern California Range Complex. First, the size and speed of these surface vessels pose some probability of collisions between marine mammals and sea turtles. Second, this amount of traffic represents an acute or chronic source of disturbance to marine animals in the Southern California Range Complex, although it is not clear what environmental cue marine animals might respond to: the sounds of waters being displaced by the ships, the sounds of the ships' engines, or a combination of environmental cues surface vessels produce while they transit.

Probability of Collisions. Given the speeds at which these vessels are likely to move, they pose potential hazards to marine mammals. The Navy's operational orders for ships (and aircraft) that are underway are designed to prevent collisions between surface vessels participating in naval exercises and endangered whales that might occur in the action area. These measures, which include observers on the bridge of ships, requirements for course and speed adjustments to maintain safe distances from whales, and having any ship that observes whales to alert other ships in the area, have historically been effective measures for avoiding collisions between surface vessels and whales

Although the probability of a collision seem fairly small given the measures that are in place, 20 to 60 additional surface vessels engaged in training maneuvers in the Action Area poses some risk of disturbing large whales that might occur in the Action Area. Particularly when that traffic is placed in the context of animals that are likely to have had extensive prior experience with existing levels of vessel traffic associated with inter-island transportation, commercial ship traffic, whale-watching vessels, leisure cruises, and research vessels that were discussed in the *Environmental Baseline* of this Opinion.

Disturbance. Studies of interactions between surface vessels and marine mammals have demonstrated that surface vessels represent a source of acute and chronic disturbance for marine mammals (Au and Green 1990, Au and Perryman 1982, Bain *et al.* 2006, Bauer 1986, Bejder 1999, 2006a, 2006b; Bryant *et al.* 1984, Corkeron 1995, Erbé 2000, Félix 2001, Goodwin and Cotton 2004, Hewitt 1985, Lemon *et al.* 2006, Lusseau 2003, 2006; Lusseau and Bejder 2007, Magalhães *et al.* 2002, Ng and Leung 2003, Nowacek *et al.* 2001, Richter *et al.* 2003, 2006; Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams and Ashe 2007, Williams *et al.* 2002, 2006a, 2006b; Würsig *et al.* 1998). Specifically, in some circumstances, marine mammals respond to vessels with the same behavioral repertoire and tactics they employ when they encounter predators.

These studies establish that free-ranging cetaceans engage in avoidance behavior when surface vessels move toward them. It is not clear whether these responses are caused by the physical presence of a surface vessel, the underwater noise generated by the vessel, or an interaction between the two (Goodwin and Green 2004; Lusseau 2006). Several, authors, however, suggest that the noise generated by the vessels is probably an important contributing factor to the responses of cetaceans to the vessels (Blane and Jackson 1994, Evans *et al.* 1992, 1994), so we may not be able to treat the effects of vessel traffic as independent of engine and other sounds associated with the vessels.

For surface vessels, the set of variables that help determine whether marine mammals are likely to be disturbed include:

1. *number of vessels*. The behavioral repertoire marine mammals have used to avoid interactions with surface vessels appears to depend on the number of vessels in their perceptual field (the area within which animals detect acoustic, visual, or other cues) and the animal's assessment of the risks associated with those vessels (the primary index of risk is probably vessel proximity relative to the animal's flight initiation distance).

   Below a threshold number of vessels (which probably varies from one species to another, although groups of marine mammals probably shared sets of patterns), studies have shown that whales will attempt to avoid an interaction using horizontal avoidance behavior. Above that threshold, studies have shown that marine mammals will tend to avoid interactions using vertical avoidance behavior, although some marine mammals will combine horizontal avoidance behavior with vertical avoidance behavior (see Response Analyses for further discussion);

2. *the distance between vessel and marine mammals* when the animal perceives that an approach has started and during the course of the interaction;

3. *the vessel's speed and vector*;

4. *the predictability of the vessel's path*. That is, whether the vessel stays on a single path or makes continuous course changes;

6. *noise associated with the vessel* (particularly engine noise) and the rate at which the engine noise increases (which the animal may treat as evidence of the vessel's speed);

7. *the type of vessel* (displacement versus planing), which marine mammals may be interpret as evidence of a vessel's maneuverability.

Because of the number of vessels involved in U.S. Navy training exercises, their speed, their use of course changes as a tactical measure, and sounds associated with their engines and displacement of water along their bowline, the available evidence leads us to expect marine mammals to treat Navy vessels as potential stressors. Further, without considering differences in sound fields associated with any active sonar that is used during these exercises, the available evidence suggests that major training exercises (for example, RIMPAC, USWEX, and Multiple Strike Group exercises), unit- and intermediate-level exercises, and RDT&E activities would represent different stress regimes because of differences in the number of vessels involved, vessel maneuvers, and vessel speeds.

Much of the increase in ambient noise levels in the oceans over the last 50 years has been attributed to increased shipping, primarily due to the increase in the number and tonnage of ships throughout the world, as well as the growth and increasing interconnection of the global economy and trade between distant nations (National Resource Council 2003). Commercial fishing vessels, cruise ships, transport boats, recreational boats, and aircraft, all contribute sound into the ocean (National Resource Council 2003). Military vessels underway or involved in naval operations or exercises, also introduce anthropogenic noise into the marine environment.

Sounds emitted by large vessels can be characterized as low-frequency, continuous, and tonal, and sound pressure levels at a source will vary according to speed, burden, capacity and length (Richardson *et al.* 1995). Vessels ranging from 135 to 337 meters (*Nimitz*-class aircraft carriers, for example, have lengths of about 332 meters) generate peak source sound levels from 169-200 dB between 8 Hz and 430 Hz. Given the sound propagation of low frequency sounds, a large vessel in this sound range can be heard 139-463 kilometers away (Ross 1976 *in* Polefka 2004).

We recognize that Navy vessels almost certainly incorporate quieting technologies that reduce their acoustic signature (relative to the acoustic signature of similarly-sized vessels) in order to reduce their vulnerability to detection by enemy vessels (Southall 2005). Nevertheless, we do not assume that any quieting technology would be sufficient to prevent marine mammals from detecting sounds produced by approaching Navy vessels and perceiving those sounds as predatory stimuli.

5.1.2 Disturbance from Aircraft

Most of the activities the U.S. Navy proposes to conduct in the Southern California Range Complex also involve some level of activity from aircraft that include helicopters, maritime patrols, and fighter jets. Under the proposed alternative, the U.S. Navy plans to conduct about 3,970 air combat maneuvers, 1,690 anti-submarine warfare tracking exercises, and 245 anti-submarine torpedo exercises among other exercises. Low-flying aircraft produce sounds that marine mammals can hear when they occur at or near the ocean's surface. Helicopters generally tend produce sounds that can be heard at or below the ocean's surface more than fixed-wing aircraft of similar size and

larger aircraft tend to be louder than smaller aircraft. Underwater sounds from aircraft are strongest just below the surface and directly under the aircraft. Sounds from aircraft would not have physical effects on marine mammals but represent acoustic stimuli (primarily low-frequency sounds from engines and rotors) that have been reported to affect the behavior of some marine mammals.

Although several studies have demonstrated the potential adverse effects of aircraft on pinnipeds on haul-out sites or rookeries, Richardson *et al.* (1995) reported that there is no evidence that single or occasional aircraft flying above large whales and pinnipeds in-water cause long-term displacement of these mammals. However, several authors have reported that sperm whales do not react to fixed-wing aircraft or helicopters in some circumstances (Clarke 1956, Gambell 1968, Green *et al.* 1992) and react in others (Clarke 1956, Fritts *et al.* 1983, Mullin *et al.* 1991, Patenaude *et al.* 2006, Richter *et al.* 2003, 2006, Smultea *et al.* 2008, Würsig *et al.* 1998).

Although we recognize sounds produced by aircraft as a potential stressor, we do not have sufficient information to estimate the probability of marine animals being exposed to this stressor associated with the training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009 .

5.1.3 High-frequency active sonar

Several of the pingers associated with torpedoes, particularly MK-48 torpedoes, and other ordnance the U.S. Navy plans to use in the Southern California Range Complex each year over the twelve-month period beginning in January 2009 produce high-frequency sounds (see Table 8).

5.1.4 Mid-frequency active sonar

Naval sonars operate on the same basic principle as fish-finders (which are also a kind of sonar): brief pulses of sound, or "pings," are projected into the ocean and an accompanying hydrophone system in the sonar device listens for echoes from targets such as ships, mines or submarines. Several sonar systems are likely to be employed during the activities the U.S. Navy plans to conduct in the Southern California Range Complex, but two systems in particular pose potential risks to listed resources (we should note that other navies that might be involved in the proposed exercises, such as Canada, employ similar active sonar systems as well, but we do not have the information necessary to describe those systems).

The AN/SQS-53 is a large, active-passive, bow-mounted sonar that has been operational since 1975 (see Table 8). AN/SQS-53 is the U.S. Navy's most powerful surface ship sonar and is installed on Ticonderoga (22 units) and Arleigh Burke I/II/IIIa (51 units) class vessels in the U.S. Navy (Polmar 2001, D`Spain *et al.* 2006). This sonar transmits at center frequencies of 2.6 kHz and 3.3 kHz at sources levels up to 235 dB_{RMS} re: 1 μPa at 1 meter. The sonar has pulse durations between 1 and 2 seconds, with about 24-second intervals between pulses. AN/SQS-53 operates at depths of about 7 meters.

The AN/SQS-53 is a computer-controlled, hull-mounted surface-ship sonar that has both active and passive operating capabilities, providing precise information for anti-submarine warfare weapons control and guidance. The system is designed to perform direct-path anti-submarine warfare search, detection, localization, and tracking from a hull-

mounted transducer array. The AN/SQS-53 sonar is installed on Arleigh Burke Class guided missile destroyers and Ticonderoga Class guided missile cruisers. The AN/SQS-53 Kingfisher is a modification that provides a surface ship with the ability to detect detection objects.

Table 8. Description and attributes of sonar sources proposed for use in the Southern California Range Complex

Sonar Source	Depth	Center Freq	Source Level	Emission Spacing	Vertical Directivity	Horizontal Directivity
MK-48	27 m	>10 kHz	classified	144 m	Omni	Omni
AN/SQS-53 (search mode)	7 m	3.5 kHz	235 dB	154 m	Omni	240° Forward-looking
AN/SQS-53 (Kingfisher mode)	7 m	3.5 kHz	235 dB	4.6 m	20° Width 42° D/E	120° Forward-looking
AN/SQS-56	6 m	7.5 kHz	225 dB	154 m	Omni	240° Forward-looking
AN/SSQ-62	27 m	8 kHz	201 dB	450 m	Omni	Omni
AN/AQS-22	27 m	4.1 kHz	217 dB	15 m	Omni	Omni
AN/BQQ-10	7 m	classified	classified	n/a	Omni	Omni
AN/BQQ-15	7 m	>10 kHz	classified	n/a	Omni	Omni
AN/SSQ-125	varies	classified	classified	450 m	Omni	Omni
SLQ-25 NIXIE	varies	classified	classified	n/a	n/a	n/a

The AN/SQS-56 system is a lighter active-passive bow-mounted sonar that has been operational since 1977. AN/SQS-56 is installed on FFG-7 (33 units) class guided missile frigates in the U.S. Navy (Polmar 2001, D`Spain *et al.* 2006). This sonar transmits at center frequencies of 6.8 kHz, 7.5 kHz, and 8.2 kHz. at 225 dB_{RMS} re: 1 μPa at 1 meter source level. This sonar also has pulse durations between 1 and 2 seconds, with about 24-second intervals between pulses. AN/SQS-56 operates at depths of about 6 meters.

The AN/SSQ-62C Directional Command Activated Sonobuoy System (DICASS) sonar system is part of a sonobuoy that operates under direct command of fixed-wing aircraft or helicopters. The system can determine the range and bearing of the target relative to the sonobuoys position and can deploy to various depths within the water column. After it enters the water, the sonobuoy transmits sonar pulses (continuous waveform or linear frequency modulation) upon command from the aircraft. The echoes from the active sonar signal are processed in the buoy and transmitted to the receiving station onboard the launching aircraft.

The duration, rise times, and wave form of sonar transmissions that would be used during Navy training exercise are classified; however, the characteristics of the transmissions that were used during the Bahamas exercises might help illustrate attributes of the transmissions from these two sonar sources. During the Bahamas exercises, these two sonars transmitted 1 – 2 second pulses once every 24 seconds (D'Spain *et al.* 2006). Pulses had rise times of 0.1 – 0.4 seconds and typically consisted of three waveforms with nominal bandwidths up to 100 Hz (D'Spain *et al.* 2006). Both sonar create acoustic fields that are omnidirectional in azimuth, although AN/SQS-53 also can create beams covering 120˚ azimuthal sectors that can be swept from side to side during transits (D'Spain *et al.* 2006). Waveforms of both sonar systems are frequency modulated with continuous waves (D'Spain *et al.* 2006).

Sound Propagation

Near an ocean's surface (roughly the uppermost 150 feet), the sound field will be normally dominated by sound generated by wave action, rain, and other surface activity; that would mask most anthropogenic sounds. Below the surface area of this mixed layer, depth (pressure) dominates the sound speed profile and the sound's speed *increases* with depth. Below the mixed layer, sea temperatures drop rapidly in an area referred to as the thermocline. In this region, temperature dominates the sound speed profile and speed decreases with depth. Finally, beneath the thermocline, the temperature becomes fairly uniform and increasing pressure causes the sound speed profile to increase with depth.

Acoustic waveguides, which include surface ducts as well as the SOFAR (sonar fixing and ranging) channel and deep sound channel of deep waters, focus sound from sources within the waveguide to long ranges. Surface ducts are acoustic waveguides that occur in the uppermost part of the water column when water near the surface are mixed by convection by surface wave activity generated by atmospheric winds. This mixing forms a surface layer with nearly constant temperatures so that sound speeds in the layer increase with depth. If sufficient energy is subsequently reflected downward from the surface, the sound can become "trapped" by a series of repeated upward refractions and downward reflections to create surface ducts or "surface channels". Surface ducts commonly form in the winter because the surface is cooled relative to deeper water; as a result, surface ducts are predictable for certain locations at specific times of the year.

Sound trapped in a surface duct can travel for relatively long distances with its maximum range of propagation dependent on the specifics of the sound speed profile, the frequency of the sound, and the reflective characteristics of the surface. As a general rule, surface duct propagation will increase as the temperature becomes more uniform and depth of the layer increases. For example, a sound's transmission is improved when windy conditions create a well-mixed surface layer or in high-latitude midwinter conditions where the mixed layer extends to several hundred feet deep.

5.1.5 Explosions (including pressure waves and sound field)

The U.S. Navy plans to continue to employ several kinds of explosive ordnance in the Southern California Range Complex (Table 9). Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. At its source, 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 net effective weight of the explosive warhead, the type of explosive material, and the detonation depth. The net explosive weight accounts for the first two parameters. The net explosive weight of an explosive is the weight of only the explosive material in a given round, referenced to the explosive power of 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 of the explosives the Navy uses in the Southern California Range Complex are munitions that detonate essentially upon impact, the effective source

depths are very shallow so 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. To remain consistent with previous models the Navy has used, the Navy used source depths of one foot for gunnery rounds. For missiles and bombs, the Navy used source depths of 2 meters. For MK-48 torpedoes, which detonate immediately below a target's hull, the Navy used nominal depths of 50 feet for their analyses.

The number of endangered or threatened species that might be exposed to explosions associated with this ordnance treat each in-water explosion as an independent event. The cumulative effect of a series of explosives can often be estimated by addition if the detonations are spaced widely in time and space which would provide marine animal's sufficient time to move out of an area affected by an explosion. As a result, the populations of animals that are exposed to in-water explosions are assumed to consist of different animals each time.

Table 9. Explosive ordnance, net weight and depths of detonations of the ordnance (from U.S. Navy 2007, 2008a)

Ordnance	Net Explosive Weight	Detonation Depth
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-84	945 lbs	2 m
MK-48	851 lbs	50 ft
Demolition Charges	20 lbs	Bottom

Underwater Detonations Associated with a SINKEX

The U.S. Navy plans to conduct sinking exercises (SINKEX) as part of major training exercises in the Southern California Range Complex. 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 SINKEXs are ever the same, the *Programmatic SINKEX Overseas Environmental Assessment* (March 2006) for the Western North Atlantic describes a representative case derived from past exercises.

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 may be 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 of maximum exposure.

Because SINKEXs are one of the cases in which simple adding energy associated with individual types of ordnance might not be appropriate, the U.S. Navy used a "representative" sinking exercise as the basis for its modeling. To the degree that an actual SINKEX involves more or less ordnance, those estimates would vary upward or downward.

Table 10. Representative sequence of weapons fired during a Sink Exercise (from U.S. Navy 2007, 2008a)

Time (in hours 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.

5.1.6 Disturbance Associated with Human Presence on Beaches

The U.S. Fish and Wildlife Service has jurisdiction over sea turtles when they are above mean higher high water (generally, when they are on a beach). We assume that any effects of the activities the U.S. Navy proposes on sea turtles using or nesting on beaches in the Southern California Range Complex have been or will be addressed in separate consultations with the U.S. Fish and Wildlife Service.

5.1.7 Parachutes Released During Deployment of Sonobuoys

When AN/SQS-62 DICASS sonobuoys impact the water surface after being deployed from aircraft, their parachute assemblies of sonobuoys are jettisoned and sink away from the sonobuoy, while a float containing an antenna is inflated. The parachutes are made of nylon and are about 8 feet in diameter. At maximum inflation, the canopies are between 0.15 to 0.35 square meters (1.6 to 3.8 squared feet). The shroud lines range from 0.30 to 0.53 meters (12 to 21 inches) in length and are made of either cotton polyester with a 13.6 kilogram (30 pound) breaking strength or nylon with a 45.4 kilogram (100 pound) breaking strength. All parachutes are weighted with a 0.06 kilogram (2 ounce) steel material weight, which would cause the parachute to sink from the surface within about 15 minutes, although actual sinking rates depend on ocean conditions and the shape of the parachute.

The subsurface assembly descends to a selected depth, and the sonobuoy case falls away and sea anchors deploy to stabilize the hydrophone (underwater microphone). The operating life of the seawater battery is eight hours, after which the sonobuoy scuttles itself and sinks to the ocean bottom. For the sonobouys, concentrations of metals released from batteries were calculated to be 0.0011 mg/L lead, 0.000015mg/L copper, and 0.0000001mg/L silver.

5.2 Exposure Analysis

As discussed in the *Approach to the Assessment* section of this opinion, our exposure analyses are designed to determine whether listed resources are likely to co-occur with the direct and indirect beneficial and adverse effects of

actions and the nature of that co-occurrence. In this step of our analyses, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an Action's effects and the populations or subpopulations those individuals represent.

Based on the limited empirical information available, we cannot use that information to estimate the number of endangered or threatened marine animals that might be exposed to the activities the U.S. Navy plans to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009 . Although Navy watchstanders have reported the number of large or small cetaceans they observed during some of the exercises that have been conducted in the Southern California Range Complex in the past, those observations do not identify particular species, only represent individuals that were at the ocean's surface, and only represent those individuals that might have been sighted given the sea surface and visibility conditions when the observations were reported. Because marine animals only spend a portion of their time at the ocean's surface and because the ability to detect marine animals depends on sea states and visibility, the number of marine mammals reported by Navy watchstanders would not correspond to the number of marine animals actually exposed to Navy activities in the Southern California Range Complex. Further, the area encompassed by sound fields produced by activities like active sonar transmissions are so large that it would be almost impossible to identify or estimate the number of different marine species that are actually be exposed to the sound field, the received levels associated with the exposure, or changes in the pattern of exposures over the course of an exercise or test.

As a result, the U.S. Navy, NMFS, and most other entities (for example, oil and gas industries for drilling platforms, geophysics organizations that conduct seismic surveys, etc.) that try to estimate the number of marine animals that might be exposed to active sound sources in the marine environment rely on computer models, simulations, or some kind of mathematical algorithm to estimate the number of animals that might be exposed to a sound source. Like all models, these approaches are based on assumptions and are sensitive to those assumptions.

It is important to note that these simulations tend to over-estimate the number of marine mammals that might be exposed to one or more of the activities the U.S. Navy plans to conduct in the Southern California Range Complex. In most cases, these over-estimates will be substantial and could imply that marine mammals are continuously exposed to U.S. Navy training activities in the Southern California Range Complex. However, most exposures will be periodic or episodic rather than continuous; marine mammals might not be exposed to entire training events that occur in deeper, pelagic waters and may be exposed several times to training events that occur in coastal waters.

At an encounter rate of 0.002 per kilometer, one would expect to sight whales in only 2 kilometers of a 1,000 kilometer transect. At an encounter rate of 0.004 per kilometer, one would expect to sight whales in only 4 kilometers of a 1,000 kilometer transect. At an encounter rate of 0.005 per kilometer, one would expect to sight whales in only 5 kilometers of a 1,000 kilometer transect. During most of the transect lines, whales would not be encountered: during slightly more than 17 hours of survey time, Mobley (2008) made 26 sightings of marine animals in waters between and north of the Islands of Oahu and Molokai. In surveys conducted from a surface vessel in the same region, Smultea *et al.* (2008) encountered eight cetacean groups over a seven-day cruise. Marine mammals and sea turtles would be encountered periodically or episodically, not continuously, although they are certain to be exposed to the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the next

twelve months. Many of the exercises and other activities the U.S. Navy proposes will begin and end without encountering any marine animals.

5.2.1 Exposure to Vessel Traffic

We did not estimate the number of endangered or threatened species that are likely to be exposed to vessel traffic independent of the number of individuals that might be exposed to active sonar associated with those exercises (primarily because the data we would have needed to support those analyses were not available). Nevertheless, we assume that any individuals of the endangered or threatened species that occur in the Action Area during major training exercises (for example, COMPTUEX and JTFEX) are likely to be exposed to visual and acoustic stimuli associated with vessel traffic and related activities. Unit-level training exercises and RDT&E activities involve fewer vessels, have shorter duration, and are much more localized, so fewer endangered and threatened species would be exposed to vessel traffic during these smaller exercises.

5.2.2 Exposure to Aircraft Traffic

We did not estimate the number of endangered or threatened species that are likely to be exposed to aircraft traffic — during take-offs and landings and at altitudes low enough for the sounds of their flight to be salient below the ocean's surface — independent of the number of individuals that might be exposed to active sonar associated with those exercises (primarily because the data we would have needed to support those analyses were not available). Nevertheless, we assume that any individuals of the endangered or threatened species that occur in the Action Area during major training exercises (for example, COMPTUEX and JTFEX) are likely to be exposed to acoustic stimuli associated with aircraft traffic.

Many unit-level training exercises and RDT&E activities do not involve aircraft traffic, involve less traffic when they involve traffic at all, have shorter duration, and affect much more localized areas than major exercises, so fewer endangered and threatened species would be exposed to aircraft traffic during these smaller exercises.

5.2.3 Exposure to Mid-Frequency Active Sonar

The empirical information available does not allow us to empirically estimate the number of marine mammals that might be exposed to mid-frequency active sonar during the activities that are proposed to occur in the Southern California Range Complex that might compare with counts reported by an observer with perfect knowledge of patterns of marine mammal abundance in the Southern California Range Complex.

The narratives that follow present two different approaches to estimating the number of whales that might interact with sound fields associated with mid-frequency active sonar in the Southern California Range Complex: (1) the method the U.S. Navy and NMFS' Permits Division used in their 2008 Environmental Impact Statement on the Southern California Range Complex to estimate the number of marine mammals that might be "taken" (as that term is defined pursuant to the MMPA) during activities the U.S. Navy proposes to conduct in the Southern California Range Complex. The "take" the Permits Division proposes to authorize using the Letters of Authorization would reflect these "take" estimates; and (2) an exposure model NMFS' Endangered Species Division developed using components of an established ecological model (the Hollings' disc equation) to estimate the number of endangered

and threatened marine mammals that are likely to be exposed to active sonar during activities the U.S. Navy proposes to conduct in the Southern California Range Complex (the data necessary to estimate the number of sea turtles that might be exposed to active sonar was not available so we did not develop exposure estimates for these species).

As discussed in the *Approach to the Assessment* section of this Opinion, these two different approaches represent two different kinds of interactions. The approach NMFS' Permits Division and the U.S. Navy used was designed to estimate the number of times marine mammals might be "taken" (as that term is defined pursuant to the MMPA) as a result of their exposure to active sonar or underwater detonations during training activities while the approach we developed for this Opinion is designed to estimate the number of times individual animals are likely to be exposed to active sonar, regardess of whether they are "taken" as a result of that exposure. The results of these approaches will be different because, in most cases, the number of animals "taken" by an action would be a subset of the number of animals that are exposed to the action because (1) in some circumstances, animals might not respond to an exposure and (2) some responses may be adverse for an individual animal without constituting a form of "take" (for example, some physiological stress responses only have fitness consequences when they are sustained and would only constitute a "take" as a result of cumulative exposure). As a result, the estimates produced by those approaches are not comparable to the exposure estimates we produce in this Opinion.

MITIGATION MEASURES TO MINIMIZE THE LIKELIHOOD OF EXPOSURE TO MID-FREQUENCY ACTIVE SONAR. The Navy proposes to implement a suite of mitigation measures to prevent marine mammals from being to mid frequency active sonar at high received levels. As discussed in the *Description of the Proposed Action*, these measures are centered on safety zones that trigger reductions in maximum transmission levels depending on the proximity of one or more marine mammals to surface vessels, helicopters, and submarines that might be transmitting active sonar or preparing to transmit. These measures rely primarily on Navy watchstanders, helicopter pilots, and other Navy assets detecting marine mammals visually so that the Navy can take the appropriate action.

To the degree that the Navy detects marine mammals visually, these safety zones might reduce the number of marine mammals that are exposed to mid-frequency active sonar or the intensity of their exposure. However, the effectiveness of visual monitoring is limited to daylight hours, and its effectiveness declines during poor weather conditions (JNCC 2004). In line transect surveys, the range of effective visual sighting (the distance from the ship's track or the *effective strip width*) varies with an animal's size, group size, reliability of conspicuous behaviors (blows), pattern of surfacing behavior, and positions of the observers (which includes the observer's height above the water surface). For most large baleen whales, effective strip width can be about 3 km (1.6 nm) up through Beaufort 6 (Buckland *et al.* 1993). For harbor porpoises the effective strip width is about 250 m (273 yd), because they are much smaller and less demonstrative on the surface than baleen whales (Palka 1996).

Further, several studies of interactions between seismic surveys and marine mammals and a proposed low-frequency active sonar system and marine mammals concluded that dedicated marine mammal observers were more effective at detecting marine mammals, were more effective at detecting marine mammals at greater distances than Navy watchstanders (watchstanders of the Navies of other countries), were better at identifying the marine mammal to species, and reported a broader range of behaviors than other personnel (Aicken *et al.* 2005; Stone 2000, 2001, 2003). It is not clear, however, how the U.S. Navy's watchstanders and lookouts, who are specifically trained to

identify objects in the water surrounding Navy vessels compare with observers who are specifically trained to detect and identify marine mammals. NMFS is working with the Navy to determine the effectiveness of this component of Navy monitoring program and the degree to which it is likely to minimize the probability of exposing marine mammals to mid-frequency active sonar.

A multi-year study conducted on behalf of the United Kingdom's Ministry of Defense (Aicken *et al.* 2005) concluded that Big Eye binoculars were not helpful. Based on these studies, we would conclude that requiring surface vessels equipped with mid-frequency active sonar to have Big Eye binoculars in good working order is not likely to increase the number of marine mammals detected at distances sufficient to avoid exposing them to received levels that might result in adverse consequences.

The percentage of marine animals Navy personnel would not detect, either because they will pass unseen below the surface or because they will not be seen at or near the ocean surface, is difficult to determine. However, for minke whales, Schweder *et al.* (1992) estimated that visual survey crews did not detect about half of the animals in a strip width. Palka (1996) and Barlow (1988) estimated that visual survey teams did not detect about 25 percent of the harbor porpoises in a strip width. The information available leads us to conclude that the combinations of safey zones triggered by visual observations would still allow most marine mammals and sea turtles to be exposed to md-frequency active sonar transmissions because most marine animals will not be detected at the ocean's surface.

5.2.1.1 U.S. Navy Exposure Estimates for Proposed Actions in the Southern California Range Complex

Over the past year, the U.S. Navy updated the approach it used to estimate the number of marine mammals that might be exposed to the activities the U.S. Navy plans to conduct in the Southern California Range Complex each over the five-year period beginning in January 2009. What follows is a brief summary of the Navy's current approach, for more details, refer to Appendix F of the U.S. Navy's Environmental Impact Statement on the Southern California Range Complex (U.S. Navy 2007 and 2008a).

The U.S. Navy and Permits Division applied an updated approach that focuses on a suite of representative provinces based on sound velocity profiles, bathymetries, and bottom types. Within each of these provinces, the U.S. Navy modeled transmission losses in 5 meter increments and used the results to build sound fields (based on maximum sound pressure levels). The U.S. Navy then calculates an impact volume, which is the volume of water in which an acoustic metric exceeds a specified threshold; in this case, the metric is either energy flux density (in a limited band or across a full band), peak pressure, or positive impulse. By multiplying impact volumes with estimates of animal densities in three dimensions (densities distributed by area and depth), the U.S. Navy estimated the expected number of animals that might be exposed to an acoustic metric (energy flux density, peak pressure, or positive impulse) at levels that exceed specified thresholds. Specifically, the U.S. Navy calculated impact volumes for sonar operations (using energy flux density to estimate the probability of injury), peak pressure, and a Goertner modified positive impulse (for onset of slight lung injury associated with explosions).

To calculate impact volumes, the U.S. Navy used a "risk continuum" (a curve that related the probability of a behavioral response given exposure to a received level that is generally represented by sound pressure level, but included sound exposure level to deal with threshold shifts) that the U.S. Navy and NMFS developed to this area then multiplied that area by a vector that represented the densities of the different species of marine animals that are

expected to occur in the Southern California Range Complex. The risk continuum, which the U.S. Navy adapted from a mathematical model developed by Feller (1968), was estimated using three data sources: data from controlled experiments conducted at the U.S. Navy's Space and Naval Warfare Systems Center in San Diego, California (Finneran *et al.* 2001, 2003, 2005; Finneran and Schlundt 2004; Schlundt *et al.* 2000), data from a reconstruction of an incident in which killer whales were probably exposed to mid-frequency active sonar (Fromm 2004, Department of the Navy 2003), and a suite of studies of the response of baleen whales to low-frequency sound sources (Nowacek *et al.* 2004).

Estimates Produced by this Approach

This approach to estimating the number of endangered and threatened marine mammals that might be "taken" as a result of being exposed to active sonar associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex each year over the five-year period beginning in January 2009 produced the following results:

BLUE WHALES. The model used by the U.S. Navy and Permits Division identified 541 instances in which blue whales might be exposed to received levels that cause them to respond with behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the Marine Mammal Protection Act of 1972). In addition, they identified another 67 instances in which blue whales might accumulate energy sufficient to result in temporary shifts in hearing sensitivity and one blue whale would be expected to accumulate energy sufficient to result in permanent shift in hearing sensitivity.

FIN WHALES. The model used by the U.S. Navy and Permits Division identified 155 instances in which fin whales might be exposed to received levels that cause them to respond with behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the Marine Mammal Protection Act of 1972). In addition, they identified another 12 instances in which fin whales might accumulate energy sufficient to result in temporary shifts in hearing sensitivity. No fin whales would be expected to accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity.

HUMPBACK WHALES. The model used by the U.S. Navy and Permits Division identified 16 instances in which humpback whales might be exposed to received levels that cause them to respond with behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the Marine Mammal Protection Act of 1972). In addition, they identified another 2 instances in which humpback whales might accumulate energy sufficient to result in temporary shifts in hearing sensitivity. No humpback whales would be expected to accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity.

SEI WHALES. The model used by the U.S. Navy and Permits Division estimated identified no instances in which sei whales might be exposed to received levels that cause them to respond with behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the Marine Mammal Protection Act of 1972). and no sei whales would be expected to accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity.

SPERM WHALES. The model used by the U.S. Navy and Permits Division estimated identified 140 instances in which sperm whales might be exposed to received levels that cause them to respond with behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the Marine Mammal Protection Act of 1972). In addition, they identified another 8 instances in which sperm whales might accumulate energy sufficient to result in temporary shifts in hearing sensitivity. No sperm whales would be expected to accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity.

GUADALUPE FUR SEALS. The model used by the U.S. Navy and Permits Division estimated identified 870 instances in which Guadalupe fur seals might be exposed to received levels that cause them to respond with behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the Marine Mammal Protection Act of 1972). In addition, they identified another 190 instances in which these fur seals might accumulate energy sufficient to result in temporary shifts in hearing sensitivity. No Guadalupe fur seals would be expected to accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity.

5.2.1.3 Exposure Estimates Developed for This Opinion

As described in the *Approach to the Assessment* section of this Opinion, the models the U.S. Navy used to estimate the number of marine mammals that might be "taken," as that term is defined by the MMPA, by active sonar and underwater detonations. Our jeopardy analyses, however, must consider all potential effects of proposed actions, including direct or indirect beneficial and adverse effects that do not necessarily rise to the level of "take," as that term is defined by the ESA[4]. For example, jeopardy analyses must consider the direct beneficial or adverse effects of actions on endangered or threatened individuals as well as indirect effects that results from how competitors, prey, symbionts, or the habitat of those listed individuals respond to an action. Therefore, we cannot begin our analyses with estimates of the number of individuals that might be "taken" (as that term is defined by the MMPA) because our analyses must consider direct and indirect effects that do not necessarily represent one or more form of "take."

As discussed in the *Approach to the Assessment* section of this Opinion, we conduct our jeopardy analyses by first identifying the potential stressors associated with an action, then we determine whether endangered species, threatened species, or designated critical habitat are likely to occur in the same space and at the same time as these potential stressors. If we conclude that such co-occurrence is likely, we then try to estimate the nature of that co-occurrence. These two steps represent our *exposure analyses*, which are designed to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an Action's effects and the populations or subpopulations those individuals represent.

For our exposure analyses, NMFS developed a model to estimate the number of times endangered or threatened marine mammals might be exposed to active sonar or underwater detonations from an ecological model that estimates the rate at which a predator encounters prey. Holling (1959) studied predation of small mammals on pine sawflies and found that predation rates increased with increasing densities of prey populations. In that paper, Holling

[4] Section 3 of the Endangered Species Act of 1973, as amended, defines "take" as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 U.S.C 1533).

described a model that is commonly called the "disc equation" because it describes the path of foraging predators as a moving disc that represents the predator's sensory field (normally with two-dimensions) as it searches for prey.

Holling developed the disc equation to describe a predator's functional response to prey densities; however, a component of that equation estimates the number or prey a predator is likely to encounter during a hunt. NMFS adapted this component of the Holling's disc equation by assuming that Navy vessels were the "predators," their sensory field (2*r*, in square kilometers) represented the sound field of an active sonar system, and their speed (*s*) represented 10 knots, and whose search time represented the duration of an exercise (in hours). We used the "detectability" variable to reflect the amount of time a marine mammal might spent at depths within the sound field of an active sonar system (in the case of whales), the amount of time a pinniped spent in the water (in this case, for Guadalupe fur seals), or the amount of time a marine mammal would not occur in a "sonar shadow" created by one of the islands. The results of this model are comparable to exposure estimates groups such as the Lamont-Doherty Earth Observatory and LGL Environmental Research Associates use to estimate the number of marine mammals that might be exposed during seismic surveys.

As discussed in the *Approach to the Assessment* section of this Opinion, we used this equation to model a scenario that assumed that marine mammal densities never changed and that individual animals did not move during the course of an exercise (which is the closest approximation of the U.S. Navy's models). This scenario assumed ship speeds of 10 knots (or 18.25 kilometers per hour), which is the same assumption contained in the Navy's models. Both scenarios were based on estimates of the area the would be ensonified at different received levels that the Navy presented in its Environmental Impact Statements for the Southern California Range Complex (U.S. Navy 2007, 2008 and see Table 11).

Table 11. Area ensonified by different received levels of mid-frequency active sonar that formed the basis for the area encompassed by a sound field for NMFS' exposure estimates (modified from Tables 3-3 and 3-4 of U.S. Navy 2008)

Distances at Which Received Levels Could Occur by Season		
Received Level	**Cold Season (November to April)**	**Warm Season (May – October)**
Below 140 dB SPL	44 –140 km	8.3 – 40 km
140>Level>150 dB SPL	19 –44 km	3.4 – 8.3 km
150>Level>160 dB SPL	6.7 –19 km	1.3 – 3.4 km
160>Level>170 dB SPL	2.2 – 6.7 km	0.5 – 1.3 km
170>Level>180 dB SPL	0.68 – 2.2 km	200 – 500 m
180>Level>190 dB SPL	210 –680 meters	100 – 200 m
190>Level>200 dB SPL	60 – 210 meters	50 – 100 m
200>Level>210 dB SPL	2- -60 meters	0 – 50 m
Above 210 dB SPL	0 – 20 meters	-

Finally, based on the information the U.S. Navy provided, we assumed the U.S. Navy would conduct eight major training exercises each year for a total of 1,445 hours of active sonar from several sources. We also assumed the U.S. Navy would conduct several integrated training exercises each year for a total of 683 hours of active sonar from several sources. Finally, we assumed that the U.S. Navy would produce about 1,280 hours of active sonar during

unit-level and maintenance training activities and research, development, test and evaluation activities. Roughly half of these sonar hours would occur during the cold season and the other half would occur during the warm season. For major training exercises, we modeled the number of exposure events associated with each exercise (rather than an annual total) because the abundance of several of the endangered and threatened species discussed in the following narratives vary seasonally so animals exposed to one major training exercises are less likely to be exposed to a second major training exercise during the same year.

Exposure Estimates Produced by this Approach

NMFS' approach to estimating the number of endangered and threatened marine mammals that might be exposed to active sonar associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex each over the five-year period beginning in January 2009 produced the following results (also see Table 12):

BLUE WHALES. Based on our exposure analyses, each year we would expect about 5,432 instances in which blue whales might be exposed to mid-frequency active sonar associated with major training exercises conducted in the Southern California Range Complex during the cold season . We would expect about 1,030 instances in which blue whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 4,239 exposure events involving blue whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 804 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 9,670 exposure events involving blue whales that we estimate would occur during the cold season is slightly lower than the 9,900 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 1,834 exposure events that we estimate would occur during the warm season is slightly lower than the 1,890 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

During the cold season, about 85.6 percent of exposure events would occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

We assume the blue whales that might be exposed to active sonar associated with Navy training activities in the Southern California Range Complex will be individuals from the eastern North Pacific population or stock, which occur in waters from California to Alaska in summer and fall and migrate to offshore waters from Mexico to Costa Rica during winter months (Calambokidis et al. 1990, NMFS 2006). The blue whales that occur off southern California reach their peak abundance from June to November (Burtenshaw *et al*. 2004) and their lowest abundance during cold-water months (Calambokidis 1995, Forney and Barlow 1998, Larkman and Veit 1998). Because blue whales forage in waters off southern California and reproduce elsewhere, we assume the blue whales that occur in the action area would be adults, juveniles, or calves, but would not consist of cows accompanied by neonate calves.

Table 12. Annual estimates of the number of exposure events involving endangered and threatened marine mammals and active sonar in the Southern California Range Complex by species and season (cold versus warm season). These estimates assume that half of the sonar hours would occur during the cold season and the other half would occur in the warm season (see text for further explanation). Because of rounding, row entries and row totals may differ.

Species	Number of Encounters (No. Individuals)			
	140 - 190 dB	190-210 dB	>210 dB	Totals
Blue whale				
Major Training Exercises (Cold season)	5,406	23	2	**5,432**
Major Training Exercises (Warm season)	1,018	6	6	**1,030**
Other Training Activities (Cold season)	4,219	18	2	**4,239**
Other Training Activities (Warm season)	794	5	5	**804**
Species Total				**11,505**
Fin whale				
Major Training Exercises (Cold season)	1,050	14	1	**1,055**
Major Training Exercises (Warm season)	599	4	4	**607**
Other Training Activities (Cold season)	823	11	1	**823**
Other Training Activities (Warm season)	468	3	3	**473**
Species Total				**2,958**
Humpback whale				
Major Training Exercises (Cold season)	52	0	0	**52**
Major Training Exercises (Warm season)	16	0	0	**16**
Other Training Activities (Cold season)	41	0	0	**41**
Other Training Activities (Warm season)	41	0	0	**41**
Species Total				**150**
Sei whale				
Major Training Exercises (Cold season)	7	0	0	**7**
Major Training Exercises (Warm season)	2	0	0	**2**
Other Training Activities (Cold season)	5	0	0	**5**
Other Training Activities (Warm season)	2	2	2	**5**
Species Total				**18**
Sperm whale				
Major Training Exercises (Cold season)	11,449	50	5	**1,150**
Major Training Exercises (Warm season)	353	2	2	**358**
Other Training Activities (Cold season)	8,935	39	4	**1,508**
Other Training Activities (Warm season)	276	2	2	**279**

Table 12. Annual estimates of the number of exposure events involving endangered and threatened marine mammals and active sonar in the Southern California Range Complex by species and season (cold versus warm season). These estimates assume that half of the sonar hours would occur during the cold season and the other half would occur in the warm season (see text for further explanation). Because of rounding, row entries and row totals may differ.

Species	Number of Encounters (No. Individuals)			
	140 - 190 dB	190-210 dB	>210 dB	Totals
Species Total				**2,685**
Guadalupe fur seal				
Major Training Exercises (Cold season)	184	1	0	**184**
Major Training Exercises (Warm season)	35	0	0	**35**
Other Training Activities (Cold season)	143	1	0	**144**
Other Training Activities (Warm season)	27	0	0	**27**
Species Total				**391**

Because the abundance of blue whales reach their peak abundance from June to November, which encompasses only a portion of the cold season, we have more confidence in our exposure estimates for the warm season than for the cold season and believe the number of exposure events we estimated for the cold season substantially over-estimate the actual number of exposure events (unless the Navy conducts 4 major training exercises in the month of October, which does not seem probable).

FIN WHALES. Based on our exposure analyses, each year we would expect about 1,055 instances in which fin whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 607 instances in which fin whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 823 exposure events involving fin whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 473 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 1,879 exposure events involving fin whales that we estimate would occur during the cold season is slightly lower than the 1,930 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 1,080 exposure events that we estimate would occur during the warm season is slightly lower than the 1,113 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with blue whales, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

HUMPBACK WHALES. Based on our exposure analyses, we would expect about 52 instances in which humpback whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 16 instances in which humpback whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 41 exposure events involving humpback whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 41 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 93 exposure events involving humpback whales that we estimate would occur during the cold season is slightly lower than the 96 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 57 exposure events that we estimate would occur during the warm season is an increase from the 30 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with blue and fin whales, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

We assume that the humpback whales that occur in the Southern California Range Complex would be individuals from the eastern North Pacific population or "stock" which inhabits waters from Costa Rica to southern British Columbia. These whales are most abundant in coastal waters off California during spring and summer, and off Mexico during autumn and winter. As a result, we believe the estimates for the warm season are more reliable than the estimates for the cold season. Further, because humpback whales forage in waters off southern California and reproduce elsewhere, we assume the humpback whales that occur in the action area would be adults, juveniles, or calves, but would not consist of cows accompanied by neonate calves.

SEI WHALES. Based on our exposure analyses, each year we would expect about seven instances in which sei whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect two instances in which sei whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 5 exposure events involving sei whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 5 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 12 exposure events involving sei whales that we estimate would occur during the cold season is the same we would expect to occur as part of the baseline condition (with current training schedules). The seven exposure events that we estimate would occur during the warm season is slightly more than the four exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

During the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

We do not have sufficient information on the distribution and abundance of sei whales to determine which population or populations of these whales are likely to occur in the Southern California Range Complex, when they are likely to occur, or what age classes would occur there. However, we assume they could occur in any season.

SPERM WHALES. Based on our exposure analyses, each year we would expect about 1,150 instances in which sperm ales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 358 instances in which sperm whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 1,508 exposure events involving sperm whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 279 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 2,048 exposure events involving sperm whales that we estimate would occur during the cold season is slightly lower than the 2,110 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 637 exposure events that we estimate would occur during the warm season is slightly lower than the 650 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with the other whales species, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

We assume that any sperm whales exposed to active sonar during Navy training activities in the Southern California Range Complex will represent individuals from the California-Oregon-Washington population or "stock." Although the distribution of these sperm whales varies seasonally, the abundance of these sperm whales reaches two peaks during the year: from April through mid-June and from late August through mid-November (NMFS 2006). Therefore, we assume

The sperm whale was reported to be rare over the continental shelf of the Southern California Bight, but abundant directly offshore of the Southern California Bight (Bonnell and Dailey 1993). During the 1991 and 1993 NMFS ship-based surveys, sperm whales were more abundant farther offshore and farther south than they were in the Southern California Bight. There are widely scattered sightings of sperm whales in deep waters of the Southern California Range Complex in the warm-water period, and few sightings in the cold-water period. No sperm whales were sighted during the 1998–1999 NMFS' aerial surveys of the San Clemente Island range complex (Carretta *et al*.

2000). Vessel surveys conducted in 2001 and 2005 both yielded sightings of sperm whales (Forney 2007; Appler et al. 2004). However, sperm whales are found in the Southern California Range Complex throughout the year (Carretta *et al*. 2000).

GUADALUPE FUR SEALS. Based on our exposure analyses, each year we would expect about 184 instances in which Guadalupe fur seals might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 35 instances in which Guadalupe fur seals might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 144 exposure events involving Guadalupe fur seals during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 27 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 328 exposure events involving Guadalupe fur seals that we estimate would occur during the cold season is slightly lower than the 340 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 62 exposure events that we estimate would occur during the warm season is about the same as the number of exposure events that we would expect to occur as part of the baseline condition (64 exposure events with current training schedules).

Like the whale species, during the cold season, about 85.6 percent of these exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

Because Guadalupe fur seals tend to forage further north as the waters become warmer and remain further south as surface water becomes colder, the abundance of these fur seals will vary widely and that variance would cause us to over-estimate the probable number of times these fur seals are likely to be exposed to active sonar. Because these fur seals form land-based rookeries and their pups remain on those rookeries for the first few months of their lives, we assume that any Guadalupe fur seals that occur in the action area would be pre- or post-reproductive adults or juveniles. Because adult males are territorial during the breeding season and adult females are likely to remain closer to rookeries when they are feeding pups than when they are not, we also assume that Guadalupe fur seals that occur in the action area during the summer months would be non-reproducing females or juvenile males.

5.2.4 Exposure to Explosions

As discussed in the *Description of the Proposed Action* and *Potential Stressors*, the U.S. Navy plans to conduct a suite of exercises that involve the use of explosive ordnance (see discussion in Section 5.13 and Table 13).

MITIGATION MEASURES TO MINIMIZE THE LIKELIHOOD OF EXPOSURE TO EXPLOSIONS. The Navy proposes to employ a suite of measures to protect endangered and threatened marine mammals and sea turtles from being exposed to underwater detonations and mining operations during the activities they plan to conduct in the Southern California

Range Complex (including sinking exercises). These measures involve site-selection procedures, exclusion zones, and monitoring protocols that comply with Marine Protection, Research, and Sanctuaries Act permits as well as procedures developed and tested during the ship shock trial on the USS WINSTON S CHURCHILL. These monitoring protocols were studied extensively (Clarke and Norman 2005) and those studies concluded that the monitoring protocols effectively insured that marine mammals or sea turtles did not occur within 3.7 kilometers of the underwater detonations.

By incorporating safety zones, monitoring, and shut down procedures similar to those associated with the USS WINSTON S CHURCHILL shock trials into underwater detonations and mining operations that occur in the Southern

Table 13. Estimates of the number of marine mammals that might be exposed to pressure waves or received levels associated with explosions during the proposed exercises. Numbers in parentheses are corrected to consider the effects of mitigative measures (from U.S. Navy 2008a). TTS = temporary threshold shift; TM = Tympanic membrane injury

Species	Potential Behavioral Harassment		Potential Injury	Potential Mortality
	177 dB re 1 μPa^2-s	23 psi or 182 dB re 1 μPa^2-s	13 psi-ms / 205 dB re 1 μPa^2-s	31 psi-ms
	Behavioral Harassment	TTS (mitigation considered)	Slight Lung or TM Injury	Onset Massive Lung Injury
Blue whale	2	2	0	0
Fin whale	2	1	0	0
Sei whale	0	0	0	0
Humpback whale	0	0	0	0
Sperm whale	2	1	0	0
Guadalupe fur seal	2	2	0	0
Total	**8**	**6**	**0**	**0**

California Range Complex over the twelve-month period beginning in January 2009, the U.S. Navy should prevent marine mammals and sea turtles from being exposed to energy from underwater detonations associated with the two proposed sinking exercises. Based on the information available, these mitigation and monitoring protocols are likely to prevent endangered or threatened marine mammals and sea turtles from being exposed to detonations associated with these exercises, which would reduce or eliminate their probability of being adversely affected by these detonations.

Nevertheless, the Navy estimated the number of marine mammals that might be exposed to explosions associated with this ordnance (Table 13). If the mitigation measures the Navy plans on employing are as effective in the Southern California Range Complex as they were during the ship shock trial on the USS WINSTON S CHURCHILL, these are overestimates of the number of animals that are likely to be exposed.

5.2.5 Analyses of Probable Exposure of Sea Turtles to Sonobuoys

When AN/SQS-62 DICASS sonobuoys impact the water surface after being deployed from aircraft, the parachute assemblies of sonobuoys deployed by aircraft are jettisoned and sink away from the sonobuoy, while a float containing an antenna is inflated. The parachutes are made of nylon and are about 8 feet in diameter. At maximum

inflation, the canopies are between 0.15 to 0.35 square meters (1.6 to 3.8 squared feet). Shroud lines range from 0.30 to 0.53 meters (12 to 21 inches) in length and are made of either cotton polyester with a 13.6 kilogram (30 pound) breaking strength or nylon with a 45.4 kilogram (100 pound) breaking strength. All parachutes are weighted with a 0.06 kilogram (2 ounce) steel material weight, which would cause the parachute to sink from the surface within about 15 minutes, although actual sinking rates depend on ocean conditions and the shape of the parachute.

The subsurface assembly descends to a selected depth, and the sonobuoy case falls away and sea anchors deploy to stabilize the hydrophone (underwater microphone). The operating life of the seawater battery is eight hours, after which the sonobuoy scuttles itself and sinks to the ocean bottom. For the sonobouys, concentrations of metals released from batteries were calculated to be 0.0011 mg/L lead, 0.000015mg/L copper, and 0.0000001mg/L silver.

Sea turtles that occur in the Southern California Range Complex might encounter one or more of the parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. Whales also might encounter one or more of these parachutes and become entangled as it sinks to the bottom or once it is on the seafloor. We cannot, however, determine whether such interactions are probable, given the relatively small number of sonobuoys that would be employed in each of the exercises, the relatively large geographic area involved, and the relatively low densities of sea turtles and whales that are likely to occur in the Action Area.

5.3 Response Analyses

As discussed in the *Approach to the Assessment* section of this biological opinion, response analyses determine how listed resources are likely to respond after being exposed to an Action's effects on the environment or directly on listed species themselves. For the purposes of consultations on activities involving active sonar, our assessments try to detect the probability of lethal responses, sensory impairment (permanent and temporary threshold shifts and acoustic masking), physiological responses (particular stress responses), behavioral responses, and social responses that might result in reducing the fitness of listed individuals. Ideally, our response analyses consider and weigh evidence of adverse consequences, beneficial consequences, or the absence of such consequences.

It is important to begin these analyses by stating that, to the best of our knowledge, no data or other information are available from actual exposures of endangered or threatened marine mammals to mid-frequency active sonar in either captive or natural settings. We are aware of the studies of the behavioral responses of small cetaceans given exposed to mid-frequency active sonar that are being conducted at the U.S. Navy's instrumented training range in the Bahamas (the AUTEC range); however, those studies are still in the infancy and no data from them are available at the time of this writing. We are also aware of and have cited initial data available from controlled exposure experiments that are being conducted on killer whales by the Norwegian Defense Ministry; we will incorporate additional information from those studies as the information becomes available.

Without empirical information on the actual responses of endangered and threatened species to mid-frequency active sonar, we reviewed the best scientific and commercial data available to assess the probable responses of endangered and threatened species to mid-frequency active sonar. In the narratives that follow this introduction, we summarize the best scientific and commercial data on the responses of marine animals to mid-frequency active sonar. Then we

use that information to make inferences about the probable responses of the endangered and threatened we are considering in this Opinion.

5.3.1 Potential Responses of Listed Species to Vessel Traffic

Numerous studies of interactions between surface vessels and marine mammals have demonstrated that free-ranging marine mammals engage in avoidance behavior when surface vessels move toward them. It is not clear whether these responses are caused by the physical presence of a surface vessel, the underwater noise generated by the vessel, or an interaction between the two (Goodwin and Green 2004; Lusseau 2006). However, several authors suggest that the noise generated during motion is probably an important factor (Blane and Jackson 1994, Evans *et al.* 1992, 1994). These studies suggest that the behavioral responses of marine mammals to surface vessels is similar to their behavioral responses to predators.

As we discussed previously, based on the suite of studies of cetacean behavior to vessel approaches (Au and Green 1990, Au and Perryman 1982, Bain *et al.* 2006, Bauer 1986, Bejder 1999, 2006a, 2006b; Bryant *et al.* 1984, Corkeron 1995, David 2002, Erbé 2000, Félix 2001, Magalhães *et al.* 2002, Goodwin and Cotton 2004, Hewitt 1985, Lusseau 2003, 2006; Lusseau and Bejder 2007, Ng and Leung 2003, Nowacek *et al.* 2001, Richter *et al.* 2003, 2006; Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams and Ashe 2007, Williams *et al.* 2002, 2006a, 2006b; Würsig *et al.* 1998), the set of variables that help determine whether marine mammals are likely to be disturbed by surface vessels include:

1. *number of vessels*. The behavioral repertoire marine mammals have used to avoid interactions with surface vessels appears to depend on the number of vessels in their perceptual field (the area within which animals detect acoustic, visual, or other cues) and the animal's assessment of the risks associated with those vessels (the primary index of risk is probably vessel proximity relative to the animal's flight initiation distance).

   Below a threshold number of vessels (which probably varies from one species to another, although groups of marine mammals probably shared sets of patterns), studies have shown that whales will attempt to avoid an interaction using horizontal avoidance behavior[5]. Above that threshold, studies have shown that marine mammals will tend to avoid interactions using vertical avoidance behavior, although some marine mammals will combine horizontal avoidance behavior with vertical avoidance behavior (Bryant *et al.* 1984, Cope *et al.* 2000, David 2002, Lusseau 2003, Kruse 1991, Nowacek *et al.* 2001, Stensland and Berggren 2007, Williams and Ashe 2007);

2. *the distance between vessel and marine mammals* when the animal perceives that an approach has started and during the course of the interaction (Au and Perryman 1982, David 2002, Hewitt 1985, Kruse 1991);

3. *the vessel's speed and vector* (David 2002);

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[5] As discussed in the *Approach to the Assessment* section of this Opinion, we distinguish between "avoidance," "evasion," and "escape" using the distinctions proposed by Weihs and Webb (1984): "avoidance" is a shift in position by prey before a potential predator begins an attack; "evasion" is an response by potential prey to an perceived attack from a potential predator; and "escape" is the most acute form of evasive behavior.

4. *the predictability of the vessel's path*. That is, cetaceans are more likely to respond to approaching vessels when vessels stay on a single or predictable path (Acevedo 1991, Angradi *et al.* 1993; Browning and Harland 1999; Lusseau 2003, 2006; Williams *et al.* 2002, 2006a, 2006b) than when it engages in frequent course changes (Evans *et al. 1*994, Lusseau 2006, Williams *et al.* 2002)

6. *noise associated with the vessel* (particularly engine noise) and the rate at which the engine noise increases (which the animal may treat as evidence of the vessel's speed; David 2002, Lusseau 2003, 2006);

7. *the type of vessel* (displacement versus planing), which marine mammals may be interpret as evidence of a vessel's maneuverability (Goodwin and Cotton 2004);

8. the behavioral state of the marine mammals (David 2002, Lusseau 2003, 2006; Würsig *et al.* 1998). For example, Würsig *et al.* (1998) concluded that whales were more likely to engage in avoidance responses when the whales were "milling" or "resting" than during other behavioral states.

Most of the investigations cited earlier reported that animals tended to reduce their visibility at the water's surface and move horizontally away from the source of disturbance or adopt erratic swimming strategies (Corkeron 1995, Lusseau 2003, Lusseau 2004, 2005*a*; Notarbartolo di Sciara *et al.* 1996, Nowacek *et al.* 2001, Van Parijs and Corkeron 2001, Williams *et al.* 2002). In the process, their dive times increased, vocalizations and jumping were reduced (with the exception of beaked whales), individuals in groups move closer together, swimming speeds increased, and their direction of travel took them away from the source of disturbance (Edds and Macfarlane 1987, Baker and Herman 1989, Kruse 1991, Polacheck and Thorpe 1990, Evans *et al. 1*992, Lütkebohle 1996, Nowacek *et al. 1*999). Some individuals also dove and remained motionless, waiting until the vessel moved past their location. Most animals finding themselves in confined spaces, such as shallow bays, during vessel approaches tended to move towards more open, deeper waters (Stewart *et al.* 1982, Kruse 1991). We assume that this movement would give them greater opportunities to avoid or evade vessels as conditions warranted.

Although most of these studies focused on small cetaceans (for example, bottlenose dolphins, spinner dolphins, spotted dolphins, harbor porpoises, beluga whales, and killer whales), studies of large whales have reported similar results for fin and sperm whales (David 2002, Notarbartolo di Sciara *et al.* 1996, 2002). Baker *et al.* (1983) reported that humpbacks in Hawai'i responded to vessels at distances of 2 to 4 km. Richardson *et al.* (1985) reported that bowhead whales (*Balaena mysticetus*) swam in the opposite direction of approaching seismic vessels at distances between 1 and 4 km and engage in evasive behavior at distances under 1 km. Fin whales also responded to vessels at a distances of about 1 km (Edds and Macfarlane 1987).

Some cetaceans detect the approach of vessels at substantial distances. Finley *et al.* (1990) reported that beluga whales seemed aware of approaching vessels at distances of 85 km and began to avoid the approach at distances of 45-60 km. Au and Perryman (1982) studied the behavioral responses of eight schools of spotted and spinner dolphins (*Stenella attenuata* and *S. longirostris*) to an approaching ship (the NOAA vessel *Surveyor*: 91.4 meters, steam-powered, moving at speeds between 11 and 13 knots) in the eastern Pacific Ocean (10°15 N lat., 109°10 W long.). They monitored the response of the dolphin schools to the vessel from a Bell 204 helicopter flying a track line ahead of the ship at an altitude of 366 – 549 meters (they also monitored the effect of the helicopter on dolphin movements and concluded that it had no observable effect on the behavior of the dolphin schools). All of the schools continuously adjusted their direction of swimming by small increments to continuously increase the distance between the

school and the ship over time. The animals in the eight schools began to flee from the ship at distances ranging from 0.9 to 6.9 nm. When the ship turned toward a school, the individuals in the school increased their swimming speeds (for example, from 2.8 to 8.4 knots) and engaged in sharp changes in direction.

Hewitt (1985) reported that five of 15 schools of dolphin responded to the approach of one of two ships used in his study and none of four schools of dolphin responded to the approach of the second ship (the first ship was the NOAA vessel *David Jordan Starr*; the second ship was the *Surveyor*).Spotted dolphin and spinner dolphins responded at distances between 0.5 to 2.5 nm and maintained distances of 0.5 to 2.0 nm from the ship while striped dolphins allows much closer approaches. Lemon *et al.*(2006) reported that bottlenose dolphin began to avoid approaching vessels at distances of about 100 m.

Würsig *et al.* (1998) studied the behavior of cetaceans in the northern Gulf of Mexico in response to survey vessels and aircraft. They reported that *Kogia* species and beaked whales (ziphiids) showed the strongest avoidance reactions to approaching ships (avoidance reactions in 11 of 13 approaches) while spinner dolphins, Atlantic spotted dolphins, bottlenose dolphins, false killer whales, and killer whales either did not respond or approached the ship (most commonly to ride the bow). Four of 15 sperm whales avoided the ship while the remainder appeared to ignore its approach.

Because of the number of vessels involved in U.S. Navy training exercises, their speed, their use of course changes as a tactical measure, and sounds associated with their engines and displacement of water along their bowline, the available evidence leads us to expect marine mammals to treat Navy vessels as potential stressors. Further, without considering differences in sound fields associated with any active sonar that is used during these exercises, the available evidence suggests that major training exercises (for example, RIMPAC, USWEX, and Multiple Strike Group exercises), unit- and intermediate-level exercises, and RDT&E activities would represent different stress regimes because of differences in the number of vessels involved, vessel maneuvers, and vessel speeds.

Animals that perceive an approaching potential predator, predatory stimulus, or disturbance stimulus have four behavioral options (see Blumstein 2003 and Nonacs and Dill 1990):

a. ignore the disturbance stimulus entirely and continue behaving as if a risk of predation did not exist;

b. alter their behavior in ways that minimize their perceived risk of predation, which generally involves fleeing immediately;

c. change their behavior proportional to increases in their perceived risk of predation which requires them to monitor the behavior of the predator or predatory stimulus while they continue their current activity, or

d. take proportionally greater risks of predation in situations in which they perceive a high gain and proportionally lower risks where gain is lower, which also requires them to monitor the behavior of the predator or disturbance stimulus while they continue their current activity.

The latter two options are energetically costly and reduce benefits associated with the animal's current behavioral state. As a result, animals that detect a predator or predatory stimulus at a greater distance are more likely to flee at a greater distance (see Holmes *et al.* 1993, Lord *et al.* 2001). Some investigators have argued that short-term

avoidance reactions can lead to longer term impacts such as causing marine mammals to avoid an area (Salden 1988, Lusseau 2005) or alter a population's behavioral budget (Lusseau 2004) which could have biologically significant consequences on the energetic budget and reproductive output of individuals and their populations.

Of the endangered and threatened species that occur in the Southern California Range Complex, the endangered and threatened sea turtles are most likely to ignore U.S. Navy vessels entirely and continue behaving as if the vessels and any risks associated with those vessels did not exist. The estimates that follow assume that any endangered and threatened cetaceans that occur between 600 meters and two kilometers (cold season) or 500 meters to 1.3 kilometers (warm season) of vessels engaged in training exercises in the Southern California Range Complex might respond to those vessels (this distance roughly corresponds with a received levels of 170 dB in the cold season and about 160 dB in the warm season), although they might engage in avoidance behavior at greater distances. The estimated probabilities of the different responses are based on posterior probabilities from Bayesian analyses (described in the *Approach to the Assessment*) of the outcomes of 1,021 responses of cetaceans to approaches by vessels extracted from 123 published papers and other publications.

PROBABLE RESPONSES OF BLUE WHALES TO VESSELS. Of the 86 instances[6] in which blue whales might occur between 600 meters and two kilometers during the cold season or the 54 instances in which blue whales might occur between 500 meters and 1.3 kilometers during the warm season of surface vessels involved in major training exercises over the next twelve months, the whales are likely to avoid being exposed to the vessel traffic in 26 of those instances and are likely to change their behavior in response to their exposure in another 9 instances. Most of these avoidance responses would consist of slow movements away from vessels the animals perceive are on an approaching course, perhaps accompanied by slightly longer dives (or longer intervals between blows). Most the changes in behavior would consist of a shift from behavioral states that have low energy requirements (resting or milling) to behavioral states with higher energy requirements (active swimming or traveling). In the remaining 51 instances, the whales are either not likely to respond or are not likely to respond in ways that might be adverse to the whales (the responses might represent an approach or attentive movement, a small change in orientation in the waters, etc.).

PROBABLE RESPONSES OF FIN WHALES TO VESSELS. Of the 51 instances in which fin whales might occur between 600 meters and two kilometers during the cold season or the 32 instances in which fin whales might occur between 500 meters and 1.3 kilometers during the warm season of surface vessels involved in najor training exercises over the next twelve months, the whales are likely to avoid being exposed to the vessel traffic in 15 of those instances and are likely to change their behavior in response to their exposure in another five instances. Like blue whales, most of these avoidance responses would consist of slow movements away from vessels the animals perceive are on an approaching course, perhaps accompanied by slightly longer dives (or longer intervals between blows). Most the changes in behavior would consist of a shift from behavioral states that have low energy requirements (resting or milling) to behavioral states with higher energy requirements (active swimming or traveling). In the remaining exposure events, the whales are either not likely to respond or are not likely to respond in ways that might be adverse

[6] These estimates reflect the sum of the estimates of the number of instances in which endangered species might be exposed to active sonar at received levels of 170 – 180 dB, 180 – 190 dB, and > 190 dB in Table 12, which means they would be within two kilometers of a ship transmitting active sonar

to the whales (the responses might represent an approach or attentive movement, a small change in orientation in the waters, etc.).

PROBABLE RESPONSES OF HUMPBACK WHALES TO VESSELS. Of the one instance in which humpback whales might occur between 600 meters and two kilometers during the cold season or the instance in which humpback whales might occur between 500 meters and 1.3 kilometers during the warm season of surface vessels involved in najor training exercises over the next twelve months, the whales are not likely to respond to the approach of Navy vessels.

PROBABLE RESPONSES OF SEI WHALES TO VESSELS. Based on our exposure analyses, sei whales are not likely to occur between 600 meters and two kilometers during the cold season or between 500 meters and 1.3 kilometers during the warm season of surface vessels over the next twelve months.

PROBABLE RESPONSES OF SPERM WHALES TO VESSELS. Of the 182 instances in which sperm whales might occur between 600 meters and two kilometers during the cold season or the 19 instances in which sperm whales might occur between 500 meters and 1.3 kilometers the whales are likely to avoid being exposed to the vessel traffic in 37 of those instances and are likely to change their behavior in response to their exposure in another 12 instances. Like the other large whales discussed earlier, most of these avoidance responses would consist of slow movements away from vessels the animals perceive are on an approaching course, perhaps accompanied by slightly longer dives (or longer intervals between blows). Most the changes in behavior would consist of a shift from behavioral states that have low energy requirements (resting or milling) to behavioral states with higher energy requirements (active swimming or traveling), particularly social groups that include neonates or calves. In the remaining 133 exposure events, the whales are either not likely to respond or are not likely to respond in ways that might be adverse to the whales (the responses might represent an approach or attentive movement, a small change in orientation in the waters, etc.).

As with humpback whales, we assume that sperm whales would respond to both the active sonar, any salient acoustic cues produced by surface vessels involved in an exercise, and their perception of whether ships are approaching them or moving away when they decide whether or not to avoid the active sonar. Based on the evidence available, sperm whales seem more likely to exhibit avoidance responses when they initially detect or recognize these cues and the avoidance would consist of horizontal movement away from an exercise at slow to moderate swimming speeds.

Based on the information available, endangered and threatened sea turtles are most likely to ignore U.S. Navy vessels entirely and continue behaving as if the vessels and any risks associated with those vessels did not exist.

5.3.2 Potential Responses of Listed Species to Air Traffic

There are few studies of the responses of marine animals to air traffic and the few that are available have produced mixed results. Some investigators report some responses while others report no responses. Richardson *et al.* (1995) reported that there is no evidence that single or occasional aircraft flying above large whales and pinnipeds in-water cause long-term displacement of these mammals. Several authors have reported that sperm whales did not react to fixed-wing aircraft or helicopters in some circumstances (Au and Perryman 1982, Clarke 1956, Gambell 1968,

Green *et al.* 1992) and reacted in others (Clarke 1956, Fritts *et al.* 1983, Mullin *et al.* 1991, Patenaude *et al.* 2006, Richter *et al.* 2003, 2006, Smultea *et al.* 2008, Würsig *et al.* 1998). Richardson *et al.* (1985) reported that bowhead whales (*Balaena mysticetus*) responded behaviorally to fixed-wing aircraft that were used in their surveys and research studies when the aircraft were less than 457 meters above sea level; their reactions were uncommon at 457 meters, and were undetectable above 610 meters. They also reported that bowhead whales did not respond behaviorally to helicopter overflights at about 153 meters above sea level.

Smultea *et al.* (2008) studied the response of sperm whales to low-altitude (233-269 m) flights by a small fixed-wing airplane Kauai and reviewed data available from either other studies. They concluded that sperm whales responded behaviorally to aircraft passes in about 12 percent of encounters. All of the reactions consisted of sudden dives and occurred when the aircraft was less than 360 m from the whales (lateral distance). They concluded that the sperm whales had perceived the aircraft as a predatory stimulus and responded with defensive behavior. In at least one case, Smultea and *et al.* (2008) reported that the sperm whales formed a semi-circular "fan" formation that was similar to defensive formations reported by other investigators.

5.3.3 Potential Responses of Listed Species to Active Sonar

As discussed in the *Approach to the Assessment* section of this Opinion, we conduct response analyses to determine whether and how listed species and designated critical habitat are likely to respond after being exposed to an Action's effects. For the purposes of consultations on activities that involve active sonar, our assessments try to detect the probability of lethal responses, sensory impairment (permanent and temporary threshold shifts and acoustic masking), physiological responses (particular stress responses), behavioral responses, and social responses that are likely to directly or indirectly reduce the fitness of listed individuals.

Our response analyses consider and weigh all of the evidence available on the response of marine animals upon being exposed to active sonar and probable fitness consequences for the animals that exhibit particular responses or sequence of responses. It is important to acknowledge, however, that there is limited empirical evidence of how endangered or threatened marine animals respond upon being exposed to active sonar in natural settings. Therefore, the narratives that follow this introduction summarize the best scientific and commercial data available on the responses of other species to active sonar or other acoustic stimuli. Based on those data, we identify the probable responses of endangered and threatened marine animals to mid-frequency active sonar transmissions.

Figure 3 illustrates the conceptual model we use to assess the potential responses of marine animals when they are exposed to active sonar. The narratives that follow are generally organized around the items listed in the column titled "Proximate Responses by Category" in that Figure. These analyses examine the evidence available to determine if exposing endangered and threatened species to mid-frequency active sonar is likely to cause responses that might reduce the fitness of individuals that might be exposed.

The information that follows is presented as if endangered or threatened marine animals in the Southern California Range Complex would only be exposed to mid- or low-frequency active sonar when, in fact, any individuals that occur in the area of a training event would be exposed to multiple potential stressors and would be responding to a wide array of cues from their environment including natural cues from other members of their social group, from

predators, and other living organisms. However, the information that is available generally focuses on the physical, physiological, and behavioral responses of marine mammals to one or two stressors or environmental cues rather than the suite of anthropogenic and natural stressors that most free-ranging animals must contend with in their daily existence. We present the information from studies that investigated the responses of animals to one or two stressors, but we remain aware that we might observe very different results if we presented those same animals with the suite of stressors and cues they would encounter in the wild.

5.3.3.1 Injury

For the purposes of this assessment, "injuries" represents physical trauma or damage that is a direct result of an acoustic exposure, regardless of the potential consequences of those injuries to an animal (we distinguish between injuries that result from an acoustic exposure and injuries that result from an animal's behavioral reaction to an acoustic exposure, which is discussed later in this section of the Opinion). Based on the literature available, mid-frequency active sonar might injure marine animals through two mechanisms (see "Box P" in Figure 3): acoustic resonance and noise-induced loss of hearing sensitivity (more commonly-called "threshold shift").

ACOUSTIC RESONANCE. Acoustic resonance results from hydraulic damage in tissues that are filled with gas or air that resonates when exposed to acoustic signals (Box P1 of Figure 3 illustrates the potential conesquences of acoustic resonance; see Rommel *et al.* 2007). Based on studies of lesions in beaked whales that stranded in the Canary Islands and Bahamas associated with exposure to naval exercises that involved sonar, investigators have identified two physiological mechanisms that might explain some of those stranding events: tissue damage resulting from resonance effects (Ketten 2004, Cudahy and Ellison 2001) and tissue damage resulting from "gas and fat embolic syndrome" (Fernandez *et al.* 2005, Jepson *et al.* 2003, 2005). Fat and gas embolisms are believed to occur when tissues are supersaturated with dissolved nitrogen gas and diffusion facilitated by bubble-growth is stimulated within those tissues (the bubble growth results in embolisms analogous to the "bends" in human divers).

Cudahy and Ellison (2001) analyzed the potential for resonance from low frequency sonar signals to cause injury and concluded that the expected threshold for *in vivo* (in the living body) tissue damage for underwater sound is on the order of 180 to 190 dB. There is limited direct empirical evidence (beyond the evidence available in Schlundt *et al.* 2000) to support a conclusion that 180 dB is "safe" for marine mammals; however, evidence from marine mammal vocalizations suggests that 180 dB is not likely to physically injure marine mammals. For example, Frankel (1994) estimated the source level for singing humpback whales to be between 170 and 175 dB; McDonald *et al.* (2001) calculated the average source level for blue whale calls as 186 dB, Watkins *et al.* (1987) found source levels for fin whales up to 186 dB, and Møhl *et al.* (2000) recorded source levels for sperm whale clicks up to 223 dB_{rms}. Because whales are not likely to communicate at source levels that would damage the tissues of other members of their species, this evidence suggests that these source levels are not likely to damage the tissues of the endangered and threatened species being considered in this consultation.

Crum and Mao (1996) hypothesized that received levels would have to exceed 190 dB in order for there to be the possibility of significant bubble growth due to super-saturation of gases in the blood. Jepson *et al.* (2003, 2005) and Fernández *et al.* (2004, 2005) concluded that *in vivo* bubble formation, which may be exacerbated by deep, long-duration, repetitive dives may explain why beaked whales appear to be particularly vulnerable to sonar exposures.

Based on the information available, the endangered or threatened marine mammals and sea turtles that we are considering in this Opinion are not likely to experience acoustic resonance. All of the evidence available suggests that this phenomenon poses potential risks to smaller cetaceans like beaked whales rather than the larger cetaceans that have been listed as endangered. Thus far, this phenomenon has not been reported for or associated with sea turtles, perhaps because they do not engage in dive patterns that are similar to those of beaked whales.

NOISE-INDUCED LOSS OF HEARING SENSITIVITY. Noise-induced loss of hearing sensitivity[7] or "threshold shift" refers to an ear's reduced sensitivity to sound following exposure to loud noises: when an ear's sensitivity to sound has been reduced, sounds must be louder for the individual affected to detect and recognize it. Noise-induced loss of hearing sensitivity is usually represented by the increase in intensity (in decibels) sounds must have to be detected. Although noise-induced losses in hearing sensitivity rarely affect the entire frequency range an ear might be capable of detecting, only a few investigators have reported the frequency range affected by a hearing loss.

An animal can experience either temporary threshold shift (TTS) or permanent threshold shift (PTS). TTS can last from minutes or hours to days. When PTS occurs, there is physical damage to the sound receptors in the ear. This can result in total or partial deafness, or an animal's hearing can be impaired in specific frequency ranges (Box P2 of Figure 3 illustrates the potential consequences of noise-induced loss in hearing sensitivity).

Although the published body of science literature contains numerous theoretical studies and discussion papers on hearing impairments that can occur with exposure to a strong sound, only a few studies provide empirical information on noise-induced loss in hearing sensitivity in non-human animals. Richardson *et al* (1995) concluded that there was no empirical evidence that exposure to active sonar transmissions with the kind of intensity can cause PTS in any marine mammals; instead the probability of PTS has been inferred from studies of TTS. Richardson *et al.* (1995) hypothesized that marine mammals within less than 100 meters of a sonar dome might be exposed to mid-frequency active sonar transmissions at received levels greater than 205 dB re 1 μPa which might cause TTS. Erbe (2002). argued that killer whales would have to stay within 50 meters of a single boat for 8 hours a day, 5 days a week, for up to 50 years to experience a permanent threshold shift of 2 – 5 dB as a result of exposure to engine noise, although exposing killer whales to multiple vessels could cumulatively produce temporary or permanent threshold shifts.

Schlundt *et al.* (2000; see also Finneran *et al.* 2001, 2003) provided a detailed summary of the behavioral responses of trained marine mammals during TTS tests conducted at the Navy's SPAWAR Systems Center with 1-second tones. Schlundt *et al.* (2000) reported on eight individual TTS experiments that were conducted in San Diego Bay. Fatiguing stimuli durations were 1 second. Because of the variable ambient noise in the bay, low-level broadband masking noise was used to keep hearing thresholds consistent despite fluctuations in the ambient noise.

[7] Animals can experience losses in hearing sensitivity through other mechanisms. The processes of aging and several diseases cause some humans to experience permanent losses in their hearing sensitivity. Body burdens of toxic chemicals can also cause animals, including humans, to experience permanent and temporary losses in their hearing sensitiviy (for example, see Mills and Going 1982 and Fechter and Pouyanos 2005).

Finneran *et al.* (2001, 2003) conducted TTS experiments using 1-second duration tones at 3 kHz. The test method was similar to that of Schlundt *et al.* except the tests were conducted in a pool with a very low ambient noise level (below 50 dB re 1 $\mu Pa^2/Hz$), and no masking noise was used. The signal was a sinusoidal amplitude modulated tone with a carrier frequency of 12 kHz, modulating frequency of 7 Hz, and SPL of approximately 100 dB re 1 μPa. Two separate experiments were conducted. In the first, fatiguing sound levels were increased from 160 to 201 dB SPL. In the second experiment, fatiguing sound levels between 180 and 200 dB re 1 μPa were randomly presented.

Based on the information available, and given the speeds at which Navy vessels operate during the activities they proposed to conduct in the Southern California Range Complex, the protective measures the Navy proposes to employ during an exercise, and the probable avoidance responses of those animals upon exposure, we think it is highly unlikely that large whales would routinely accumulate acoustic energy sufficient to cause noise-induced loss of hearing sensitivity. At the ship speeds involved, collisions would present a greater risk than noise-induced hearing loss; as we have discussed previously, the Navy's protective measures, which are designed to detect large whales (and other objects) in their path to protect the ships from being damaged during a collision, are also likely to prevent large whales from being exposed to received levels sufficient to cause hearing losses.

5.3.3.2 Acoustic Masking

Marine mammals use acoustic signals for a variety of purposes that differ among species, but include communication between individuals, navigation, foraging, reproduction, and learning about their environment (Erbe and Farmer 2000, Tyack 2000). Masking, or auditory interference, generally occurs when sounds in the environment are louder than and of a similar frequency to, auditory signals an animal is trying to receive. Masking, therefore, is a phenomenon that affects animals that are trying to receive acoustic information about their environment, including sounds from other members of their species, predators, prey, and sounds that allow them to orient in their environment (the responses of animals sending acoustic signals are addressed in the next subsection). Masking these acoustic signals can disturb the behavior of individual animals, groups of animals, or entire populations (Box M of Figure 3 illustrates the potential consequences of acoustic masking).

Richardson *et al.* (1995b) argued that the maximum radius of influence of an industrial noise (including broadband low frequency sound transmission) on a marine mammal is the distance from the source to the point at which the noise can barely be heard. This range is determined by either the hearing sensitivity of the animal or the background noise level present. Industrial masking is most likely to affect some species' ability to detect communication calls and natural sounds (i.e., vocalizations from other members of its species, surf noise, prey noise, etc.; Richardson *et al.* 1995).

Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses produced 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). Sperm whales have moved out of areas after the start of air gun seismic testing (Davis *et al.* 1995). Seismic air guns produce loud, broadband, impulsive noise (source levels are son the order of 250 dB) with "shots" every 15 seconds, 240 shots per hour, 24 hours per day during active tests. Because they spend large amounts of time at depth and use low frequency sound sperm whales are likely to be

susceptible to low frequency sound in the ocean (Croll *et al* 1999). Furthermore, because of their apparent role as important predators of mesopelagic squid and fish, changes in their abundance could affect the distribution and abundance of other marine species.

The echolocation calls of toothed whales are subject to masking by high frequency sound. Human data indicate low frequency sound can mask high frequency sounds (i.e., upward masking). Studies on captive odontocetes by Au *et al.* (1974, 1985, 1993) indicate that some species may use various processes to reduce masking effects (e.g., adjustments in echolocation call intensity or frequency as a function of background noise conditions). There is also evidence that the directional hearing abilities of odontocetes are useful in reducing masking at the high frequencies these cetaceans use to echolocate, but not at the low-to-moderate frequencies they use to communication (Zaitseva *et al.* 1980).

Based on the evidence available, the endangered baleen whales that are considered in this Opinion — blue, fin, and sei whales — are not likely to experience acoustic masking because they are low-frequency hearing specialists who attend to environmental cues at frequencies that are much lower than mid-frequency active sonar. Similarly, the endangered and threatened sea turtles that are considered in this Opinion are low frequency hearing specialists and, as a result, are not likely to experience acoustic masking by mid-frequency active sonar.

Field investigations of humpback whale songs suggest that humpback whales have an upper frequency limit reaching as high as 24 kHz (Au *et al.* 2006). Based on this information, it is reasonable to assume that the active mid-frequency sonar the U.S. Navy would employ during the activities they plan to conduct in the Southern California Range Complex between July and November 2008 is within the hearing and vocalization range of humpback whales. As a result, we assume that some of the humpback whales that are exposed to mid-frequency active sonar during one or more of the proposed exercises might experience acoustic masking as a result of their exposure.

Based on their hearing sensitivities, which overlap the frequency range of mid-frequency active sonar, the evidence available leads us to conclude that sonar transmissions might mask environmental cues at the lower range of sperm whale hearing. Although there is no published audiogram for sperm whales, these whales would be expected to have good, high frequency hearing because their inner ear resembles that of most dolphins, and appears tailored for ultrasonic (>20 kHz) reception (Ketten 1994). The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate, which suggest that neonatal sperm whales respond to sounds from 2.5 to 60 kHz.

5.3.3.3 Impaired Communication

Communication is an important component of the daily activity of animals and ultimately contributes to their survival and reproductive success. Animals communicate to find food (Elowson *et al.* 1991, Marler *et al.* 1986, Stokes 1971), acquiring mates (Patricelli *et al.* 2006, Ryan 1985, Stokes 1971), assessing other members of their species (Owings *et al.* 2002, Parker 1974, Sullivan 1984), evading predators (Greig-Smith 1980, Marler 1955, Vieth *et al.* 1980), and defending resources (Alatalo *et al.* 1990, Falls 1963, Zuberbuehler *et al.* 1997). Human activities that impair an animal's ability to communicate effectively might have significant effects on the animals experiencing the impairment.

Communication usually involves individual animals that are producing a vocalization or visual or chemical display for other individuals. Masking, which we have already discussed, affects animals that are trying to receive acoustic cues in their environment, including cues vocalizations from other members of the animals' species or social group. However, anthropogenic noise presents separate challenges for animals that are vocalizing. This subsection addresses the probable responses of individual animals whose attempts to vocalize or communicate are affected by active sonar.

When they vocalize, animals are aware of environmental conditions that affect the "active space" of their vocalizations, which is the maximum area within which their vocalizations can be detected before it drops to the level of ambient noise (Brenowitz 2004, Brumm *et al.* 2004, Lohr *et al.* 2003). Animals are also aware of environmental conditions that affect whether listeners can discriminate and recognize their vocalizations from other sounds, which are more important than detecting a vocalization (Brenowitz 1982, Brumm *et al.* 2004, Dooling 2004, Marten and Marler 1977, Patricelli *et al.* 2006).

Most animals that vocalize have evolved with an ability to make vocal adjustments to their vocalizations to increase the signal-to-noise ratio, active space, and salience of their vocalizations in the face of temporary changes in background noise (Brumm *et al.* 2004, Cody and Brown 1969, Egnor *et al.* 2006, Patricelli *et al.* 2006). In some instances, the vocal adjustment may depend on when a competing signal occurs in a vocal sequence; for example, Egnor *et al.* (2006) reported that tamarin made different vocal adjustments depending on whether they were disturbed at the beginning of their calls, during the middle of their calls, or at the end of their call. Nevertheless, bocalizing animals have been reported to make one or more of the following adjustments to preserve the active space and salience of their vocalizations:

1. Adjust the frequency structure of vocalizations (Box C1.2 of Figure 3). Animals responding in this way adjust the frequency structure of their calls and songs by increasing the minimum frequency of their vocalizations while maximum frequencies remain the same. This reduces the frequency range of their vocalizations and reduces the amount of overlap between their vocalizations and background noise.

Slabbekorn and Ripmeister (2008), Slabbekorn and den Boer-Visser (2006), and Slabbekorn and Peet (2003) studied patterns of song variation among individual great tits (*Parus major*) in an urban population in Leiden, The Netherlands, and among 20 different urban and forest populations across Europe and the United Kingdom. Adult males of this species that occupied territories with more background noise (primarily traffic noise) sang with higher minimum frequencies than males occupying non-urban or quieter sites. Peak or maximum frequencies of these songs did not shift in the face of high background noise or competing signals.

2. Adjust the amplitude of vocalizations (Box C1.1 of Figure 3). Animals responding in this way increase the amplitude or pitch of their calls and songs by placing more energy into the entire vocalization or, more commonly, shifting the energy into specific portions of the call or song.

This response is called the "Lombard reflex" or "Lombard effect" and represents a short-term adaptation to vocalizations in which a signaler increases the amplitude of its vocalizations in response to an increase in the amplitude of background noise (Lombard 1911). This phenomenon has been studied extensively in humans, who

raise the amplitude of the voices while talking or singing in the face of high, background levels of sound (Lombard 1911, Tonkinson 1990).

Other species experience the same phenomenon when they vocalize in the presence of high levels of background sound. Brumm (2004) studied the songs of territorial male nightingales (*Luscinia megarhynchos*) in the city of Berlin, Germany, to determine whether and to what degree background noise (from automobile traffic) produced a Lombard effect in these birds. Based on his studies, the birds increased the volume of their songs in response to traffic noise by 14 dB (their songs were more than 5 times louder than birds vocalizing in quiet sites). Cynx *et al.* (1998) reported similar results based on their study of zebra finches (*Taeniopygia guttata*) exposed to white noise.

Although this type of response also has not been studied extensively in marine animals, Scheifele *et al.* (2005) reported that beluga whales in the St. Lawrence River increased the decibel levels of their vocalizations from 80.46-86.76 dB in conditions without noise to 91.74-99.10 dB when confronted with vessel noise.

Holt *et al.* (2007) reported that endangered southern resident killer whales (*Orcinus orca*) in Haro Strait off the San Juan Islands in Puget Sound, Washington, increased the amplitude of their social calls in the face of increased sounds levels of background noise.

3. Adjust temporal structure of vocalizations (Box C1.2 of Figure 3). Animals responding this way adjust the temporal structure of their vocalizations by changing the timing of modulations, notes, and syllables within vocalizations or increasing the duration of their calls or songs.

Cody and Brown (1969) studied the songs of adult male Bewick wrens and wrentits that occupied overlapping territories and whose songs had similar physical characteristics (similar song lengths, frequency structure, and amplitude). They reported that wrentits adjusted the timing of their songs so they occurred when the songs of the Bewick wrens subsided.

Ficken *et al.* (1974) studied vocalizations of ten red-eyed vireos (*Vireo olivaceus*) and least flycatchers (*Empidonax minimus*) at Lake Itasca, Minnesota (a total of 2283 songs). They reported that flycatchers avoided acoustic interference from red-eyed vireos by inserting their shorter songs between the longer songs of the vireos. Although there is some mutual avoidance of acoustic interference, the flycatcher tends more strongly to insert its short songs in between the longer songs of the vireo rather than vice versa. Indeed, most of the overlap occurred when the flycatcher began singing just after the vireo had begun, suggesting that the flycatcher had not heard the vireo begin singing.

A few studies have demonstrated that marine mammals make the same kind of vocal adjustments in the face of high levels of background noise. Rendell and Gordon (1999) reported that long-finned pilot whales (*Globicephala melas*) in the Ligurian Sea made several vocal adjustments in call whistles when putatively exposed to active sonar transmissions at frequencies of 4-5 kHz (reference and received levels were not reported).

Miller *et al.* (2000) recorded the vocal behavior of singing humpback whales continuously for several hours using a towed, calibrated hydrophone array. They recorded at least two songs in which the whales were exposed to low-frequency active sonar transmissions (42 second signals at 6 minute intervals; sonar was broadcast so that none of

the singing whales were exposed at received levels greater than 150 dB re 1μPa). They followed sixteen singing humpback whales during 18 playbacks. In nine follows, whales sang continuously throughout the playback; in four follows, the whale stopped singing when he joined other whales (a normal social interaction); and in five follows, the singer stopped singing, presumably in response to the playback. Of the six whales whose songs they analyzed in detail, songs were 29% longer, on average, during the playbacks. Song duration returned to normal after exposure, suggesting that the whale's response to the playback was temporary.

Fristrup *et al.* (2003) studied the length of 378 humpback whale songs recorded before, during, and after broadcasts from SURTASS LFA sonar in the 150-320 Hz frequency band at sound pressure levels between 140 and 205 dB re 1 μPa. Mean song lengths were 13.8 min (s.d. = 3.1, minimum = 5.4, median = 13.5, max = 33.3 minutes). Songs that overlapped with pings were longer than songs that did not overlap and whale songs were significantly longer when a ping occurred close to end of a song. The largest increases in song length were observed in songs that were sung between 1 and 2 hours after the last ping.

Foote *et al.* (2004) compared recordings of endangered southern resident killer whales that were made in the presence or absence of boat noise in Puget Sound during three time periods between 1977 and 2003. They concluded that the duration of primary calls in the presence of boats increased by about 15% during the last of the three time periods (2001 to 2003). They suggested that the amount of boat noise may have reached a threshold above which the killer whales needs to increase the duration of their vocalization to avoid masking by the boat noise.

4. Adjust the temporal delivery of vocalizations (Boxes C1.3 – C1.5 of Figure 3). Animals responding in this way change when they vocalize or changing the rate at which they repeat calls or songs.

For example, tawny owls (*Strix aluco*) reduce the rate at which they call during rainy conditions (Lengagne and Slater 2002). Brenowitz (1982) concluded that red-winged blackbirds (*Agelaius phoeniceus*) had the largest active space, or broadcast area, for their calls at dawn because of relatively low turbulence and background noise when compared with other times of the day. Brown and Handford (2003) concluded that swamp and white-throated sparrows (*Melospiza georgiana* and *Zonotrichia albicollis*, respectively) tended to sing at dawn, as opposed to other times of the day, because they encountered the fewest impediments to acoustic transmissions during that time of the day. For example, Miksis-Olds (2006) surmised that Florida manatees (*Trichechus manatus latirostris*) in Sarasota Bay, Florida, appear to wait until the morning, when background noise levels associated with vessel traffic decline, before vocalizing when they are resting.

Many animals will combine several of these strategies to compensate for high levels of background noise. For example, Brumm *et al.* (2004) reported that common marmosets (*Callithrix jacchus*) increased the median amplitude of the twitter calls as well as the duration of the calls in response to increased background noise. King penguins (*Aptenodytes patagonicus*) increase the number of syllables in a call series and the rate at which they repeat their calls to compensate for high background noise from other penguins in a colony or high winds (Lengagne *et al.* 1999). California ground squirrels (*Spermophilus beecheyi*) shifted the frequencies of their alarm calls in the face of high ambient noise from highway traffic (Rabin *et al.* 2003). However, they only shifted the frequency of the second and third harmonic of these alarm calls, without changing the amount of energy in the first harmonic. By emphasizing the higher harmonics, the ground squirrels placed the peak energy of their alarm calls above the

frequency range of the masking noise from the highway. Wood and Yezerinac (2006) reported that song sparrows (*Melospiza melodus*) increased the frequency of the lowest notes in their songs and reduced the amplitude of the low frequency range of their songs. Fernandez-Juricic *et al.* (2005) reported that house finches (*Carpodacus mexicanus*) adopted the same strategy to compensate for background noise.

Although this form of vocal adjustment has not been studied extensively in marine animals, Dahlheim (1987) studied the effects of man-made noise, including ship, outboard engine and oil-drilling sounds, on gray whale calling and surface behaviours in the San Ignacio Lagoon, Baja, California. She reported statistically significant increases in the calling rates of gray whales and changes in calling structure (as well as swimming direction and surface behaviours) after exposure to increased noise levels during playback experiments. Although whale responses varied with the type and presentation of the noise source, she reported that gray whales generally increased their calling rates, the level of calls received, the number of frequency-modulated calls, number of pulses produced per pulsed-call series and call repetition rate as noise levels increased.

Parks *et al.* (2007) reported that surface active groups of North Atlantic right whales would adopt this strategy as the level of ambient noise increased. As ambient noise levels increased from low to high, the minimum frequency of right whale "scream calls" increased from 381.4 Hz (± 16.50), at low levels of ambient noise, to 390.3 Hz (± 15.14) at medium noise levels, to 422.4 Hz (± 15.55) at high noise levels. Surface active groups of North Atlantic right whales would also increase the duration and the inter-call interval of their vocalizations as the level of ambient noise increased. As noise levels increased from low to high, the duration of right whale "scream calls" would increase from 1.18 seconds (± 0.08) at low levels of ambient noise to 1.22 seconds (± 0.08) at high noise levels (durations decreased to 1.11 seconds ± 0.07 at medium noise levels). The inter-call intervals of these vocalizations would increase from 17.9 seconds (± 5.06) at low levels of ambient noise, to 18.5 seconds (± 4.55) at medium noise levels, to 28.1 seconds (± 4.63) at high noise levels.

Biassoni *et al.* (2001) studied the effects of exposing sining humpback whales to low-frequency active sonar in Hawai'i. They concluded that the average number of phrases did not differ with exposure; longer songs during exposure had more phrase repetitions and were, as a result, more redundant. Singers also switched from a frequency modulated to a rarer amplitude modulated phrase type overlapping sonar transmissions. Finding rapid and dynamic changes in humpback whale displays in response to LFA sonar suggests that singers have an ability to compensate for interference to anthropogenic sounds.

POTENTIAL FITNESS CONSEQUENCES OF VOCAL ADJUSTMENTS. Although the fitness consequences of these vocal adjustments remain unknown, like most other trade-offs animals must make, some of these strategies probably come at a cost (Patricelli *et al.* 2006). For example, vocalizing more loudly in noisy environments may have energetic costs that decrease the net benefits of vocal adjustment and alter the bird's energy budget (Brumm 2004, Wood and Yezerinac 2006). Lambrechts (1996) argued that shifting songs and calls to higher frequencies was also likely to incur energetic costs.

In addition, Patricelli *et al.* (2006) argued that females of many species use the songs and calls of males to determine whether a male is an appropriate potential mate (that is, the must recognize the singer as a member of their species); if males must adjust the frequency or temporal features of their vocalizations to avoid masking by noise, they may no

longer be recognized by females of the same species (Brumm 2004, Slabbekoorn and Peet 2003, Wood and Yezerinac 2006). Although this line of reasoning was developed for bird species, the same line of reasoning should apply to marine mammals, particularly for species like fin and sei whales whose song structures appear to be very similar.

However, if an animal fails to make vocal adjustments in presence of masking noise, that failure might cause the animal to experience reduced reproductive success or longevity because it fails to communicate effectively with other members of its species or social group, including potential mates.

Based on the evidence available, the endangered baleen whales that are considered in this Opinion — blue, fin, and sei whales — are not likely to experience impaired communication because they vocalize at frequencies that are much lower than mid-frequency active sonar. Because the endangered and threatened sea turtles that are considered in this Opinion do not appear to vocalize, they are not likely to experience impaired communication by mid-frequency active sonar.

Field investigations of humpback whale songs suggest that humpback whales have an upper frequency limit reaching as high as 24 kHz (Au *et al.* 2006). Based on this information, it is reasonable to assume that the active mid-frequency sonar the U.S. Navy would employ during major training and RDT&E activities is within the vocalization range of humpback whales. As a result, we assume that some of the humpback whales that are exposed to mid-frequency active sonar during one or more of the proposed exercises might experience impaired communication as a result of that exposure. Because the dominant energy in humpback whale songs and calls are in frequency ranges that are substantially lower than that of mid-frequency active sonar, however, we believe humpback whales are likely to protect the saliency of their songs and calls without making the vocal adjustments that have been reported for North Atlantic right whales confronted with increases in continuous, low-frequency sound sources.

Based on their hearing sensitivities, which overlap the frequency range of mid-frequency active sonar, the evidence available leads us to conclude that sonar transmissions might mask environmental cues at the lower range of sperm whale hearing. Although there is no published audiogram for sperm whales, these whales would be expected to have good, high frequency hearing because their inner ear resembles that of most dolphins, and appears tailored for ultrasonic (>20 kHz) reception (Ketten 1994). The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate, which suggest that neonatal sperm whales respond to sounds from 2.5 to 60 kHz.

As a result, we assume that some of the sperm whales that are exposed to mid-frequency active sonar during one or more of the proposed exercises might experience impaired communication as a result of that exposure. Because the dominant energy in sperm whale songs and calls overlaps with the frequency range of mid-frequency active sonar, sperm whales may have to make one or more of the vocal adjustments discussed in this subsection to preserve the saliency of their vocalizations. Because any reductions in the active space of sperm whales caused by active sonar transmissions associated with the proposed exercises would be temporary and episodic, any these vocal adjustments sperm whales would have to make would also be temporary.

5.3.3.4 Allostasis

Classic stress responses begin when an animal's central nervous system perceives a potential threat to its homeostasis. That perception triggers stress responses regardless of whether a stimulus actually threatens the animal; the mere perception of a threat is sufficient to trigger a stress response (Moberg 2000, Sapolsky *et al.* 2005, Seyle 1950). Once an animal's central nervous system perceives a threat, it mounts a biological response or defense that consists of a combination of the four general biological defense responses: behavioral responses, autonomic nervous system responses, neuroendocrine responses, or immune response.

In the case of many stressors, an animal's first and most economical (in terms of biotic costs) response is behavioral avoidance of the potential stressor or avoidance of continued exposure to a stressor (Box B1 of Figure 3). An animal's second line of defense to stressors involves the autonomic nervous system and the classical "fight or flight" response which includes the cardiovascular system, the gastrointestinal system, the exocrine glands, and the adrenal medulla to produce changes in heart rate, blood pressure, and gastrointestinal activity that humans commonly associate with "stress." These responses have a relatively short duration and may or may not have significant long-term effect on an animal's welfare.

An animal's third line of defense to stressors involves its neuroendocrine or sympathetic nervous systems; the system that has received the most study has been the hypothalmus-pituitary-adrenal system (also known as the HPA axis in mammals or the hypothalamus-pituitary-interrenal axis in fish and some reptiles). Unlike stress responses associated with the autonomic nervous system, virtually all neuroendocrine functions that are affected by stress – including immune competence, reproduction, metabolism, and behavior – are regulated by pituitary hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Moberg 1987, Rivier 1995, Box S1.1 of Figure 3) and altered metabolism (Elasser *et al.* 2000), reduced immune competence (Blecha 2000) and behavioral disturbance. Increases in the circulation of glucocorticosteroids (cortisol, corticosterone, and aldosterone in marine mammals; see Romano *et al.* 2004) have been equated with stress for many years.

The primary distinction between *stress* (which is adaptive and does not normally place an animal at risk) and *distress* is the biotic cost of the response. During a stress response, an animal uses glycogen stores that can be quickly replenished once the stress is alleviated. In such circumstances, the cost of the stress response would not pose a risk to the animal's welfare (the sequence of boxes beginning with Box S2 in Figure 3). However, when an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other biotic functions which impairs those functions that experience the diversion. For example, when mounting a stress response diverts energy away from growth in young animals, those animals may experience stunted growth. When mounting a stress response diversts energy from a fetus, an animal's reproductive success and its fitness will suffer. In these cases, the animals will have entered a pre-pathological or pathological state which is called "distress" (*sensu* Seyle 1950) or "allostatic loading" (*sensu* McEwen and Wingfield 2003). This pathological state will last until the animal replenishes its biotic reserves sufficient to restore normal function (the sequence of boxes beginning with Box S2 in Figure 3 illustrate the potential consequences of these stress responses for the fitness of individual animals).

Relationships between these physiological mechanisms, animal behavior, and the costs of stress responses have also been documented fairly well through controlled experiment; because this physiology exists in every vertebrate that

has been studied, it is not surprising that stress responses and their costs have been documented in both laboratory and free-living animals (for examples see, Holberton *et al.* 1996, Hood *et al.* 1998, Jessop *et al.* 2003, Krausman *et al.* 2004, Lankford *et al.* 2005, Reneerkens *et al.* 2002, Thompson and Hamer 2000). Although no information has been collected on the physiological responses of marine mammals upon exposure to anthropogenic sounds, studies of other marine animals and terrestrial animals would lead us to expect some marine mammals to experience physiological stress responses and, perhaps, physiological responses that would be classified as "distress" upon exposure to mid-frequency and low-frequency sounds.

For example, Jansen (1998) reported on the relationship between acoustic exposures and physiological responses that are indicative of stress responses in humans (for example, elevated respiration and increased heart rates). 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 noise while Krausman *et al.* (2004) reported on the auditory and physiology stress responses of endangered Sonoran pronghorn to military overflights. Smith *et al.* (2004a, 2004b) identified noise-induced physiological stress responses in hearing-specialist fish that accompanied short- (TTS) and long-term (PTS) hearing losses. Welch and Welch (1970), reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Hearing is one of the primary senses cetaceans use to gather information about their environment and to communicate with other members of their species. Although empirical information on the relationship between sensory impairment (TTS, PTS, and acoustic masking) on cetaceans remains limited, it seems reasonable to assume that reducing an animal's ability to gather information about its environment and to communicate with other members of its species would be stressful for animals that use hearing as their primary sensory mechanism. Therefore, we assume that acoustic exposures sufficient to trigger onset PTS or TTS would be accompanied by physiological stress responses because terrestrial animals exhibit those responses under similar conditions (NRC 2003). More importantly, marine mammals might experience stress responses at received levels lower than those necessary to trigger onset TTS. Based on empirical studies of the time required to recover from stress responses (Moberg 2000), we also assume that stress responses are likely to persist beyond the time interval required for animals to recover from TTS and might result in pathological and pre-pathological states that would be as significant as behavioral responses to TTS.

5.3.3.5 Behavioral Responses

When an animal encounters humans or human activities, ranging from low-flying helicopter to the quiet wildlife photographer, an animal's response appears to follow the same economic principles used by prey when they encounter predators (Beale and Monaghan 2004, Berger *et al.* 1983, Frid 2003, Frid and Dill 2002, Gill *et al.* 2000, 2001; Gill and Sutherland 2000, 2001; Harrington and Veitch 1992, Lima 1998, Madsen 1994, Romero 2004). The level of perceived risk may result from a combination of factors that characterize disturbance stimuli, along with factors related to natural predation risk (e.g., Frid 2001, Papouchis *et al.* 2001). In response to that perceived threat, animals can experience physiological changes that prepare them for flight or fight responses or they can experience physiological changes with chronic exposure to stressors that have more serious consequences such as interruptions

of essential behavioral or physiological events, alteration of an animal's time budget, or some combinations of these responses (Frid and Dill 2002, Romero 2004, Sapolsky *et al.* 2000, Walker *et al.* 2005).

The behavioral response of animals to human disturbance have been documented to cause animals to abandon nesting and foraging sites (Sutherland and Crockford 1993), cause animals to increase their activity levels and suffer premature deaths or reduced reproductive success when their energy expenditures exceed their energy budgets (Daan *et al.* 1996, Feare 1976, Giese 1996, Mullner *et al.* 2004, Waunters *et al.* 1997), or cause animals to experience higher predation rates when they adopt risk-prone foraging or migratory strategies (Frid and Dill 2002).

Based on the evidence available from empirical studies of animal responses to human disturbance, marine animals are likely to exhibit one of several behavioral responses upon being exposed to sonar transmissions:

1. they may exhibit behaviors associated with "allostasis" or physiological stress responses (see the preceding discussion under Allostasis and Boxes B1 or B2 and S of Figure 3, which illustrates the potential consequences of behavioral responses to stress);
2. they may engage in horizontal or vertical avoidance behavior to avoid exposure or continued exposure to a sound that is painful, noxious, or that they perceive as threatening (Box B1 of Figure 3) or may abandon an area;
3. they may respond to an acoustic exposure using evasive or escape behaviors, which a more extreme form of avoidance that is probably accompanied by physiological stress responses (see Box B2 of Figure 3);
4. they may continue their pre-exposure behavior and cope with the behavioral consequences of continued exposure (Box B2 of Figure 3), and
5. they may habituate to a sound or series of sounds or they might not perceive a potential sound as threatening (Box N of Figure 3).

In every instance, we are generally concerned about changes in an animals' pre-disturbance behavior — for example, a change from resting or foraging to horizontal or vertical avoidance — because we would generally conclude that animals that do not change their behavioral state or change the rate of particular behavioral acts are either not responding to a stimulus or any responses are physiological (for example, allostasis) rather than behavioral.

After being exposed to Navy vessels, sound field associated with active sonar, or both, marine animals might experience one or more of these behavioral responses or they might exhibit a sequence of several of the behaviors presented in the preceding list (for example, an animal might continue its pre-disturbance behavior for a period of time, then abandon an area after it experiences the consequences of physiological stress) or one of these behaviors might accompany responses such as permanent or temporary loss in hearing sensitivity. The narratives that follow summarize the information available on these behavioral responses.

BEHAVIORAL AVOIDANCE OF INITIAL OR CONTINUED EXPOSURE. As used in this Opinion, *behavioral avoidance* refers to animals that abandon an area in which active sonar is being used to avoid being exposed to the sonar (regardless of how long it takes them to return), animals that avoid being exposed to the entire sound field produced by active

sonar; and animals that avoid being exposed to particular received levels within a sound field produced by active sonar.

Richardson *et al.* (1995) noted that avoidance reactions are the most obvious manifestations of disturbance in marine mammals. There are few empirical studies of avoidance responses of free-living cetaceans to mid-frequency sonar. However, Maybaum (1993) conducted sound playback experiments to assess the effects of mid-frequency active sonar on humpback whales in Hawai'ian waters. Specifically, he exposed focal pods to sounds of a 3.3-kHz sonar pulse, a sonar frequency sweep from 3.1 to 3.6 kHz, and a control (blank) tape while monitoring the behavior, movement, and underwater vocalizations. The two types of sonar signals differed in their effects on the humpback whales, the whales exhibited avoidance behavior when exposed to both sounds. The whales responded to the pulse by increasing their distance from the sound source and responded to the frequency sweep by increasing their swimming speeds and track linearity. Bowles *et al.* (1994) reported that sperm whales appeared to have altered their distribution to avoid being exposed to the low-frequency transmissions associated with the Heard Island Feasibility Test and the whales returned when the transmissions stopped.

More recently, Kvadsheim *et al.* (2007) conducted a controlled exposure experiment in which killer whales (*Orcinus orca*) that had been fitted with D-tags were exposed to mid-frequency active sonar (Source A: a 1.0 s upsweep 209 dB @ 1 - 2 kHz every 10 seconds for 10 minutes; Source B: with a 1.0 s upsweep 197 dB @ 6 - 7 kHz every 10 s for 10 min). When exposed to Source A, a tagged whale and the group it was traveling with did not appear to avoid the source. When exposed to Source B, the tagged whales along with other whales that had been carousel feeding, ceased feeding during the approach of the sonar and moved rapidly away from the source. When exposed to Source B, Kvadsheim and his co-workers reported that a tagged killer whale seemed to try to avoid further exposure to the sound field by immediately swimming away (horizontally) from the source of the sound; by engaging in a series of erratic and frequently deep dives that seem to take it below the sound field; or by swimming away while engaged in a series of erratic and frequently deep dives. Although the sample sizes in this study are too small to support statistical analysis, the behavioral responses of the orcas were consistent with the results of other studies.

Blue and fin whales have occasionally been reported in areas ensonified by airgun pulses; however, there have been no systematic analyses of their behavioral reactions to airguns. Sightings by observers on seismic vessels off the United Kingdom suggest that, at times of good sightability, the number of blue, fin, sei, and humpback whales seen when airguns are shooting are similar to the numbers seen when the airguns are not shooting (Stone 1997, 1998, 2000, 2001). However, fin and sei whale sighting rates were higher when airguns were shooting, which may result from their tendency to remain at or near the surface at times of airgun operation (Stone 2003). The analysis of the combined data from all years indicated that baleen whales stayed farther from airguns during periods of shooting (Stone 2003). Baleen whales also altered course more often during periods of shooting and more were headed away from the vessel at these times, indicating some level of localized avoidance of seismic activity (Stone 2003).

Brownell (2004) reported the behavioral responses of western gray whales off the northeast coast of Sakhalin Island to sounds produced by seismic activities in that region. In 1997, the gray whales responded to seismic activities by changing their swimming speed and orientation, respiration rates, and distribution in waters around the seismic surveys. In 2001, seismic activities were conducted in a known feeding area of these whales and the whales left the feeding area and moved to areas farther south in the Sea of Okhotsk. They only returned to the feeding are several

days after the seismic activities stopped. The potential fitness consequences of displacing these whales, especially mother-calf pairs and "skinny whales," outside of their the normal feeding area is not known; however, because gray whales, like other large whales, must gain enough energy during the summer foraging season to last them the entire year. Sounds or other stimuli that cause them to abandon a foraging area for several days seems almost certain to disrupt their energetics and force them to make trade-offs like delaying their migration south, delaying reproduction, reducing growth, or migrating with reduced energy reserves.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 second pulsed sounds at frequencies similar to those emitted by the multi-beam sonar that is used by geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid a sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such responses to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). It is not clear whether or to what degree the responses of captive animals might be representative of the responses of marine animals in the wild. For example, wild cetaceans sometimes avoid sound sources well before they are exposed to received levels such as those used in these experiments. Further, the responses of marine animals in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

Richardson *et al.* (1995a) and Richardson (1997, 1998) used controlled playback experiments to study the response of bowhead whales in Arctic Alaska. In their studies, bowhead whales tended to avoid drill ship noise at estimated received levels of 110 to 115 dB and seismic sources at estimated received levels of 110 to 132 dB. Richardson *et al.* (1995) concluded that some marine mammals would tolerate continuous sound at received levels above 120 dB re 1 μPa for a few hours. These authors concluded that most marine mammals would avoid exposures to received levels of continuous underwater noise greater than 140 dB when source frequencies were in the animal's most sensitive hearing range.

Several authors noted that migrating whales are likely to avoid stationary sound sources by deflecting their course slightly as they approached a source (LGL and Greenridge 1987 in Richardson *et al.* 1995). Malme *et al.* (1983, 1984) studied the behavioral responses of gray whales (*Eschrictius robustus*) that were migrating along the California coast to various sound sources located in their migration corridor. The whales they studied showed statistically significant responses to four different underwater playbacks of continuous sound at received levels of approximately 120 dB. The sources of the playbacks were typical of a drillship, semisubmersible, drilling platform, and production platform.

Morton *et al.* (2004) exposed killer whales (*Orcinus orca*) to sounds produced by acoustic harassment devices (devices that were designed to harass harbor seals, source levels were 194 dB at 10 kHz re 1μPa at 1 meter). They concluded that observations of killer whales declined dramatically in the experimental area (Broughton Archipelago) during the time interval the harassment devices had been used (but not before or after the use). Other investigators

concluded that gray whales and humpback whales abandoned some of their coastal habitat in California and Hawai'i, respectively, because of underwater noise associated with extensive vessel traffic (Gard 1974, Reeves 1977, Salden 1988).

Nowacek *et al.* (2004) conducted controlled exposure experiments on North Atlantic right whales using ship noise, social sounds of con-specifics, and an alerting stimulus (frequency modulated tonal signals between 500 Hz and 4.5 kHz). Animals were tagged with acoustic sensors (D-tags) that simultaneously measured movement in three dimensions. Whales reacted strongly to alert signals at received levels of 133-148 dB SPL, mildly to conspecific signals, and not at all to ship sounds or actual vessels. The alert stimulus caused whales to immediately cease foraging behavior and swim rapidly to the surface.

Several studies have demonstrated that cetaceans will avoid human activities such as vessel traffic, introduced sounds in the marine environment, or both. Lusseau (2003) reported that bottlenose dolphins in Doubtful Sound, New Zealand, avoided approaching tour boats by increasing their mean diving interval. Male dolphins began to avoid tour boats before the boats were in visible range, while female dolphins only began to avoid the boats when the boats became intrusive (he attributed the differential responses to differences in energetics: the larger body size of male dolphins would allow them to compensate for the energy costs of the avoidance behavior more than female dolphins). Bejder *et al.* (2006) studied the effects of vessel traffic on bottlenose dolphins in Shark Bay, Australia, over three consecutive 4.5-year periods. They reported that the dolphins avoided the bay when two tour operators began to operate in the bay.

Marine mammals may avoid or abandon an area temporarily during periods of high traffic or noise, returning when the source of the disturbance declines below some threshold (Lusseau 2004, Allen and Read 2000). Alternatively, they might abandon an area for as long as the disturbance persists. For example, Bryant *et al.* (1984 *in* Polefka 2004) reported that gray whales abandoned a calving lagoon in Baja California, Mexico following the initiation of dredging and increase in small vessel traffic. After the noise-producing activities stopped, the cow-calf pairs returned to the lagoon; the investigators did not report the consequences of that avoidance on the gray whales. Gard (1974) and Reeves (1977) reported that underwater noise associated with vessel traffic had caused gray whales to abandon some of their habitat in California for several years. Salden (1988) suggested that humpback whales avoid some nearshore waters in Hawai'i for the same reason.

As Bejder *et al.* (2006) argued, animals that are faced with human disturbance must evaluate the costs and benefits of relocating to alternative locations; those decisions would be influenced by the availability of alternative locations, the distance to the alternative locations, the quality of the resources at the alternative locations, the conditions of the animals faced with the decision, and their ability to cope with or "escape" the disturbance (citing Beale and Monaghan 2004a, 2004b; Gill *et al.* 2001, Frid and Dill 2002, Lima and Dill 1990). When animals shift from one site to an alternative site, we should assume that the costs of tolerating a disturbance have exceeded any benefits of remaining in the location they are leaving.

The evidence available suggests that most marine mammals will try to avoid continued exposed to mid-frequency active sonar (if the sonar is a salient acoustic signal given their hearing sensitivity), the ships associated with the active sonar, or both. However, the process of avoiding exposures can be costly to marine animals if (a) they are

forced to abandon a site that is important to their life history (for example, if they are forced to abandon a feeding or calving area), (b) their flight response disrupts and important life history event (for example, reproduction), or (c) their diving pattern becomes sufficiently erratic, or if they strand or experience higher predation risk during the process of abandoning a site.

The evidence available also suggests that marine mammals might experience more severe consequences if they are compelled to avoid continued exposure to active sonar, but circumstances do not allow them to avoid or "escape" further exposure. At least six circumstances might prevent an animal's from escaping further exposure to mid-frequency active sonar and could produce any of one the following outcomes:

1. when swimming away (an attempted "escape") brings marine mammals into a shallow coastal feature that causes them to strand;
2. they cannot swim away because the exposure occurred in a coastal feature that leaves marine mammals no "escape" route (for example, a coastal embayment or fjord that surrounds them with land on three sides, with the sound field preventing an "escape");
3. they cannot swim away because the marine mammals are exposed to multiple sound fields in a coastal or oceanographic feature that act in concert to prevent their escape;
4. they cannot dive "below" the sound field while swimming away because of shallow depths;
5. to remain "below" the sound field, they must engage in a series of very deep dives with interrupted attempts to swim to the surface (which might lead to pathologies similar to those of decompression sickness);
6. any combination of these phenomena.

Although causal relationships between beaked whale stranding events and active sonar remain unknown, several authors have hypothesized that stranding events involving these species in the Bahamas and Canary Islands may have been triggered when the whales changed their dive behavior to avoid exposure to active sonar (Cox *et al.* 2006, Rommel *et al.* 2006). These authors proposed two mechanisms by which the behavioral responses of beaked whales upon being exposed to active sonar might result in a stranding event. First, beaked whales that occur in deep waters that are in close proximity to shallow waters (for example, the "canyon areas" that are cited in the Bahamas stranding event; see D'Spain and D'Amico 2006), may respond to active sonar by swimming into shallow waters to avoid further exposures and strand if they were not able to swim back to deeper waters.

Second, beaked whales exposed to active sonar might alter their dive behavior (see Box B1.2.1 of Figure 3). Changes in their dive behavior might cause them to remain at the surface or at depth for extended periods of time which could lead to hypoxia directly by increasing their oxygen demands or indirectly by increasing their energy expenditures (to remain at depth) and increase their oxygen demands as a result. If beaked whales are at depth when they detect a ping from an active sonar transmission and change their dive profile leading to formation of significant gas bubbles, which damage multiple organs or interfere with normal physiological function (Cox *et al.* 2006, Rommel *et al.* 2006, Zimmer and Tyack 2007).

Because many species of marine mammals make repetitive and prolonged dives to great depths, it has long been assumed that marine mammals have evolved physiological mechanisms to protect against the effects of rapid and repeated decompressions. Although several investigators have identified physiological adaptations that may protection marine mammals against nitrogen gas supersaturation (alveolar collapse and elective circulation; Kooyman *et al.* 1972; Ridgway and Howard 1979), Ridgway and Howard (1979) reported that bottlenose dolphins (*Tursiops truncatus*) that were trained to dive repeatedly had muscle tissues that were substantially supersaturated with nitrogen gas. Houser *et al.* (2001) used these data to model the accumulation of nitrogen gas within the muscle tissue of other marine mammal species and concluded that cetaceans that dive deep and have slow ascent or descent speeds would have tissues that are more supersaturated with nitrogen gas than other marine mammals.

Based on these data, Cox *et al.* (2006) hypothesized that a critical dive sequence might make beaked whales more prone to stranding in response to acoustic exposures. The sequence began with (1) very deep (to depths as deep as 2 kilometers) and long (as long as 90 minutes) foraging dives with (2) relatively slow, controlled ascents, followed by (3) a series of "bounce" dives between 100 and 400 meters in depth (also see Zimmer and Tyack 2007). They concluded that acoustic exposures that disrupted any part of this dive sequence (for example, causing beaked whales to spend more time at surface without the bounce dives that are necessary to recover from the deep dive) could produce excessive levels of nitrogen super-saturation in their tissues, leading to gas bubble and emboli formation that produces pathologies similar to decompression sickness.

POTENTIAL FITNESS CONSEQUENCES OF BEHAVIORAL AVOIDANCE. As discussed in the introduction to this subsection of our response analyses, several authors have reported that disturbance stimuli cause animals to abandon nesting and foraging sites (Sutherland and Crockford 1993), cause animals to increase their activity levels and suffer premature deaths or reduced reproductive success when their energy expenditures exceed their energy budgets (Daan *et al.* 1996, Feare 1976, Giese 1996, Mullner *et al.* 2004, Waunters *et al.* 1997), or cause animals to experience higher predation rates when they adopt risk-prone foraging or migratory strategies (Frid and Dill 2002). Each of these studies addressed the consequences the occur when animals shift from one behavioral state (for example, resting or foraging) to another behavioral state (avoidance or escape behavior) because of human disturbance or disturbance stimuli.

If marine mammals respond to Navy vessels that are transmitting active sonar in the same way that they might respond to a predator, their probability of flight responses should increase when they perceive that Navy vessels are approaching them directly, because a direct approach may convey detection and intent to capture (Burger and Gochfeld 1981, 1990, Cooper 1997, 1998). The probability of avoidance responses should also increase as received levels of active sonar increase (and the ship is, therefore, closer) and as ship speeds increase (that is, as approach speeds increase). For example, the probability of flight responses in Dall's sheep *Ovis dalli dalli* (Frid 2001*a,* 2001*b*), ringed seals *Phoca hispida* (Born *et al.* 1999), Pacific brant (*Branta bernicl nigricans*) and Canada geese (*B. Canadensis*) increased as a helicopter or fixed-wing aircraft approached groups of these animals more directly (Ward *et al.* 1999). Bald eagles (*Haliaeetus leucocephalus*) perched on trees alongside a river were also more likely to flee from a paddle raft when their perches were closer to the river or were closer to the ground (Steidl and Anthony 1996).

One consequence of behavioral avoidance results from changing the energetics of marine mammals because of the energy required to avoid surface vessels or the sound field associated with active sonar (Frid and Dill 2002). Most animals can avoid that energetic cost by swimming away at slow speeds or those speeds that are at or near the minimum cost of transport (Miksis-Olds 2006), as has been demonstrated in Florida manatees (Hartman 1979, Miksis-Olds 2006).

Those costs increase, however, when animals shift from a resting state, which is designed to conserve an animal's energy, to an active state that consumes energy the animal would have conserved it they had not been disturbed. Marine mammals that have been disturbed by anthropogenic noise and vessel approaches are commonly reported to shift from restirng behavioral states to active behavioral states, which would imply that the incur an energy cost. Morete *et al.* (2007) reported that undisturbed humpback whale cows that were accompanied by their calves were frequently observed resting while their calves circled them (milling) and rolling interspersed with dives. When vessel approached, the amount of time cows and calves spent resting and milling, respectively declined significantly. These results are similar to those reported by Scheidat *et al.* (2004) for the humpback whales they observed off the coast of Ecuador.

Constantine and Brunton (2001) reported that bottlenose dolphins in the Bay of Islands, New Zealand only engaged in resting behavior 5 percent of the time when vessels were within 300 meters compared with 83 percent of the time when vessels were not present. Miksis-Olds (2006) and Miksis-Olds *et al.* (2005) reported that Florida manatees in Sarasota Bay, Florida, reduced the amount of time they spent milling and increased the amount of time they spent feeding when background noise levels increased. Although the acute costs of these changes in behavior are not likely to exceed an animals' ability to compensate, the chronic costs of these behavioral shifts are uncertain

Based on the evidence available, we believe the endangered whales that are being considered in this Opinion are likely to avoid being exposed to Navy training exercises or, if they are exposed, are likely to avoid continued exposure to the exercises. Fin, humpback, sei, and sperm whales would probably be alerted to the start of an exercise by the low-frequency sounds produced by Navy surface vessels entering an area to begin an exercise. Because waters off southern California is an important foraging area for blue, fin, humpback, sei, and sperm whales, they seem likely to try to avoid an area in which surface vessels area moving at speed accompanied by active sonar transmissions, low-frequency sounds produced by aircraft and helicopters, sonobuoys, and submarines.

ATTENTIONAL CAPTURE. Attention is the cognitive process of selectively concentrating on one aspect of an animal's environment while ignoring other things (Posner 1994). Because animals (including humans) have limited cognitive resources, there is a limit to how much sensory information they can process at any time. The phenomenon called "attentional capture" occurs when a stimulus (usually a stimulus that an animal is not concentrating on or attending to) "captures" an animal's attention. This shift in attention can occur consciously or unconsciously (for example, when an animal hears sounds that it associates with the approach of a predator) and the shift in attention can be sudden (Dukas 2002, van Rij 2007). Once a stimulus has captured an animal's attention, the animal can respond by ignoring the stimulus, assuming a "watch and wait" posture, or treat the stimulus as a disturbance and respond accordingly, which includes scanning for the source of the stimulus or "vigilance" (Cowlishaw *et al.* 2004).

Vigilance is normally an adaptive behavior that helps animals determine the presence or absence of predators, assess their distance from conspecifics, or to attend cues from prey (Bednekoff and Lima 1998, Treves 2000). Despite those benefits, however, vigilance has a cost of time: when animals focus their attention on specific environmental cues, it is not attending to other activities such a foraging. These costs have been documented best in foraging animals, where vigilance has been shown to substantially reduce feeding rates (Saino 1994, Beauchamp and Livoreil 1997, Fritz *et al.* 2002).

Animals will spend more time being vigilant, which translates to less time foraging or resting, when disturbance stimuli approach them more directly, remain at closer distances, have a greater group size (for example, multiple surface vessels), or when they co-occur with times that an animal perceives increased risk (for example, when they are giving birth or accompanied by a calf). Most of the published literature, however, suggests that direct approaches will increase the amount of time animals will dedicate to being vigilant. For example, bighorn sheep and Dall's sheep dedicated more time being vigilant, and less time resting or foraging, when aircraft made direct approaches over them (Frid 2001, Stockwell *et al.* 1991).

Several authors have established that long-term and intense disturbance stimuli can cause population declines by reducing the body condition of individuals that have been disturbed, followed by reduced reproductive success, reduced survival, or both (Daan *et al.* 1996, Madsen 1994, White 1983). For example, Madsen (1994) reported that pink-footed geese (*Anser brachyrhynchus*) in undisturbed habitat gained body mass and had about a 46% reproductive success compared with geese in disturbed habitat (being consistently scared off the fields on which they were foraging) which did not gain mass and has a 17% reproductive success. Similar reductions in reproductive success have been reported for mule deer (*Odocoileus hemionus*) disturbed by all-terrain vehicles (Yarmoloy *et al.* 1988), caribou disturbed by seismic exploration blasts (Bradshaw *et al.* 1998), caribou disturbed by low-elevation military jet-fights (Luick *et al.* 1996), and caribou disturbed by low-elevation jet flights (Harrington and Veitch 1992). Similarly, a study of elk (*Cervus elaphus*) that were disturbed experimentally by pedestrians concluded that the ratio of young to mothers was inversely related to disturbance rate (Phillips and Alldredge 2000).

The primary mechanism by which increased vigilance and disturbance appear to affect the fitness of individual animals is by disrupting an animal's time budget and, as a result, reducing the time they might spend foraging and resting (which increases an animal's activity rate and energy demand). For example, a study of grizzly bears (*Ursus horribilis*) reported that bears disturbed by hikers reduced their energy intake by an average of 12 kcal/min (50.2 x 10^3kJ/min), and spent energy fleeing or acting aggressively toward hikers (White *et al.* 1999).

Nevertheless, other investigators concluded that when food handling does not require visual attention, a foraging animal can avoid the energetic costs and costs in time associated with vigilance (Bednekoff and Lima 1998, Cowlishaw *et al.* 2004, Lima 1988). In these cases, however, the foraging animals relied on one sensory modality (vision) to detect food and another sensory modality (hearing) to remain aware of the approximate location and proximity of potential predators. We assume that endangered or threatened marine animals that might be foraging in the Southern California Range Complex would be able to remain aware of the number of surface vessels, proximity, speed, and approach vector through acoustic cues while foraging when they are not proximate to the ships (at distances that would normally cause them to avoid rather than evade the ships). At distances that might elicit evasive or escape behavior, however, we assume that endangered or threatened marine mammals would dedicate most or all

of their attention on the vessels. Although we cannot discount interrupted foraging caused by vigilance behavior, marine mammals in the Southern California Range Complex seems more likely to experience disrupted foraging during attempts to evade approaching surface vessels or received levels of active sonar than because of vigilance behavior.

CONTINUED PRE-DISTURBANCE BEHAVIOR, HABITUATION, OR NO RESPONSE (Box B2 of Figure 3). Under some circumstances, some of individuals that are exposed to active sonar transmissions will continue their normal behavioral activities; in other circumstances, individual animals will become aware of the sonar transmissions at lower received levels and move to avoid additional exposure or exposures at higher received levels (Richardson *et al.* 1995).

It is difficult to distinguish between animals that continue their pre-disturbance behavior without stress responses, animals that continue their behavior but experience stress responses (that is, animals that cope with disturbance), animals that habituate to disturbance (that is, they may have experienced low-level stress responses initially, but those responses abated over time), and animals that do not respond to the potential disturbance.

Watkins (1986) reviewed data on the behavioral reactions of fin, humpback, right and minke whales that were exposed to continuous, broadband low-frequency shipping and industrial noise in Cape Cod Bay is informative. He concluded that underwater sound was the primary cause of behavioral reactions in these species of whales and that the whales responded behaviorally to acoustic stimuli within their respective hearing ranges. Watkins also noted that whales showed the strongest behavioral reactions to sounds in the 15 Hz to 28 kHz range, although negative reactions (avoidance, interruptions in vocalizations, etc.) were generally associated with sounds that were either unexpected, too loud, suddenly louder or different, or perceived as being associated with a potential threat (such as an approaching ship on a collision course). In particular, whales seemed to react negatively when they were within 100 m of the source or when received levels increased suddenly in excess of 12 dB relative to ambient sounds. At other times, the whales ignored the source of the signal and all four species habituated to these sounds.

Nevertheless, Watkins concluded that whales ignored most sounds in the background of ambient noise, including the sounds from distant human activities even though these sounds may have had considerable energies at frequencies well within the whale's range of hearing. Further, he noted that fin whales were initially the most sensitive of the four species of whales, followed by humpback whales; right whales were the least likely to be disturbed and generally did not react to low-amplitude engine noise. By the end of his period of study, Watkins (1986) concluded that fin and humpback whales have generally habituated to the continuous, broad-band, noise of Cape Cod Bay while right whales did not appear to change their response.

Aicken *et al.* (2005) monitored the behavioral responses of marine mammals to a new low-frequency active sonar system that was being developed for use by the British Navy. During those trials, fin whales, sperm whales, Sowerby's beaked whales, long-finned pilot whales (*Globicephala melas*), Atlantic white-sided dolphins, and common bottlenose dolphins were observed and their vocalizations were recorded. These monitoring studies detected no evidence of behavioral responses that the investigators could attribute to exposure to the low-frequency active sonar during these trials (some of the responses the investigators observed may have been to the vessels used for the monitoring).

5.3.3.6 Stranding Events

In what follows, we address the evidence bearing on assertions from several NGOs and scientific investigator that low-frequency active sonar causes marine mammals to "strand." Some authors seemed to have contradicted themselves by first publishing articles that initially identified low frequency active sonar as the "cause" of marine mammal stranding events in the Canary Islands and the Mediterranean Sea, then later publishing articles that identify mid-frequency active sonar as the "cause" of those stranding events after the Bahamas stranding report became available. These causal claims are incoherent: the beaked whale stranding events had a causal association with either low frequency active sonar, mid-frequency active sonar, a combination of the two, or neither of the two. The earlier claims (for example, Frantis 1998) asserting low-frequency active sonar as causal are not compatible with the revised claims of a causal relationship between the stranding events and mid-frequency active sonar. As of the date of this Opinion, none of these authors have published retractions, corrections, or clarifications of their published arguments on whether they believe exposure to low-frequency active sonar, mid-frequency active sonar, or both, caused the stranding events or was a contributing cause of those events.

Despite the small number of instances in which marine mammal stranding events have been associated with mid-frequency active sonar usage and despite the fact that none of these stranding events involved endangered or threatened species, the amount of controversy that surrounds this issue requires us to address it. For these analyses, we defined a "stranded marine mammal" as "any dead marine mammal on a beach or floating nearshore; any live cetacean on a beach or in water so shallow that it is unable to free itself and resume normal activity; any live pinniped which is unable or unwilling to leave the shore because of injury or poor health" (Gulland *et al.* 2001, Wilkinson 1991).

Marine mammals are known to strand for a variety of reasons, although the cause or causes of most stranding are unknown (Geraci *et al.* 1976, Eaton 1979, Odell *et al.* 1980, Best 1982). Klinowska (1985, 1986) correlated marine mammal stranding events and geomagnetism and geomagnetic disturbance. Numerous other studies suggest that the physiology, behavior, habitat relationships, age, or condition of cetaceans may cause them to strand or might pre-dispose them the strand when exposed to another phenomenon. For example, several studies of stranded marine mammals suggest a linkage between unusual mortality events and body burdens of toxic chemicals in the stranded animals (Kajiwara *et al.* 2002, Kuehl and Haebler 1995, Mignucci-Giannoni *et al.* 2000). These suggestions are consistent with the conclusions of numerous other studies that have demonstrated that combinations of dissimilar stressors commonly combine to kill an animal or dramatically reduce its fitness, even though one exposure without the other does not produce the same result (Chroussos 2000, Creel 2005, DeVries *et al.* 2003, Fair and Becker 2000, Foley *et al.* 2001, Moberg 2000, Relyea 2005a, 2005b, Romero 2004, Sih *et al.* 2004).

Those studies suggest that, in many animal species, disease, reproductive state, age, experience, stress loading, energy reserves, and genetics combine with other stressors like body burdens of toxic chemicals to create fitness consequences in individual animals that would not occur without these risk factors. The contribution of these potential risk factors to stranding events (or causal relationships between these risk factors and stranding events) is still unknown, but the extensive number of published reports in the literature suggests that an experiment investigation into a causal relationship is warranted

Over the past three decades, several "mass stranding" events — stranding events that involve two or more individuals of the same species (excluding a single cow-calf pair) — that have occurred over the past two decades have been associated with naval operations, seismic surveys, and other anthropogenic activities that introduce sound into the marine environment.

Although only one of these events involved threatened or endangered species, we analyzed the information available on stranding events to determine if listed cetaceans are likely to strand following an exposure to mid-frequency active sonar. To conduct these analyses, we searched for and collected any reports of mass stranding events of marine mammals and identified any causal agents that were associated with those stranding events.

Global Stranding Patterns

Several sources have published lists of mass stranding events of cetaceans during attempts to identify relationships between those stranding events and military sonar (Hildebrand 2004, IWC 2005, Taylor *et al.* 2004). For example, based on a review of stranding records between 1960 and 1995, the International Whaling Commission (2005) identified ten mass stranding events of Cuvier's beaked whales had been reported and one mass stranding of four Baird's beaked whale (*Berardius bairdii*). The IWC concluded that, out of eight stranding events reported from the mid-1980s to the summer of 2003, seven had been associated with the use of mid-frequency sonar, one of those seven had been associated with the use of low-frequency sonar, and the remaining stranding event had been associated with the use of seismic airguns.

Taxonomic Patterns

Most of the stranding events reviewed by the International Whaling Commission involved beaked whales. A mass stranding of Cuvier's beaked whales (*Ziphius cavirostris*) in the eastern Mediterranean Sea occurred in 1996 (Franzis 1998) and mass stranding events involving Gervais' beaked whales (*Mesoplodon europaeus*), de Blainville's dense-beaked whales (*M. densirostris*), and Cuvier's beaked whales occurred off the coast of the Canary Islands in the late 1980s (Simmonds and Lopez-Jurado 1991). Other stranding events of beaked whales have also occurred in the Bahamas and Canary Islands (which included Gervais' beaked whales, *Mesoplodon europaeus*, de Blainville's dense-beaked whales, *M. densirostris*, and Cuvier's beaked whales; Simmonds and Lopez-Jurado 1991). The stranding events that occurred in the Canary Islands and Kyparissiakos Gulf in the late 1990s and the Bahamas in 2000 have been the most intensively-studied mass stranding events and have been associated with naval maneuvers that were using sonar. These investigations did not evaluate information associated with the stranding of Cuvier's beaked whales, *Ziphius cavirostris*, around Japan (IWC Scientific Committee 2005).

Between 1960 and 2006, 48 (68%) of the stranding events that have been reported involved beaked whales, 3 (4%) involved dolphins, and 14 (20%) involved whale species. Cuvier's beaked whales were involved in the greatest number of these events (48 or 68%), followed by sperm whales (7 or 10%), and Blainville and Gervais' beaked whales (4 each or 6%). Naval activities that are reported to have included active sonar coincided with 9 (13%) or 10 (14%) of those stranding events. Between the mid-1980s and 2003 (the period reported by the International Whaling Commission), we identified reports of 44 mass cetacean stranding events of which at least 7 have been correlated with naval exercises that were using mid-frequency sonar.

Stranding events involving baleen whales (blue, bowhead, Bryde's, fin, gray, humpback, minke, right, and sei whales) and stranding events involving sperm whales have very different patterns than those of beaked whales and other smaller cetaceans. First, mass stranding events of baleen whales are very rare. Fourteen humpback whales stranded on the beaches of Cape Cod, Massachusetts between November 1987 and January 1988 (Geraci *et al.* 1989); however, that stranding event has been accepted as being caused by neurotoxins in the food of the whales. In 1993, three humpback whales stranded on the east coast of Sao Vincente Island in the Cape Verde Archipelago, but they were in an advanced state of decay when they stranded so their cause of death remains unknown (Reiner *et al.* 1996). Finally, two minke whales (*Balaenoptera acutirostra*) stranded during the mass stranding event in the Bahamas in 2000 (see further discussion of this stranding event below) and is noteworthy because it the only mass stranding of baleen whales that has coincided with the Navy's use of mid-frequency active sonar and because there are so few mass stranding events involving baleen whales.

Sperm whales, however, commonly strand and commonly strand in groups. Our earliest record of a mass stranding of sperm whales is for six sperm whales that stranded in Belgium in 1403 or 1404 (De Smet 1997). Since then, we have identified 85 mass stranding events involving sperm whales have been reported. Of those 85 mass stranding events, 29 represent stranding events that occurred before 1958; 25 of those 29 (about 34%) stranding events occurred before 1945 (which would pre-date the use of this mid-frequency active sonar). Ten of these stranding events involved sperm whales and long-finned pilot whales (*Globicephala melas*). These mass stranding events have been reported in Australia, Europe, North America, Oceania, and South America.

Major Mass Stranding Events

In 1998, the North Atlantic Treaty Organization (NATO) Supreme Allied Commander, Atlantic Center Undersea Research Centre that conducted the sonar tests convened panels to review the data associated with the maneuvers in 1996 and beaked whale stranding events in the Mediterranean Sea. The report of these panels presented more detailed acoustic data than were available for beaked whales stranded in the Canary Islands (SACLANTCEN 1998). The NATO sonar transmitted two simultaneous signals lasting four seconds and repeating once every minute.

The simultaneous signals were broadcast at source levels of just under 230 dB re 1 μPa at 1 m. One of the signals covered a frequency range from 450-700 Hz and the other one covered 2.8-3.3 kHz. The *Ziphius* stranding events in the Kyparissiakos Gulf occurred during the first two sonar runs on each day of 12 and 13 May 1996. The close timing between the onset of sonar transmissions and the first stranding events suggests closer synchrony between the onset of the transmissions and the stranding events than was presented in Frantzis (1998). However, the Bioacoustics Panel convened by NATO concluded that the evidence available did not allow them to accept or reject sonar exposures as a causal agent in these stranding events. Their official finding was "An acoustic link can neither be clearly established nor eliminated as a direct or indirect cause for the May 1996 strandings."

KYPARISSIAKOS GULF, GREECE (1996). Frantzis (1998) reported an 'atypical' mass stranding of 12 Cuvier's beaked whales on the coast of Greece that was associated with acoustic trials by vessels from the North Atlantic Treaty Organisation (NATO). He was the first to hypothesize that these stranding events were related to exposure to low-frequency military sonar. However, the sonar in question produced both low- and mid-frequency signals (600Hz, 228 dB SPL re: 1μPa at 1m rms and 3kHz, 226 dB SPL, D'Amico and Verboom, 1998). Frantzis' hypothesis

prompted an in-depth analysis of the acoustic activity during the naval exercises, the nature of the stranding events and the possibility that the acoustic source was related to the stranding events (D'Amico and Verboom, 1998). Since full necropsies had not been conducted and no gross or histological abnormalities were noted, the cause of the stranding events could not be determined unequivocally (D'Amico and Verboom, 1998). The analyses thus provided some support but no clear evidence for the hypothesized cause-and-effect relationship of sonar operations and stranding events.

BAHAMAS (2000). Concern about potential causal relationships between low-frequency sonar and marine mammal stranding resurfaced after a beaked whale stranding in the Bahamas in 2000. Fox *et al.* (2001) ruled out natural sound sources as a possible cause of the stranding, which pointed to an anthropogenic source. In 2001, the *Joint Interim Report, Bahamas Marine Mammal Stranding Event of 14-16 March 2000* (U.S. Department of Commerce and Secretary of the Navy 2001) exonerated the low-frequency sonar but concluded that "tactical mid-range frequency sonar onboard U.S. Navy ships that were in use during the sonar exercise in question were the most plausible source of this acoustic or impulse trauma." The report also went on to conclude, "the cause of this stranding event was the confluence of Navy tactical mid-range frequency sonar and the contributory factors acting together." The contributory factors identified included "a complex acoustic environment that included the presence of a strong surface duct, unusual underwater bathymetry, intensive use of multiple sonar over an extended period of time, a constricted channel with limited access, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars."

MADEIRA, SPAIN (2000). The stranding in the Bahamas was soon followed by another atypical mass stranding of Cuvier's beaked whales in the Madeira Islands. Between 10 and 14 May 2000, three Cuvier's beaked whales stranded on two islands in the Madeira archipelago. NATO naval exercises involving multiple ships occurred concurrently with these stranding events, although NATO has thus far been unwilling to provide information on the sonar activity during their exercises. Only one of the stranded animals was marginally fresh enough for a full necropsy (24 hours post-stranding). The necropsy revealed evidence of haemorrhage and congestion in the right lung and both kidneys (Freitas, 2004), as well as evidence of intracochlear and intracranial haemorrhage similar to that observed in the Bahamas beaked whales (D. Ketten, unpublished data).

CANARY ISLANDS (2002). In September 2002, a beaked whale stranding event occurred in the Canary Islands. On 24 September, 14 beaked whales (7 Cuvier's beaked whales, 3 Blainville's beaked whales, 1 Gervais' beaked whale, *M. europeaus*, and 3 unidentified beaked whales) stranded on the beaches of Fuerteventura and Lanzarote Islands, close to the site of an international naval exercise (called Neo-Tapon 2002) held that same day. The first animals are reported to have stranded about four hours after the onset of the use of mid-frequency sonar activity (3- 10kHz, D'Spain *et al.* 2006; Jepson *et al.* 2003). Seven whales (1 female Blainville's beaked whale, 1 female Gervais' beaked whale and 5 male Cuvier's beaked whales) are known to have died that day (Fernández *et al.* 2005). The remaining seven live whales were returned to deeper waters. Over the next three days, three male and one female Cuvier's beaked whales were found dead and a carcass of an unidentified beaked whale was seen floating offshore.

A total of nine Cuvier's beaked whales, one Blainville's beaked whale and one Gervais' beaked whale were examined post mortem and studied histopathologically (one Cuvier's beaked whale carcass was lost to the tide). No inflammatory or neoplastic processes were noted grossly or histologically and no pathogens (e.g. protozoa, bacteria

and viruses, including morbillivirus) were identified. Stomach contents were examined in seven animals and six of them had recently eaten, possibly indicating that the event(s) leading to their deaths had had a relatively sudden onset (Fernández *et al.* 2005). Macroscopic examination revealed that the whales had severe, diffuse congestion and haemorrhages, especially in the fat in the jaw, around the ears, in the brain (e.g. multifocal subarachnoid haemorrhages) and in the kidneys (Fernandez, 2004; Fernandez *et al.* 2004). Gas bubble-associated lesions were observed in the vessels and parenchyma (white matter) of the brain, lungs, subcapsular kidney veins and liver; fat emboli were observed in epidural veins, liver sinusoids, lymph nodes and lungs (Jepson *et al.* 2003; Fernandez, 2004; Fernandez *et al.* 2004; 2005). After the event, researchers from the Canary Islands examined past stranding records and found reports of eight other stranding events of beaked whales in the Canaries since 1985, at least five of which coincided with naval activities offshore (Martín *et al.* 2004).

GULF OF CALIFORNIA (2002). In September 2002, marine mammal researchers vacationing in the Gulf of California, Mexico discovered two recently deceased Cuvier's beaked whales on an uninhabited island. They were not equipped to conduct necropsies and in an attempt to contact local researchers, found that a research vessel had been conducting seismic surveys approximately 22km offshore at the time that the stranding events occurred (Taylor *et al.* 2004). The survey vessel was using three acoustic sources: (1) seismic air guns (5-500Hz, 259dB re: 1mPa Peak to Peak (p-p); Federal Register, 2003); (2) sub-bottom profiler (3.5kHz, 200dB SPL; Federal Register, 2004); and (3) multi-beam sonar (15.5kHz, 237dB SPL; Federal Register, 2003). Whether or not this survey caused the beaked whales to strand has been a matter of debate because of the small number of animals involved and a lack of knowledge regarding the temporal and spatial correlation between the animals and the sound source. This stranding underlines the uncertainty regarding which sound sources or combinations of sound sources may cause beaked whales to strand. Although some of these stranding events have been reviewed in government reports or conference proceedings (e.g. Anonymous 2001, Evans and Miller 2004), many questions remain. Specifically, the mechanisms by which beaked whales are affected by sound remain unknown. A better understanding of these mechanisms will facilitate management and mitigation of sound effects on beaked whales.

As a result, in April 2004, the United States' Marine Mammal Commission convened a workshop of thirty-one scientists from a diverse range of relevant disciplines (e.g. human diving physiology and medicine, marine mammal ecology, marine mammal anatomy and physiology, veterinary medicine and acoustics) to explore issues related to the vulnerability of beaked whales to anthropogenic sound. The purpose of the workshop was to (1) assess the current knowledge of beaked whale biology and ecology and recent beaked whale mass stranding events; (2) identify and characterize factors that may have caused the stranding events; (3) identify ways to more adequately investigate possible cause and effect relationships; and (4) review the efficacy of existing monitoring and mitigation methods. This paper arose out of the discussions at that workshop.

HANALEI BAY, KAUA'I, HAWAI'I (2004). On 3 – 4 July 2004, between 150 and 200 melon-headed whales (*Peponocephala electra*) occupied the shallow waters of Hanalei Bay, Kaua'i, Hawai'i for over 28 hours. These whales, which are usually pelagic, milled in the shallow confined bay and were returned to deeper water with human assistance. The whales are reported to have entered the Bay in a single wave formation on July 3, 2004, and were observed moving back into shore from the mouth of the Bay shortly thereafter. On the next morning, the whales were herded out of the Bay with the help of members of the community, the Hanalei Canoe Club, local and Federal

employees, and staff and volunteers with the Hawai'ian Islands Stranding Response Group and were out of visual sight later that morning.

One whale, a calf, had been observed alive and alone in Hanalei Bay on the afternoon of 4 July 2004 and was found dead in the Bay the morning of 5 July 2004. A full necropsy performed on the calf could not determine the cause of its death, although the investigators concluded that maternal separation, poor nutritional condition, and dehydration was probably a contributing factor in the animal's death.

Environmental factors, abiotic and biotic, were analyzed for any anomalous occurrences that would have contributed to the animals entering and remaining in Hanalei Bay. The bathymetry in the bay is similar to many other sites in the Hawai'ian Island chain and dissimilar to that which has been associated with mass stranding events in other parts of the U.S. The weather conditions appeared to be normal for the time of year with no fronts or other significant features noted. There was no evidence for unusual distribution or occurrence of predator or prey species or unusual harmful algal blooms. Weather patterns and bathymetry that have been associated with mass stranding events elsewhere were not found to occur in this instance.

This stranding event was spatially and temporally correlated with 2004 Rim of the Pacific exercises. Official sonar training and tracking exercises in the Pacific Missile Range Facility warning area did not commence until about 0800 hrs (local time) on 3 July and were ruled out as a possible trigger for the initial movement into Hanalei Bay. However, the six naval surface vessels transiting to the operational area on 2 July had been intermittently transmitting active mid-frequency sonar [for ~9 hours total] as they approached from the south. After ruling out other phenomena that might have caused this stranding, NMFS concluded that the active sonar transmissions associated with the 2004 Rim of the Pacific exercise were a plausible contributing causal factor in what may have been a confluence of events. Other factors that may have contributed to the stranding event include the presence of nearby deep water, multiple vessels transiting in a directed manner while transmitting active sonar over a sustained period, the presence of surface sound ducting conditions, or intermittent and random human interactions while the animals were in the Bay.

OTHER MASS STRANDING EVENTS. Several unusual stranding events have also occurred in Chinese waters in 2004 during a period when large-scale naval exercises were taking place in nearby waters south of Taiwan (IWC 2005). Between 24 February and 10 March 2004, 9-10 short-finned pilot whales (*Globicephala macrorhynchus*), one ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*), one striped dolphin (*Stenella coeruleoalba*), seven short-finned pilot whales, and one short-finned pilot whale were reported to have stranded. The stranding events were unusual (with respect to the species involved) compared to previous stranding records since 1994 for the region. Gross examination of the only available carcass, a ginkgo-toothed beaked whale, revealed many unusual injuries to structures that are associated with, or related to acoustics or diving. The injuries, the freshness of the carcass, its discovery location and the coincidence of the event with a military exercise suggest that this beaked whale died from acoustic or blast trauma that may have been caused by exposure to naval activities south of Taiwan. Taiwanese newspapers reported that live ammunition was used during these exercises. At the same time, natural phenomena that might cause whales to strand – such as earthquakes and underwater volcanoes – have not been ruled out in these cases.

Association Between Mass Stranding Events and Exposure to Active Sonar

Several authors have noted similarities between some of these stranding incidents: they occurred in islands or archipelagoes with deep water nearby, several appeared to have been associated with acoustic waveguides like surface ducting, and the sound fields created by ships transmitting mid-frequency sonar (Cox *et al.* 2006, D'Spain *et al.* 2006). Although Cuvier's beaked whales have been the most common species involved in these stranding events (81% of the total number of stranded animals and see Figure 3), other beaked whales (including *Mesoplodon europeaus*, *M. densirostris*, and *Hyperoodon ampullatus*) comprise 14% of the total. Other species (*Stenella coeruleoalba*, *Kogia breviceps* and *Balaenoptera acutorostrata*) have stranded, but in much lower numbers and less consistently than beaked whales.

Based on the evidence available, however, we cannot determine whether (a) *Ziphius cavirostris* is more prone to injury from high-intensity sound than other species, (b) their behavioral responses to sound makes them more likely to strand, or (c) they are more likely to be exposed to mid-frequency active sonar that other cetaceans (for reasons that remain unknown). Because the association between active sonar exposures and marine mammals mass stranding events is not consistent — some marine mammals strand without being exposed to sonar and some sonar transmissions are not associated with marine mammal stranding events despite their co-occurrence — other risk factors or a groupings of risk factors probably contribute to these stranding events.

STRANDING PATTERNS ASSOCIATED WITH RIM OF THE PACIFIC EXERCISES IN HAWAI'I. Nitta (1991) reported that between 1936 and 1988, 8 humpback whales, 1 fin whale, and 5 sperm whales stranded in the Hawai'ian Archipelago. In a partial update of that earlier report, Maldini *et al.* (2005) identified 202 toothed cetaceans that had stranded between 1950 and 2002. Sperm whales represented 10 percent of that total. Until recently, however, there has been no correlation between the number of known stranding events and the Navy's anti-submarine training exercises in Hawai'i. The number of stranding events have increased over time, but the number of stranding events in the main Hawai'ian Islands recorded between 1937 and 2002 is low compared with other geographic areas (although this may be an result of having large areas of coastline where no people or few people can report a stranding). Known stranding events also occurred in all months with no significant temporal trend (Maldini *et al.* 2005).

The Navy has conducted Rim of the Pacific exercises every second year since 1968 and anti-submarine warfare activities have occurred in each of the 19 exercises that have occurred thus far. This observation supports several different inferences. One line of reasoning is: if the mid-frequency sonar employed during those exercises killed or injured whales whenever the whales encountered the sonar, mass stranding events are likely to have occurred at least once or twice over the 38-year period since 1968. With one exception, there is little evidence of a pattern in the record of stranding events reported for the main Hawai'ian Islands.

A second line of reasoning leads to a very different conclusion: the absence of reports of stranding events may result from the small number of people searching for stranded animals relative to the coastline of Hawai'i —although stranding events have been reported in the Hawai'ian Islands since 1937, no toothed whales were reported until 1950 — or it may be because only a fraction of the whales that are killed or injured in Hawai'ian waters strand (as opposed to sinking, being transported to the open ocean by the strong currents that flow across the northern shore of the islands, or being eaten by predators like sharks). Faerber and Baird (2007) presented evidence that supports this

inference. They compared patterns of beaked whale stranding events in the Canary Islands and the main Hawai'ian Islands (they compared water depths immediately adjacent to shore, accessibility of shorelines, and population densities relative to land area and amount of shoreline) and concluded that beaked whales were less likely to strand in the main Hawai'ian Islands and were not likely to be detected if they did strand.

Finally, the apparent absence of stranding events coincident with the 38 years of antisubmarine warfare training exercises in waters off the main Hawai'ian islands could also suggest that mid-frequency sonar transmissions pose a hazard to cetaceans in some circumstances, but not others (for example, see the discussion under *Behavioral Avoidance*).

The Probable Responses of Listed Species to Mid-Frequency Active Sonar

Based on the evidence available, the mid-frequency sonars associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex each year over the twelve-month period beginning in January 2009 are not likely to kill or injure threatened or endangered marine mammals. However, little is known about the effect of short-term disruptions of a marine mammal's normal behavior (Richardson *et al.* 1995). Most of the evidence available suggests that most sources of disturbance do not directly kill or injure marine mammals. The evidence available also does not lead us to expect threatened or endangered cetaceans to strand or suffer resonance effects from the mid-frequency sonars associated with the ASW exercises that the U.S. Navy plans to conduct in the Southern California Range Complex over the next twelve months.

In this case, the absence of such reports given the number of exercises the Navy has conducted in the Southern California Range Complex over the past 40 years suggests that exposing endangered or threatened marine animals to active sonar associated with Navy activities in the action area are not likely to kill or fatally injure those animals. Any direct or indirect effects of the Navy's training and other activities in the Southern California Range Complex are more likely to affect the communication, behavior, and stress loading of endangered and threatened marine animals in the range complex. The effects of those responses are much more difficult to detect, although those responses all are known to reduce the fitness of individual animals and, as a result, their consequences are not trivial.

The probabilities of the different responses that appear in the narratives that follow are based on the posterior probabilities produced by Bayesian analyses (described in the *Approach to the Assessment*) of the outcomes of 211 responses of cetaceans to active sonar extracted from 31 published papers and other publications. Based on those analyses and assuming that the responses of marine mammals that were reported in the literature would be representative of the responses of endangered marine mammals in the Southern California Range Complex, about 13.62 percent of the endangered marine mammals would not respond to their exposure to active sonar, 13.91 percent would respond by making vocal adjustments, 0.76 percent would exhibit avoidance responses (they woud avoid the sound field or particular received levels), 6.81 percent would exhibit evasive responses, 4.73 percent would exhibit disturbance responses (a shift from one behavioral state to another behavioral state; most commonly from behavioral states with low-energy demands such as resting or milling to behavioral states with higher energy demands such as traveling), 25.54 percent would exhibit unspecified behavioral responses that would be considered "adverse" for the individual animals affected; and 34.63 percent would exhibit behavioral responses that would not be considered

adverse for the individual animals affected. The estimates in the following discussions were produced by multiplying these percentages by the number of animals exposed.

BLUE WHALES. Based on our exposure analyses, each year we would expect about 5,432 instances in which blue whales might be exposed to mid-frequency active sonar associated with major training exercises conducted in the Southern California Range Complex during the cold season . We would expect about 1,030 instances in which blue whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 4,239 exposure events involving blue whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 804 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 9,670 exposure events involving blue whales that we estimate would occur during the cold season is slightly lower than the 9,900 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 1,834 exposure events that we estimate would occur during the warm season is slightly lower than the 1,890 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

During the cold season, about 85.6 percent of exposure events would occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

We assume the blue whales that might be exposed to active sonar associated with Navy training activities in the Southern California Range Complex will be individuals from the eastern North Pacific population or stock, which occur in waters from California to Alaska in summer and fall and migrate to offshore waters from Mexico to Costa Rica during winter months (Calambokidis et al. 1990, NMFS 2006). The blue whales that occur off southern California reach their peak abundance from June to November (Burtenshaw *et al*. 2004) and their lowest abundance during cold-water months (Calambokidis 1995, Forney and Barlow 1998, Larkman and Veit 1998). Because the abundance of blue whales reach their peak abundance from June to November, which encompasses only a portion of the cold season, we have more confidence in our exposure estimates for the warm season than for the cold season and believe the number of exposure events we estimated for the cold season over-estimate the actual number of exposure events. Because blue whales forage in waters off southern California and reproduce elsewhere, we assume the blue whales that occur in the action area would be adults, juveniles, or calves, but would not consist of cows accompanied by neonate calves.

In the event blue whales are exposed to mid-frequency sonar, the information available on blue whales exposed to received levels of active mid-frequency sonar suggests that they are not likely to hear mid-frequency (1 kHz–10 kHz) sounds. Blue whales vocalizations include a variety of sounds described as low frequency moans or long pulses in the 10-100 Hz band (Cummings and Thompson 1971; Edds 1982; Thompson and Friedl 1982; McDonald *et al.* 1995; Clark and Fristrup 1997; Rivers 1997). The most typical signals are very long, patterned sequences of tonal infrasonic sounds in the 15-40 Hz range. Ketten (1997) reports the frequencies of maximum energy between 12 and

18 Hz. Short sequences of rapid calls in the 30-90 Hz band are associated with animals in social groups (Clark personal observation and McDonald personal communication cited in Ketten 1997). The context for the 30-90 Hz calls suggests that they are used to communicate but do not appear to be related to reproduction. Blue whale moans within the frequency range of 12.5-200 Hz, with pulse duration up to 36 seconds, have been recorded off Chile (Cummings and Thompson 1971). The whale produced a short, 390 Hz pulse during the moan. Based on this information blue whales exposed to received levels of active mid-frequency sonar are not likely to hear mid-frequency sounds; if they do not hear the sounds, they are not likely to respond physiologically or behaviorally to those received levels.

PROBABLE RESPONSE OF FIN WHALES. Based on our exposure analyses, each year we would expect about 1,055 instances in which fin whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 607 instances in which fin whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 823 exposure events involving fin whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 473 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 1,879 exposure events involving fin whales that we estimate would occur during the cold season is slightly lower than the 1,930 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 1,080 exposure events that we estimate would occur during the warm season is slightly lower than the 1,113 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with blue whales, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB..

As discussed in the *Status of the Species* section of this Opinion, fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981; Watkins *et al.* 1987a; Edds 1988; Thompson *et al.* 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (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 contains twenty cycles (Tyack 1999). This information would lead us to conclude that fin whales exposed to these received levels of active mid-frequency sonar are not likely to respond if they are exposed to mid-frequency (1 kHz–10 kHz) sounds.

PROBABLE RESPONSE OF HUMPBACK WHALES. Based on our exposure analyses, we would expect about 52 instances in which humpback whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 16 instances in which humpback whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 41 exposure events involving humpback whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 41 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 93 exposure events involving humpback whales that we estimate would occur during the cold season is slightly lower than the 96 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 57 exposure events that we estimate would occur during the warm season is an increase from the 30 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with blue and fin whales, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB..

We assume that the humpback whales that occur in the Southern California Range Complex would be individuals from the eastern North Pacific population or “stock” which inhabits waters from Costa Rica to southern British Columbia. These whales are most abundant in coastal waters off California during spring and summer, and off Mexico during autumn and winter. As a result, we believe the estimates for the warm season are more reliable than the estimates for the cold season. Further, because humpback whales forage in waters off southern California and reproduce elsewhere, we assume the humpback whales that occur in the action area would be adults, juveniles, or calves, but would not consist of cows accompanied by neonate calves.

Nevertheless, we would not expect humpback whales to be exposed to all of the major training exercises and other activities that would occur in the Southern California Range Complex over the next five years. There is almost no empirical information available on how humpback whales respond to active sonar exposures. The 68 whales that were observed during the monitoring surveys associated with Undersea Warfare Exercises that were conducted in Hawai'i in March 2008 were not reported to have exhibited unusual behavior or changes in behavior during the surveys (and these whales occurred in the areas where these whales reproduce and should be more sensitive to disturbance).

As discussed in the *Status of the Species* narrative for humpback whales, these whales produce a wide variety of sounds. During the breeding season males sing long, complex songs, with frequencies in the 25-5000 Hz range and intensities as high as 181 dB (Payne 1970, Thompson *et al.* 1986, Winn *et al.* 1970). Source levels average 155 dB and range from 144 to 174 dB (Thompson *et al.* 1979). The songs appear to have an effective range of approximately

10 to 20 km. Animals in mating groups produce a variety of sounds (Silber 1986, Tyack 1981; Tyack and Whitehead 1983).

Humpback whales produce sounds less frequently in their feeding areas like waters off Southern California. Feeding groups produce distinctive sounds ranging from 20 Hz to 2 kHz, with median durations of 0.2-0.8 seconds and source levels of 175-192 dB (Thompson *et al.* 1986). These sounds are attractive and appear to rally animals to the feeding activity (D'Vincent *et al.* 1985, Sharpe and Dill 1997). In summary, humpback whales produce at least three kinds of sounds:

1. Complex songs with components ranging from at least 20Hz – 4 kHz with estimated source levels from 144 – 174 dB; these are mostly sung by males on the breeding grounds (Payne 1970; Winn *et al.* 1970a; Richardson *et al.* 1995)
2. Social sounds in the breeding areas that extend from 50Hz – more than 10 kHz with most energy below 3kHz (Tyack and Whitehead 1983, Richardson *et al.* 1995); and
3 Feeding area vocalizations that are less frequent, but tend to be 20Hz – 2 kHz with estimated sources levels in excess of 175 dB re 1 uPa-m (Thompson *et al.* 1986, Richardson *et al.* 1995). Sounds often associated with possible aggressive behavior by males (Silber 1986,Tyack 1983) are quite different from songs, extending from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz. These sounds appear to have an effective range of up to 9 km (Tyack and Whitehead 1983).

More recently, Au *et al.* (2006) conducted field investigations of humpback whale songs led these investigators to conclude that humpback whales have an upper frequency limit reaching as high as 24 kHz. Based on this information, it is reasonable to assume that the active mid-frequency sonar the U.S. Navy would employ during training activities in the Southern California Range Complex would be within the hearing and vocalization ranges of humpback whales, although it is important to note, again, that humpback whales produce fewer vocalizations in summer foraging areas. There is limited information on how humpback whales are likely to respond upon being exposed to mid-frequency active sonar (most of the information available addresses their probable responses to low-frequency active sonar or impulsive sound sources). Humpback whales responded to sonar in the 3.1–3.6 kHz by swimming away from the sound source or by increasing their velocity (Maybaum 1990, 1993). The frequency or duration of their dives or the rate of underwater vocalizations, however, did not change.

Humpback whales have been known to react to low frequency industrial noises at estimated received levels of 115-124 dB (Malme *et al.* 1985), and to calls of other humpback whales at received levels as low as 102 dB (Frankel *et al.* 1995). Malme *et al.* (1985) found no clear response to playbacks of drill ship and oil production platform noises at received levels up to 116 dB re 1 μPa. Studies of reactions to airgun noises were inconclusive (Malme *et al.* 1985). Humpback whales on the breeding grounds did not stop singing in response to underwater explosions (Payne and McVay 1971). Humpback whales on feeding grounds did not alter short-term behavior or distribution in response to explosions with received levels of about 150dB re 1 μPa/Hz at 350Hz (Lien *et al.* 1993, Todd *et al.* 1996). However, at least two individuals were probably killed by the high-intensity, impulsed blasts and had extensive mechanical injuries in their ears (Ketten *et al.* 1993, Todd *et al.* 1996). The explosions may also have increased the number of humpback whales entangled in fishing nets (Todd *et al.* 1996). Frankel and Clark (1998)

showed that breeding humpbacks showed only a slight statistical reaction to playbacks of 60 - 90 Hz sounds with a received level of up to 190 dB. Although these studies have demonstrated that humpback whales will exhibit short-term behavioral reactions to boat traffic and playbacks of industrial noise, the long-term effects of these disturbances on the individuals exposed to them are not known.

Because their hearing range appears to overlap with the frequency range of mid-frequency active, we assume that some of the humpback whales that are exposed to mid-frequency active sonar during one or more of the proposed exercises might experience acoustic masking or impairment of acoustic communication (if they happen to vocalize while in the Southern California Range Complex), behavioral disturbance, and physiological stress responses as a result of their exposure.

Based on our analyses of the data available, the humpback whales involved in about 13 percent of the exposure events (about 3 of 23 exposure events) are not likely to respond to their exposure. The humpback whales involved in two other exposure events would adjust their vocalizations to compensate for their exposure to the sound field produced by mid-frequency active sonar; those vocal adjustments are most likely to consist of interrupted vocalizations, changing the time of day in which vocalizations occur, and increasing the amplitude of vocalizations.

No humpback whales are likely to avoid continued exposure to mid-frequency active sonar or engage in evasive behavior as a result of their exposure. Humpback whales involved in one exposure event would exhibit behavioral disturbance or a shift from one behavioral state to another; they are most likely to shift from a foraging behavioral state to an non-foraging but active behavioral state (for example, traveling).

PROBABLE RESPONSES OF SEI WHALES. Based on our exposure analyses, each year we would expect about seven instances in which sei whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect two instances in which sei whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 5 exposure events involving sei whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 5 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 12 exposure events involving sei whales that we estimate would occur during the cold season is the same we would expect to occur as part of the baseline condition (with current training schedules). The seven exposure events that we estimate would occur during the warm season is slightly more than the four exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

During the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

As discussed in the *Status of the Species* section of this opinion, we have no specific information on the sounds produced by sei whales or their sensitivity to sounds in their environment. Based on their anatomical and physiological similarities to both blue and fin whales, we assume that the hearing thresholds of sei whales will be similar as well and will be centered on low-frequencies in the 10-200 Hz. This information would lead us to conclude that, like blue and fin whales, sei whales exposed to these received levels of active mid-frequency sonar are not likely to respond if they are exposed to mid-frequency (1 kHz–10 kHz) sounds.

PROBABLE RESPONSES OF SPERM WHALES. Based on our exposure analyses, each year we would expect about 1,150 instances in which sperm ales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 358 instances in which sperm whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 1,508 exposure events involving sperm whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 279 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 2,048 exposure events involving sperm whales that we estimate would occur during the cold season is slightly lower than the 2,110 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 637 exposure events that we estimate would occur during the warm season is slightly lower than the 650 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with the other whales species, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

We assume that any sperm whales exposed to active sonar during Navy training activities in the Southern California Range Complex will represent individuals from the California-Oregon-Washington population or “stock.” Although the distribution of these sperm whales varies seasonally, the abundance of these sperm whales reaches two peaks during the year: from April through mid-June and from late August through mid-November (NMFS 2006), although sperm whales occur throughout the year on the Southern California Range Complex.

Based on their hearing sensitivities, which overlap the frequency range of mid-frequency active sonar, sonar transmissions might mask environmental cues at the lower range of sperm whale hearing. Although there is no published audiogram for sperm whales, sperm whales would be expected to have good, high frequency hearing because their inner ear resembles that of most dolphins, and appears tailored for ultrasonic (>20 kHz) reception (Ketten 1994). The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate, which suggest that neonatal sperm whales respond to sounds from 2.5 to 60 kHz.

Based on the frequencies of their vocalizations, which overlap the frequency range of mid-frequency active sonar, sonar transmissions might temporarily reduce the active space of sperm whale vocalizations. Most of the energy of sperm whales clicks is concentrated at 2 to 4 kHz and 10 to 16 kHz, which overlaps with the mid-frequency sonar. Other studies indicate sperm whales' wide-band clicks contain energy between 0.1 and 20 kHz (Weilgart and Whitehead 1993, Goold and Jones 1995). Ridgway and Carder (2001) measured low-frequency, high amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a neonate sperm whale.

There is some evidence of disruptions of clicking and behavior from sonars (Goold 1999, Watkins and Scheville1975, Watkins *et al.* 1985), pingers (Watkins and Scheville 1975), the Heard Island Feasability Test (Bowles *et al.* 1994), and the Acoustic Thermometry of Ocean Climate (Costa *et al.*1998). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders (Watkins and Scheville 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise, echosounder, and fishfinder emissions from a flotilla of 10 vessels. Watkins and Scheville (1975) showed that sperm whales interrupted click production in response to pinger (6 to 13 kHz) sounds. They also stopped vocalizing for brief periods when codas were being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

As discussed previously, sperm whales have been reported to have reacted to military sonar, apparently produced by a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins *et al.* 1985). Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 sec pulsed sounds at frequencies similar to those emitted by multi-beam sonar that is used in geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans some-times avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

Other studies identify instances in which sperm whales did not respond to anthropogenic sounds. Sperm whales did not alter their vocal activity when exposed to levels of 173 dB re 1 μPa from impulsive sounds produced by 1 g TNT detonators (Madsen and Mohl 2000). Richardson *et al.* (1995) citing a personal communication with J. Gordon suggested that sperm whales in the Mediterranean Sea continued calling when exposed to frequent and strong military sonar signals. When Andre *et al.* (1997) exposed sperm whales to a variety of sounds to determine what sounds may be used to scare whales out of the path of vessels, sperm whales were observed to have startle reactions to 10 kHz pulses (180 db re 1 μPa at the source), but not to the other sources played to them.

Published reports identify instances in which sperm whales may have responded to an acoustic source and other instances in which they did not appear to respond behaviorally when exposed to seismic surveys. Mate *et al.* (1994) reported an opportunistic observation of the number of sperm whales to have decreased in an area after the start of airgun seismic testing. However, Davis *et al.* (2000) noted that sighting frequency did not differ significantly among the different acoustic levels examined in the northern Gulf of Mexico, contrary to what Mate *et al.* (1994) reported. In one DTAG deployment in the northern Gulf of Mexico on July 28, 2001, researchers documented that the tagged whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μPa (Johnson and Miller 2002). Sperm whales may also have responded to seismic airgun sounds by ceasing to call during some (but not all) times when seismic pulses were received from an airgun array >300 km away (Bowles *et al.* 1994).

A recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa peak-to-peak (Madsen *et al.* 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels (Stone 1997, 1998, 2000, 2001, 2003). However, the compilation and analysis of the data led the author to conclude that seismic surveys did not result in observable effects to sperm whales (Stone 2003). The results from these waters seem to show that some sperm whales tolerate seismic surveys.

Preliminary data from an experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico and a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys show that during two controlled exposure experiments in which sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa over octave band with most energy, the whales did not avoid the vessel or change their feeding efficiency (National Science Foundation 2003). Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway.

These studies suggest that the behavioral responses of sperm whales to anthropogenic sounds are highly variable, but do not appear to result in the death or injury of individual whales or result in reductions in the fitness of individuals involved. Responses of sperm whales to anthropogenic sounds probably depend on the age and sex of animals being exposed, as well as other factors. There is evidence that many individuals respond to certain sound sources, provided the received level is high enough to evoke a response, while other individuals do not.

Based on our analyses of the data available, the sperm whales involved in about 13 percent of the exposure events (about 458 of 4,024 exposure events) are not likely to respond to their exposure. The sperm whales involved in another 400 exposure events would adjust their vocalizations to compensate for their exposure to the sound field produced by mid-frequency active sonar; those vocal adjustments are most likely to consist of interrupted vocalizations, changing the time of day in which vocalizations occur, and increasing the amplitude of vocalizations.

The sperm whales involved in about 30 of the exposure events are likely to avoid continued exposure to mid-frequency active sonar, although we assume these whales would respond to both the active sonar, any salient

acoustic cues produced by surface vessels involved in an exercise, and their perception of whether ships are approaching them or moving away when they decide whether or not to avoid the active sonar. Based on the evidence available, sperm whales seem more likely to avoid continued exposure at lower, initial received levels and the avoidance would consist of horizontal movement away from an exercise at slow to moderate swimming speeds. Sperm whales involved in another 274 exposure events would engage in evasive travel which would involve faster swimming speeds, deeper dives, and short times at surface. Sperm whales involved in about 190 exposure events would exhibit behavioral disturbance or a shift from one behavioral state to another; they are most likely to shift from a resting behavioral state to an active behavioral state.

PROBABLE RESPONSE OF GUADALUPE FUR SEALS. Based on our exposure analyses, each year we would expect about 184 instances in which Guadalupe fur seals might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 35 instances in which Guadalupe fur seals might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 144 exposure events involving Guadalupe fur seals during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 27 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 328 exposure events involving Guadalupe fur seals that we estimate would occur during the cold season is slightly lower than the 340 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 62 exposure events that we estimate would occur during the warm season is about the same as the number of exposure events that we would expect to occur as part of the baseline condition (64 exposure events with current training schedules).

Like the whale species, during the cold season, about 85.6 percent of these exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

Because Guadalupe fur seals tend to forage further north as the waters become warmer and remain further south as surface water becomes colder, the abundance of these fur seals will vary widely and that variance would cause us to over-estimate the probable number of times these fur seals are likely to be exposed to active sonar. Because these fur seals form land-based rookeries and their pups remain on those rookeries for the first few months of their lives, we assume that any Guadalupe fur seals that occur in the action area would be pre- or post-reproductive adults or juveniles. Because adult males are territorial during the breeding season and adult females are likely to remain closer to rookeries when they are feeding pups than when they are not, we also assume that Guadalupe fur seals that occur in the action area during the summer months would be non-reproducing females or juvenile males.

The information available does not allow us to assess the probable responses of Guadalupe fur seals after they are exposed to mid-frequency active sonar transmissions. In the past, we have assumed the these fur seals do not seem likely to respond to those transmissions because the sonar that would be used during the proposed anti-submarine

warfare exercises transmits at frequencies below hearing thresholds for Guadalupe fur seals. However, the U.S. Navy has concluded that at about 190 of these fur seals might accumulate acoustic energy sufficient to produce temporary shifts in their hearing sensitivity. Although this is an important conclusion, it does not allow us to assess the potential fitness consequences of the noise-induced loss in hearing sensitivity because we do not know the magnitude of the loss in hearing sensitivity (a 3 dB loss in sensitivity versus a 10 dB loss in sensitivity), how long the animal might be impaired (for example, does the animal recover in minutes, hours, or days), or the frequency range affected by the loss (that is, what environmental cues might the animal fail to detect). At a minimum, we would assume that any Guadalupe fur seals that experienced a loss in hearing sensitivity would be aware of the impairment and would experience a stress response as a result.

PROBABLE RESPONSE OF SEA TURTLES. The information available has not allowed us to estimate the probability of the different sea turtles being exposed to mid-frequency active sonar associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex each year over the twelve-month period beginning in January 2009 . Further, although the information on the hearing capabilities of sea turtles is limited, but the information available suggests that the auditory capabilities of sea turtles are centered in the low-frequency range (<1 kHz) (Ridgway *et al.* 1969; Lenhardt *et al.* 1983; Bartol *et al.* 1999, Lenhardt 1994, O'Hara and Wilcox 1990). Ridgway *et al.* (1969) studied the auditory evoked potentials of three green sea turtles (in air and through mechanical stimulation of the ear) and concluded that their maximum sensitivity occurred from 300 to 400 Hz with rapid declines for tones at lower and higher frequencies. They reported an upper limit for cochlear potentials without injury of 2000 Hz and a practical limit of about 1000 Hz. This is similar to estimates for loggerhead sea turtles, which had most sensitive hearing between 250 and 1000 Hz, with rapid decline above 1000 Hz (Bartol *et al.* 1999). These hearing sensitivities are similar to the hearing sensitivities reported for two terrestrial species: pond turtles (*Pseudemys scripta*) and wood turtles (*Chrysemys inscuplta*). Pond turtles are reported to have best hearing responsiveness between 200 and 700 Hz, with slow declines below 100 Hz and rapid declines above 700 Hz and almost no sensitivity above 3000 Hz (Wever and Vernon 1956) the latter has sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Peterson 1966). We assume that these sensitivities to sound apply to the three hardshell turtles (i.e., green, loggerhead , and Olive ridley sea turtles). No audiometric data are available for leatherback sea turtles, but we assume that they have hearing ranges similar to those of other sea turtles (or at least, their hearing is more likely to be similar to other sea turtles than marine mammals). Based on this information sea turtles exposed to received levels of active mid-frequency sonar are not likely to hear mid-frequency sounds (sounds between 1 kHz and 10 kHz); therefore, they are not likely to respond physiologically or behaviorally to those received levels.

A recent study on the effects of airguns on sea turtle behavior also suggests that sea turtles are most likely to respond to low-frequency sounds. McCauley *et al.* (2000) reported that green and loggerhead sea turtles will avoid air-gun arrays at 2 km and at 1 km with received levels of 166 dB re 1 μPa and 175 db re 1 μPa, respectively. The sea turtles responded consistently: above a level of approximately 166 dB re 1 μPa $_{rms}$ the turtles noticeably increased their swimming activity compared to non-airgun operation periods. Above 175 dB re 1 μPa mean squared pressure their behavior became more erratic possibly indicating the turtles were in an agitated state. Because the sonar that would be used during the proposed exercises transmits at frequencies above hearing thresholds for sea turtles, sea turtles that are exposed to those transmissions are not likely to respond to that exposure.

5.6 Probable Responses of Listed Species to Explosions

Klima *et. al.* (1988) conducted an experiment in which Kemp's ridley and loggerhead turtles were placed in cages at four distances from a oil platform to be removed with explosives. The cages were submerged to a depth of 15 ft over the 30 ft sea bottom just prior to the simultaneous explosion of four 50.75 lb charges of nitromethane placed inside the platform pilings at a depth of 16 ft below the mudline. Loggerhead and Kemp's ridley turtles at 750 ft and 1,200 ft, as well as one loggerhead at 3,000 ft were rendered unconscious. The Kemp's ridley turtle closest to the explosion (range of 750 ft) was slightly injured, with an everted cloacal lining; ridleys at ranges of 1,200 ft, 1,800 ft and 3,000 ft were apparently unharmed. All loggerheads displayed abnormal pink coloration caused by dilated blood vessels at the base of the throat and flippers, a condition that persisted for about 3 weeks.

O'Keeffe and Young (1984) analyzed data from three underwater shock tests carried out off Panama City, Florida in 1981. During each test, a charge equivalent of 1,200 lb of TNT was detonated at mid-depth in water about 120 ft deep. At least three turtles were noted in the area following the detonations. One turtle at a range of 500 to 700 ft was killed. A second turtle at a range of 1,200 ft received minor injuries. A third turtle at 2,000 ft was apparently unaffected. At a depth of 60 ft, calculated shock wave pressures are 239, 161, 85, and 47 psi at ranges of 500, 700, 1,200, and 2,000 ft, respectively.

Based on a parametric evaluation of the effects of charge weight and depth using the Goertner (1982) model, Young (1991) concluded that a conservative safe range for non-injury to a small mammal (representative of a dolphin calf) was approximated by $R=578w^{0.28}$ (*R* is in feet and *w* is in pounds of explosive). O'Keeffe and Young (1984) proposed that a safe range for turtles from an underwater explosion could be expressed by $R = 200\ w^{1/3}$, where R is the safe range in feet and w is the charge weight in pounds. This equation was subsequently modified by Young (1991) based on safe ranges established by the NMFS for platform removal operations using explosives. The revised equation is $R = 560\ w^{1/3}$. Applied to the Klima *et. al.* (1988) observations, this equation predicts a safe range of 3,291 ft, which exceeds the greatest distance at which an effect was observed (turtle unconscious at 3,000 ft). Applied to the O'Keeffe and Young (1984) report, this equation predicts a safe range of 5,951 ft, nearly triple the range from the charge of the uninjured turtle.

The safe ranges calculated previously addressed physical injury to sea turtles but did not identify problems associated with detecting damage to sea turtle auditory systems. These effects include physical changes to the auditory system that permanently or temporarily destroy or alter a turtle's hearing. Sea turtles do not have an auditory meatus or pinna that channels sound to the middle ear, nor do they have a specialized eardrum. Instead, they have a cutaneous layer and underlying subcutaneous fatty layer, that function as a tympanic membrane. The subcutaneous fatty layer receives and transmits sound to the extra-columella, a cartilaginous disk, located at the entrance to the columella, a long, thin bone that extends from the middle ear cavity to the entrance of the inner ear or otic cavity (Ridgway *et al.* 1969). Sound arriving at the inner ear via the columella is transduced by the bones of the middle ear. Sound also arrives by bone conduction through the skull. Low frequency sounds at high source levels can also be detected by vibration-sensitive touch receptors in various other parts of the turtle's body (mechano-reception). Any disruption (permanent or temporary) of a turtle's hearing may kill or injure the turtle. On the other hand, some effects may be temporary or slight and will not have lethal results.

Sea turtle auditory sensitivity has not been well studied. A few preliminary investigations suggest that it is limited to low frequency band-widths, such as the sounds of waves breaking on a beach. The role of underwater low frequency hearing in sea turtles is unclear. It has been suggested that sea turtles may use acoustic signals from their environment as guideposts during migration and as a cue to identify their natal beaches (Moein *et al.* 1983).

Although it is possible that green turtles in the vicinity of an in-water detonation might experience a temporary or permanent threshold shift, it is not known what energy levels and received levels are necessary to induce threshold shifts. The few studies completed on the auditory capabilities of sea turtles (adult green, loggerhead, and Kemp's ridley *(Lepidochelys kempii*) suggest that they could be capable of hearing low frequency sounds (Ridgway *et al.* 1969; Moein *et al.* 1983; Lenhardt,1994). Ridgway *et al.* (1969) reported maximal sensitivity for green turtles occurred at 300 to 400 Hz, with a rapid decline in sensitivity for lower and higher tones. Similarly, Moein *et al.* (1994) reported a hearing range of about 250 to 1,000 Hz for loggerhead sea turtles, and Lenhardt (1994) stated that maximal sensitivity in sea turtles generally occurs in the range from 100 to 800 Hz. Calculated in-water hearing thresholds within the useful range appear to be high (e.g., about 160 to 200 dB re 1 μPa; Lenhardt, 1994). In the absence of more specific information that could be used to determine the acoustic harassment range for sea turtles, the U.S. Navy assumed that frequencies $\geq$100 Hz (which are the acoustical harassment ranges predicted for odontocetes) would be conservative for sea turtles.

Moein *et al.* (1983) and O'Hara and Wilcox (1990) indicate that low frequency acoustic sound transmissions at source levels of 141-150 dB could potentially cause increased surfacing behavior and deterrence from the area near a sound source. In this instance, if they surface more frequently, green turtles will not be at a greater risk of collision with vessels transiting the action area because vessel traffic will be halted during detonation operations.

Effects Resulting from Interactions of the Potential Stressors

Several organizations have argued that several of our previous biological opinions on the U.S. Navy's use of active sonar failed to consider the "cumulative impact" (in the NEPA sense of the term) of active sonar on the ocean environment and its organisms, particularly endangered and threatened species and critical habitat that has been designated for them (for example, see NRDC 2007 and Ocean Mammal Institute 2007). In each instance, we have explained how biological opinions consider "cumulative impacts" (in the NEPA sense of the term; see Approach to the Assessment for a complete treatment of this issue). There is a nuance to the idea of "cumulative impacts," however, that we have chosen to address separately and explicitly in this Opinion: potential interactions between stressors associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex and other physical, chemical, and biotic stressors that pre-exist in the environment.

Exposing living organisms to individual stressors or a suite of stressors that are associated with a specific action may be insignificant or minor when considered in isolation, but may have significant adverse consequences when they are added to other stressors, operate synergistically in combination with other stressors, or magnify or multiply the effects of other stressors. Further, the effects of life events, natural phenomena, and anthropogenic phenomena on an individual's performance will depend on the individual's phenotypic state when the individual is exposed to these phenomena. Disease, dietary stress, body burden of toxic chemicals, energetic stress, percentage body fat, age, reproductive state, and social position, among many other phenomena can "accumulate" to have substantial

influence on an organism's response to subsequent exposure to a stressor. That is, exposing animals to individual stressors associated with a specific action can interact with the animal's prior condition (can have "accumulate" and have additive, synergistic, magnifying, and multiplicative effect) and produce significant, adverse consequences that would not occur if the animal's prior condition had been different.

An illustrative example of how a combination of stressors interact was provided by Relyea (2001, 2003, 2005) who demonstrated that exposing several different amphibians to a combination of pesticides and chemical cues of natural predators, which induced stress, increased the mortality rates of the amphibians (see also Sih *et al.* 2004). For some species, exposing the amphibians to the combination of stressors produced mortality rates that were twice as high as the mortality rates associated with each individual stressor. This section considers the evidence available to determine if interactions associated with mid-frequency active sonar are likely to produce responses we have not considered already or if interactions are likely to increase the severity — and, therefore, the potential consequences — of the responses we have already considered.

The activities the U.S. proposes to conduct in the Southern California Range Complex will continue to introduce a suite of potential stressors into the marine and coastal ecosystem off Southern California that include mid-frequency and high-frequency active sonar from surface vessels, torpedoes, and dipping sonar; shock waves and sound fields associated with underwater detonations, acoustic and visual cues from surface vessels as they move through the ocean's surface, and sounds transferred into the water column from fixed-wing aircraft, helicopters, and through the hulls of hulks that are the targets of sinking exercises. Exposing endangered and threatened marine animals in the Southern California Range Complex to each of these individual stressors could pose additional potential risks as the exposures accumulate over time. Exposing endangered and threatened marine animals to this suite of stressors could pose additional potential risks as the stressors interact with one another or with other stressors that already occur in these waters.

Although we recognize these potential interactions and that these interactions might have effects on endangered and threatened species that we have not considered thus far; however, the data available do not allow us to do more than acknowledge the possibility. Consider the potential stressor that has received the most attention thus far: mid-frequency active sonar. The proposed exercises would add mid-frequency sound to ambient oceanic noise levels, which, in turn, could have cumulative impacts on the ocean environment, including listed species. During transmissions, mid-frequency sonar will add to regional noise levels. However, there are no reliable methods for assessing potential interactions between these sound sources. The U.S. Navy conducted computer simulations to assess the potential cumulative impacts of mid-frequency active sonar (Navy 2008). That assessment concluded that the "cumulative impacts" of mid-frequency sonar would be "extremely small" because the proposed RIMPAC exercise would occur for a relatively short period of time every other year, for relatively short periods of time in any given area; the system would not be stationary, and the information available suggests that the effects of any mid-frequency exposure would stop when transmissions stop.

A greater cumulative impact is likely to result from an interaction between the number of times endangered or threatened species might be exposed to active sonar and explosions in association with the activities considered in this Opinion and other activities the U.S. Navy plans to conduct in waters off Southern California during the same time interval. Over the twelve-month period beginning in January 2009, the U.S. Navy plans on conducting up to

fifteen major training exercises in the Southern California Range Complex. Each of those exercises are expected to last for several days and produce tens to 100s of hours of mid-frequency active sonar. Blue, fin, humpback, sei, sperm whales, and Guadalupe fur seals are likely to be exposed to mid-frequency active sonar associated with those exercises as well as the active sonar associated with the activities considered in this Opinion.

As a result, over the twelve-month period beginning in January 2009 , individual blue, fin, humpback sei, sperm whales, Guadalupe fur seals, are likely to be exposed to the activities associated with major training exercises in the Southern California Range Complex; including more than 1,000 anti-submarine warfare tracking exercises, 40 bombing exercises; about 900 anti-submarine warfare tracking exercises and two sinking exercises in addition to a stress regime that includes close approaches for research, exposure to whale watch vessels; exposure to fisheries and fishing gear; and other natural and anthropogenic stressors.

Richardson *et al.* (1995) provided extensive information and arguments about the potential cumulative effects of man-made noise on marine mammals. Those effects included masking, physiological effects and stress, habituation, and sensitization. Those concerns were echoed by Clark and Fristrup (2001), Michel *et al.* (2001), NRDC (2001), and others. Although all of these responses have been measured in terrestrial animals reacting to airborne, man-made noises, those studies are counterbalanced by studies of other terrestrial mammals that did not exhibit these responses to similar acoustic stimuli.

The evidence available does not allow us to reach any conclusions about potential cumulative effects of the activities considered in this Opinion and other activities that are occurring or are designed to occur in the Southern California Range Complex. We could point to the increasing abundance of humpback whales over the past 30 years and infer that the status of these whales has improved despite the combination of natural and anthropogenic stressors in those waters. As a result, the existing stress regime in waters off Southern California would not reduce the performance of the humpback whales that forage in those waters. That inference is certainly consistent with the evidence available and it might be appropriate to extend that inference to the other endangered and threatened species in waters off Southern California.

The information available does not allow us to determine whether or to what degree there are any interactions between the U.S. Navy activities considered in this Opinion, other activities the U.S. Navy is conducting or plans to conduct in the Southern California Range Complex, and other natural and anthropogenic stressors in the Action Area. The evidence available suggests that the population of at least humpback whales that forages in the Action Area has increased for the past 10 to 20 years, despite the stress regime in those waters and that this increase does not mask demographic phenomena that are likely to reverse this trend in the future (for example, biases in the percentage of males or females in the population; gaps in the age structure of the population; reduced recruitment into the adult population; or a shift in the percentage of females with high reproductive success relative to the rest of the adult female population). This evidence suggests that the activities considered in this Opinion are not likely to interact to produce interactive, synergistic, or multiplicative effects that are greater than the effects considered elsewhere in this Opinion.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

During this consultation, NMFS searched for information on future State, tribal, local, or private actions that were reasonably certain to occur in the action area. Most of the action area includes federal military reserves or is outside of territorial waters of the United States of America, which would preclude the possibility of future state, tribal, or local action that would not require some form of federal funding or authorization. NMFS conducted electronic searches of business journals, trade journals, and newspapers using *First Search*, Google, and other electronic search engines. Those searches produced no evidence of future private action in the action area that would not require federal authorization or funding and is reasonably certain to occur. As a result, NMFS is not aware of any actions of this kind that are likely to occur in the action area during the foreseeable future.

Integration and Synthesis of Effects

In the *Assessment Approach* section of this Opinion, we stated that we measure risks to individuals of endangered or threatened species using changes in the individuals' "fitness" or the individual's growth, survival, annual reproductive success, and lifetime reproductive success. When we do not expect listed plants or animals exposed to an action's effects to experience reductions in fitness, we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (Anderson 2000, Mills and Beatty 1979, Brandon 1978, Stearns 1977, 1992). As a result, if we conclude that listed plants or animals are *not* likely to experience reductions in their fitness, we would conclude our assessment.

The following discussions summarize the probable risks future Rim of the Pacific exercises, particular mid-frequency sonar transmissions and ship traffic, pose to threatened and endangered species that are likely to be exposed to those transmissions. These summaries integrate the exposure profiles presented previously with the results of the response analyses that were also presented previously.

BLUE WHALES. Based on our exposure analyses, each year we would expect about 5,432 instances in which blue whales might be exposed to mid-frequency active sonar associated with major training exercises conducted in the Southern California Range Complex during the cold season . We would expect about 1,030 instances in which blue whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 4,239 exposure events involving blue whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 804 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 9,670 exposure events involving blue whales that we estimate would occur during the cold season is slightly lower than the 9,900 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 1,834 exposure events that we estimate would occur during the warm season is slightly lower than the 1,890 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

During the cold season, about 85.6 percent of exposure events would occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB..

We assume the blue whales that might be exposed to active sonar associated with Navy training activities in the Southern California Range Complex will be individuals from the eastern North Pacific population or stock, which occur in waters from California to Alaska in summer and fall and migrate to offshore waters from Mexico to Costa Rica during winter months (Calambokidis *et al*. 1990, NMFS 2006). The blue whales that occur off southern California reach their peak abundance from June to November (Burtenshaw *et al*. 2004) and their lowest abundance during cold-water months (Calambokidis 1995, Forney and Barlow 1998, Larkman and Veit 1998). Because the abundance of blue whales reach their peak abundance from June to November, which encompasses only a portion of the cold season, we have more confidence in our exposure estimates for the warm season than for the cold season and believe the number of exposure events we estimated for the cold season over-estimate the actual number of exposure events. Because blue whales forage in waters off southern California and reproduce elsewhere, we assume the blue whales that occur in the action area would be adults, juveniles, or calves, but would not consist of cows accompanied by neonate calves.

The U.S. Navy identified 2 instances in which blue whales might be exposed to and behaviorally harassed by underwater detonations associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex. The U.S. Navy identified another 2 instances each year in which blue whales might experience temporary threshold shifts as a result of their exposure to underwater detonations, although we cannot estimate the magnitude of the threshold shift (how much a reduction in hearing sensitivity is likely to occur), the duration of the threshold shift (how long an animal would experience the loss in hearing sensitivity), or the frequency range that might be affected.

As discussed in the introduction to our *Exposure Analyses*, it is important to note that these estimates probably over-estimate the actual number of blue whales that might be exposed to one or more of the activities the U.S. Navy plans to conduct in the Southern California Range Complex. Most marine mammals would only be exposed periodically or episodically, if at all, to the activities the U.S. Navy proposes to conduct in the Southern California Range Complex. Many exercises will occur without any marine animals being exposed to U.S. Navy vessels, sound fields associated with active sonar pings, or shock waves associated with underwater detonations. For species like blue whales, which only occur in the Southern California Range Complex only seasonally and whose year-to-year abundance is highly variable, these exposure estimates probably a substantial over-estimate of the actual exposure even if they represent the best estimate available.

Because they are low-frequency hearing specialists, blue whales in the action area seem more likely to respond to the ship traffic associated with each of the activities the U.S. Navy plans to conduct in the Southern California Range Complex in ways that approximate their responses to whale watch vessels. As discussed in the *Environmental Baseline* section of this Opinion, those responses are likely to depend on the distance of a whale from a vessel, vessel speed, vessel direction, vessel noise, and the number of vessels involved in a particular maneuver. Blue whales seem most likely to try to avoid being exposed to the activities and their avoidance response is likely to increase as an exercise progresses. We do not have the information necessary to determine which of the many sounds associated with an exercise is likely to trigger avoidance behavior in blue whales (for example, engine noise, helicopter rotors, ordnance discharges, explosions, or some combination of these) or whether blue whales would avoid being exposed to specific received levels, the entire sound field associated with an exercise, or the general area

in which an exercise would occur. However, blue whales are not likely to respond to mid-frequency active sonar because they are not likely to hear those sonar transmissions.

Individual blue whales' might not respond to the vessels, while in other circumstances, whales are likely to change their surface times, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães *et al.* 2002, Richter *et al.* 2003, Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams *et al.* 2002). Some of these whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship during that attempt. However, because of the relatively short duration of individual exercises, the small number of large exercises, and the short duration of the unit- or intermediate-level training exercises, we do not expect these responses of blue whales to reduce the fitness of the fin whales that occur in the Southern California Range Complex.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual blue whales that are exposed to stressors produced by those training exercises or other activities. As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual whales would not be likely to reduce the viability of the populations those individual whales represent (that is, we would not expect reductions in the reproduction, numbers, or distribution of those populations). As a result, the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 would not appreciably reduce the blue whales' likelihood of surviving and recovering in the wild.

FIN WHALES. Based on our exposure analyses, each year we would expect about 1,055 instances in which fin whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 607 instances in which fin whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 823 exposure events involving fin whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 473 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 1,879 exposure events involving fin whales that we estimate would occur during the cold season is slightly lower than the 1,930 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 1,080 exposure events that we estimate would occur during the warm season is slightly lower than the 1,113 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with blue whales, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

The U.S. Navy identified 2 instances in which fin whales might be exposed to and behaviorally harassed by underwater detonations associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex. The U.S. Navy identified another instance each year in which fin whales might experience temporary threshold shifts as a result of their exposure to underwater detonations, although we cannot estimate the magnitude of the threshold shift (how much a reduction in hearing sensitivity is likely to occur), the duration of the threshold shift (how long an animal would experience the loss in hearing sensitivity), or the frequency range that might be affected.

As with blue whales. these estimates probably over-estimate the actual number of fin whales that might be exposed to one or more of the activities the U.S. Navy plans to conduct in the Southern California Range Complex. Most marine mammals would only be exposed periodically or episodically, if at all, to the activities the U.S. Navy proposes to conduct in the Southern California Range Complex. Many exercises will occur without any marine animals being exposed to U.S. Navy vessels, sound fields associated with active sonar pings, or shock waves associated with underwater detonations. For species like fin whales, which only occur in the Southern California Range Complex seasonally and whose year-to-year abundance is highly variable, these exposure estimates probably a substantial over-estimate of the actual exposure even if they represent the best estimate available.

As discussed in the *Status of the Species* section of this opinion, fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981; Watkins *et al.* 1987a; Edds 1988; Thompson *et al.* 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (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 contains twenty cycles (Tyack 1999). This information would lead us to conclude that fin whales exposed to these received levels of active mid-frequency sonar are not likely to respond if they are exposed to mid-frequency (1 kHz–10 kHz) sounds.

Fin whales in the action area seem likely to respond to the ship traffic associated with each of the activities the U.S. Navy plans to conduct in the Southern California Range Complex in ways that approximate their responses to whale watch vessels. As discussed in the *Environmental Baseline* section of this Opinion, those responses are likely to depend on the distance of a whale from a vessel, vessel speed, vessel direction, vessel noise, and the number of vessels involved in a particular maneuver. Fin whales seem most likely to try to avoid being exposed to the activities and their avoidance response is likely to increase as an exercise progresses. We do not have the information necessary to determine which of the many sounds associated with an exercise is likely to trigger avoidance behavior in fin whales (for example, engine noise, helicopter rotors, ordnance discharges, explosions, or some combination of these) or whether fin whales would avoid being exposed to specific received levels, the entire sound field associated with an exercise, or the general area in which an exercise would occur.

Particular whales' might not respond to the vessels, while in other circumstances, fin whales are likely to change their vocalizations, surface time, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães *et al.* 2002, Richter *et al.* 2003, Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams *et al.* 2002). Some of these whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship during that attempt. However, because of the relatively short duration of the different exercises and the small number of times the exercises are likely to be repeated during the twelve-month period beginning in January 2009, we do not expect these responses of fin whales to reduce the fitness of the fin whales that occur in the Southern California Range Complex.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual fin whales that are exposed to stressors produced by those training exercises or other activities. As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual whales would not be likely to reduce the viability of the populations those individual whales represent (that is, we would not expect reductions in the reproduction, numbers, or distribution of those populations). As a result, the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to appreciably reduce the fin whales' likelihood of surviving and recovering in the wild.

HUMPBACK WHALES. Based on our exposure analyses, we would expect about 52 instances in which humpback whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 16 instances in which humpback whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 41 exposure events involving humpback whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 41 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 93 exposure events involving humpback whales that we estimate would occur during the cold season is slightly lower than the 96 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 57 exposure events that we estimate would occur during the warm season is an increase from the 30 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with blue and fin whales, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB. No humpback whales are likely to be exposed to shock waves or sounds produced by underwater detonations associated with the training activities the U.S. Navy plans to conduct in the Southern California Range Complex.

We assume that the humpback whales that occur in the Southern California Range Complex would be individuals from the eastern North Pacific population or "stock" which inhabits waters from Costa Rica to southern British Columbia. These whales are most abundant in coastal waters off California during spring and summer, and off Mexico during autumn and winter. As a result, we believe the estimates for the warm season are more reliable than the estimates for the cold season. Further, because humpback whales forage in waters off southern California and reproduce elsewhere, we assume the humpback whales that occur in the action area would be adults, juveniles, or calves, but would not consist of cows accompanied by neonate calves.

Humpback whales produce a wide variety of sounds. During the breeding season males sing long, complex songs, with frequencies in the 25-5000 Hz range and intensities as high as 181 dB (Payne 1970; Winn *et al.* 1970a; Thompson *et al.* 1986). Source levels average 155 dB and range from 144 to 174 dB (Thompson *et al.* 1979). The songs appear to have an effective range of approximately 10 to 20 km. Animals in mating groups produce a variety of sounds (Tyack 1981; Tyack and Whitehead 1983, Silber 1986).

Humpback whales produce sounds less frequently in their summer feeding areas. Feeding groups produce distinctive sounds ranging from 20 Hz to 2 kHz, with median durations of 0.2-0.8 sec and source levels of 175-192 dB (Thompson *et al.* 1986). These sounds are attractive and appear to rally animals to the feeding activity (D'Vincent *et al.* 1985; Sharpe and Dill 1997). In summary, humpback whales produce at least three kinds of sounds:

1. Complex songs with components ranging from at least 20Hz – 4 kHz with estimated source levels from 144 – 174 dB; these are mostly sung by males on the breeding grounds (Payne 1970; Winn *et al.* 1970a; Richardson *et al.* 1995)
2. Social sounds in the breeding areas that extend from 50Hz – more than 10 kHz with most energy below 3kHz (Tyack and Whitehead 1983, Richardson *et al.* 1995); and
3. Feeding area vocalizations that are less frequent, but tend to be 20Hz – 2 kHz with estimated sources levels in excess of 175 dB re 1 uPa-m (Thompson *et al.* 1986; Richardson *et al.* 1995). Sounds often associated with possible aggressive behavior by males (Tyack 1983; Silber 1986) are quite different from songs, extending from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz. These sounds appear to have an effective range of up to 9 km (Tyack and Whitehead 1983).

More recently, Au *et al.* (2006) conducted field investigations of humpback whale songs led these investigators to conclude that humpback whales have an upper frequency limit reaching as high as 24 kHz. Based on this information, it is reasonable to assume that the active mid-frequency sonar the U.S. Navy would employ during major training and RDT&E activities are within the hearing and vocalization ranges of humpback whales. There is limited information on how humpback whales are likely to respond upon being exposed to mid-frequency active sonar (most of the information available addresses their probable responses to low-frequency active sonar or impulsive sound sources). Humpback whales responded to sonar in the 3.1–3.6 kHz by swimming away from the sound source or by increasing their velocity (Maybaum 1990, 1993). The frequency or duration of their dives or the rate of underwater vocalizations, however, did not change.

Humpback whales have been known to react to low frequency industrial noises at estimated received levels of 115-124 dB (Malme *et al.* 1985), and to conspecific calls at received levels as low as 102 dB (Frankel *et al.* 1995). Malme *et al.* (1985) found no clear response to playbacks of drill ship and oil production platform noises at received levels up to 116 dB re 1 μPa. Studies of reactions to airgun noises were inconclusive (Malme *et al.* 1985). Humpback whales on the breeding grounds did not stop singing in response to underwater explosions (Payne and McVay 1971). Humpback whales on feeding grounds did not alter short-term behavior or distribution in response to explosions with received levels of about 150dB re 1 μPa/Hz at 350Hz (Lien *et al.* 1993; Todd *et al.* 1996). However, at least two individuals were probably killed by the high-intensity, impulsed blasts and had extensive mechanical injuries in their ears (Ketten *et al.* 1993; Todd *et al.* 1996). The explosions may also have increased the number of humpback whales entangled in fishing nets (Todd *et al.* 1996). Frankel and Clark (1998) showed that breeding humpbacks showed only a slight statistical reaction to playbacks of 60 - 90 Hz sounds with a received level of up to 190 dB. Although these studies have demonstrated that humpback whales will exhibit short-term behavioral reactions to boat traffic and playbacks of industrial noise, the long-term effects of these disturbances on the individuals exposed to them are not known.

Because their hearing range appears to overlap with the frequency range of mid-frequency active, we assume that some of the humpback whales that are exposed to mid-frequency active sonar during one or more of the proposed exercises might experience acoustic masking, impairment of acoustic communication, behavioral disturbance, and physiological stress responses as a result of their exposure.

The evidence available suggests that humpback whales are likely to detect mid-frequency sonar transmissions. In most circumstances, humpback whales are likely to try to avoid that exposure or are likely to avoid areas specific areas. Those humpback whales that do not avoid the sound field created by the mid-frequency sonar might experience interruptions in their vocalizations. In either case, humpback whales that avoid these sound fields or stop vocalizing are not likely to experience significant disruptions of their normal behavior patterns because the waters off Southern California form only a small portion of their feeding range. As a result, we do not expect these disruptions to reduce the fitness (reproductive success or longevity) of any individual animal or to result in physiological stress responses that rise to the level of distress.

As discussed in the *Environmental Baseline* section of this Opinion, the strongest evidence that of the probable impact of the *Environmental Baseline* on humpback whales consists of the estimated growth rate of the humpback whale population in the North Pacific Ocean. In the 1980s, the size of the North Pacific humpback whale population was estimated to range from 1,407 to 2,100 (Baker 1985; Darling and Morowitz 1986; Baker and Herman 1987). By the mid-1990s, the population was estimated to consist of about 6,000 whales (standard error = 474) in the North Pacific (Calambokidis *et al.* 1997; Cerchio 1998; Mobley *et al.* 1999). The most recent estimate places the current population of humpback whales in the North Pacific Ocean consisted of about 18,300 whales, not counting calves (Calambokidis *et al.* 2008).

Despite small numbers that are entangled in fishing gear in the action area, this increase in the number of humpback whales suggests that the stress regime these whales are exposed to in the North Pacific Ocean has not prevented these whales from increasing their numbers in the action area. As discussed in the *Environmental Baseline* section of

this Opinion, humpback whales have been exposed to U.S. Navy training activities in the Southern California Range Complex, including vessel traffic, aircraft traffic, active sonar, and underwater detonations, for more than a generation. Although the U.S. Navy proposes to increase the frequency of some of these activities, we do not believe those increases are likely to affect the rate at which humpback whale the North Pacific population of humpback whales is increasing.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual humpback whales that are exposed to stressors produced by those training exercises or other activities. As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual whales would not be likely to reduce the viability of the populations those individual whales represent (that is, we would not expect reductions in the reproduction, numbers, or distribution of those populations). As a result, the activities the U.S. Navy plans to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009 would not be expected to appreciably reduce the humpback whales' likelihood of surviving and recovering in the wild.

SEI WHALES. Based on our exposure analyses, each year we would expect about seven instances in which sei whales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect two instances in which sei whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 5 exposure events involving sei whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 5 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 12 exposure events involving sei whales that we estimate would occur during the cold season is the same we would expect to occur as part of the baseline condition (with current training schedules). The seven exposure events that we estimate would occur during the warm season is slightly more than the four exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

During the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

As discussed in the *Status of the Species* section of this opinion, we have no specific information on the sounds produced by sei whales or their sensitivity to sounds in their environment. Based on their anatomical and physiological similarities to both blue and fin whales, we assume that the hearing thresholds of sei whales will be similar as well and will be centered on low-frequencies in the 10-200 Hz. This information would lead us to conclude that, like blue and fin whales, sei whales exposed to these received levels of active mid-frequency sonar are not likely to respond if they are exposed to mid-frequency (1 kHz–10 kHz) sounds.

Like fin whales, sei whales in the action area seem likely to respond to the ship traffic associated with each of the activities the U.S. Navy plans to conduct in the Southern California Range Complex in ways that approximate their responses to whale watch vessels. As discussed in the *Environmental Baseline* section of this Opinion, those responses are likely to depend on the distance of a whale from a vessel, vessel speed, vessel direction, vessel noise, and the number of vessels involved in a particular maneuver. Sei whales also seem most likely to try to avoid being exposed to the activities and their avoidance response is likely to increase as an exercise progresses. We do not have the information necessary to determine which of the many sounds associated with an exercise is likely to trigger avoidance behavior in sei whales (for example, engine noise, helicopter rotors, ordnance discharges, explosions, or some combination of these) or whether fin whales would avoid being exposed to specific received levels, the entire sound field associated with an exercise, or the general area in which an exercise would occur.

Particular whales' might not respond to the vessels, while in other circumstances, sei whales are likely to change their vocalizations, surface time, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães *et al.* 2002, Richter *et al.* 2003, Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams *et al.* 2002). Some of these whales might experience physiologyical stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship during that attempt. However, because of the relatively short duration of the different exercises and the small number of times the exercises are likely to be repeated during the twelve-month period beginning in January 2009, we do not expect these responses of sei whales to reduce the fitness of the sei whales that occur in the Southern California Range Complex.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual sei es that are exposed to stressors produced by those training exercises or other activities. As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual whales would not be likely to reduce the viability of the populations those individual whales represent (that is, we would not expect reductions in the reproduction, numbers, or distribution of those populations). As a result, the activities the U.S. Navy plans to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009 would not be expected to appreciably reduce the sei whales' likelihood of surviving and recovering in the wild.

SPERM WHALES. Based on our exposure analyses, each year we would expect about 1,150 instances in which sperm ales might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 358 instances in which sperm whales might be exposed to mid-frequency active sonar associated with major exercises conducted during the warm season. In addition, we would expect another 1,508 exposure events involving sperm whales during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 279 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 2,048 exposure events involving sperm whales that we estimate would occur during the cold season is slightly lower than the 2,110 exposure events that we would expect to occur as part of the baseline condition (with current

training schedules). The 637 exposure events that we estimate would occur during the warm season is slightly lower than the 650 exposure events that we would expect to occur as part of the baseline condition (with current training schedules).

As with the other whales species, during the cold season, about 85.6 percent of exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

The U.S. Navy identified 2 instances in which sperm whales might be exposed to and behaviorally harassed by underwater detonations associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex. The U.S. Navy identified another instance in which sperm whales might experience temporary threshold shifts as a result of their exposure to underwater detonations, although we cannot estimate the magnitude of the threshold shift (how much a reduction in hearing sensitivity is likely to occur), the duration of the threshold shift (how long an animal would experience the loss in hearing sensitivity), or the frequency range that might be affected.

We assume that any sperm whales exposed to active sonar during Navy training activities in the Southern California Range Complex will represent individuals from the California-Oregon-Washington population or "stock." Although the distribution of these sperm whales varies seasonally, the abundance of these sperm whales reaches two peaks during the year: from April through mid-June and from late August through mid-November (NMFS 2006), although sperm whales occur throughout the year on the Southern California Range Complex.

If exposed to mid-frequency sonar transmissions, sperm whales are likely to hear and respond to those transmissions. The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1990). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz. Sperm whales also produce loud broad-band clicks from about 0.1 to 20 kHz (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). These have source levels estimated at 171 dB re 1 μPa (Levenson 1974). Current evidence suggests that the disproportionately large head of the sperm whale is an adaptation to produce these vocalizations (Norris and Harvey 1972; Cranford 1992; but see Clarke 1979). This suggests that the production of these loud low frequency clicks is extremely important to the survival of individual sperm whales. The function of these vocalizations is relatively well-studied (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). Long series of monotonous regularly spaced clicks are associated with feeding and are thought to be produced for echolocation. Distinctive, short, patterned series of clicks, called codas, are associated with social behavior and interactions within social groups (Weilgart and Whitehead 1993).

Based on the frequencies of their vocalizations, which overlap the frequency range of mid-frequency active sonar, sonar transmissions might temporarily reduce the active space of sperm whale vocalizations. Most of the energy of sperm whales clicks is concentrated at 2 to 4 kHz and 10 to 16 kHz, which overlaps with the mid-frequency sonar. Other studies indicate sperm whales' wide-band clicks contain energy between 0.1 and 20 kHz (Weilgart and

Whitehead 1993, Goold and Jones 1995). Ridgway and Carder (2001) measured low-frequency, high amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a neonate sperm whale.

There is some evidence of disruptions of clicking and behavior from sonars (Goold 1999, Watkins and Scheville 1975, Watkins *et al.* 1985), pingers (Watkins and Scheville 1975), the Heard Island Feasability Test (Bowles *et al.* 1994), and the Acoustic Thermometry of Ocean Climate (Costa *et al.*1998). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders (Watkins and Scheville 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise, echosounder, and fishfinder emissions from a flotilla of 10 vessels. Watkins and Scheville (1975) showed that sperm whales interrupted click production in response to pinger (6 to 13 kHz) sounds. They also stopped vocalizing for brief periods when codas were being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

As discussed previously, sperm whales have been reported to have reacted to military sonar, apparently produced by a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins *et al.* 1985). Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 sec pulsed sounds at frequencies similar to those emitted by multi-beam sonar that is used in geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans some-times avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

Published reports identify instances in which sperm whales may have responded to an acoustic source and other instances in which they did not appear to respond behaviorally when exposed to seismic surveys. Mate *et al.* (1994) reported an opportunistic observation of the number of sperm whales to have decreased in an area after the start of airgun seismic testing. However, Davis *et al.* (2000) noted that sighting frequency did not differ significantly among the different acoustic levels examined in the northern Gulf of Mexico, contrary to what Mate *et al.* (1994) reported. In one DTAG deployment in the northern Gulf of Mexico on July 28, 2001, researchers documented that the tagged whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μPa (Johnson and Miller 2002). Sperm whales may also have responded to seismic airgun sounds by ceasing to call during some (but not all) times when seismic pulses were received from an airgun array >300 km away (Bowles *et al.* 1994).

A recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa peak-to-peak

(Madsen *et al.* 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels (Stone 1997, 1998, 2000, 2001, 2003). However, the compilation and analysis of the data led the author to conclude that seismic surveys did not result in observable effects to sperm whales (Stone 2003). The results from these waters seem to show that some sperm whales tolerate seismic surveys.

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).

Preliminary data from an experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico and a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys show that during two controlled exposure experiments in which sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa over octave band with most energy, the whales did not avoid the vessel or change their feeding efficiency (National Science Foundation 2003). Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway.

Other studies identify instances in which sperm whales did not respond to anthropogenic sounds. Sperm whales did not alter their vocal activity when exposed to levels of 173 dB re 1 μPa from impulsive sounds produced by 1 g TNT detonators (Madsen and Mohl 2000). Richardson *et al.* (1995) citing a personal communication with J. Gordon suggested that sperm whales in the Mediterranean Sea continued calling when exposed to frequent and strong military sonar signals. When Andre *et al.* (1997) exposed sperm whales to a variety of sounds to determine what sounds may be used to scare whales out of the path of vessels, sperm whales were observed to have startle reactions to 10 kHz pulses (180 db re 1 μPa at the source), but not to the other sources played to them.

These studies suggest that the behavioral responses of sperm whales to anthropogenic sounds are highly variable, but do not appear to result in the death or injury of individual whales or result in reductions in the fitness of individuals involved. Responses of sperm whales to anthropogenic sounds probably depend on the age and sex of animals being exposed, as well as other factors. There is evidence that many individuals respond to certain sound sources, provided the received level is high enough to evoke a response, while other individuals do not.

The sperm whales that might be exposed to the activities the U.S. Navy plans to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009, particularly active sonar transmissions, ship traffic, and explosions, would represent individuals from the California-Oregon-Washington population (or "stock"). Sperm whales occur in the Southern California Range Complex throughout the year (Rice 1960; Shallenberger 1981; Lee 1993; and Mobley *et al.* 2000).

The evidence available suggests that sperm whales are likely to detect mid-frequency sonar transmissions. In most circumstances, sperm whales are likely to try to avoid that exposure or are likely to avoid areas specific areas. For

example, sperm whales have moved out of areas after the start of air gun seismic testing (Davis *et al.* 1995). Those sperm whales that do not avoid the sound field created by the mid-frequency sonar might interrupt communications, echolocation, or foraging behavior. In either case, sperm whales that avoid these sound fields, stop communcating, echolocating or foraging might experience significant disruptions of normal behavior patterns that are essential to their individual fitness. Because of the relatively short duration of the acoustic transmissions associated with the Rim of the Pacific exercises and the other exercises the U.S. Navy plans to conduct in the Southern California Range Complex, we do not, however, expect these disruptions to result in the death or injury of any individual animal or to result in physiological stress responses that rise to the level of distress.

Like fin and sei whales, individual sperm whales are also likely to respond to the ship traffic associated with the maneuvers might approximate their responses to whale watch vessels. As discussed in the *Environmental Baseline* section of this Opinion, those responses are likely to depend on the distance of a whale from a vessel, vessel speed, vessel direction, vessel noise, and the number of vessels involved in a particular maneuver. The closer sperm whales are to these maneuvers and the greater the number of times they are exposed (using the Navy's estimates of the cumulative exposures to sounds equivalents > 173 dB as an index of potential exposures), the greater their likelihood of be exposed and responding to that exposure. Particular whales' might not respond to the vessels, while in other circumstances, sperm whales are likely to change their vocalizations, surface time, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães *et al.* 2002, Richter *et al.* 2003, Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams *et al.* 2002). Some of these whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship during that attempt. However, because of the relatively short duration of the exercise, we do not expect these responses to continue long-enough to have fitness consequences for individual sperm whales because these whales are likely to have energy reserves sufficient to meet the demands of their normal behavioral patterns and those of a stress physiology.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual sperm whales that are exposed to stressors produced by those training exercises or other activities. As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual sperm whales would not be likely to reduce the viability of the populations those individual whales represent by reducing the population dynamics, behavioral ecology, and social dynamics of those populations (that is, we would not expect reductions in the reproduction, numbers, or distribution of those populations). As a result, the activities the U.S. Navy plans to conduct in the Southern California Range Complex during the twelve-month period beginning in January 2009 would not be expected to appreciably reduce the sperm whales' likelihood of surviving and recovering in the wild.

GUADALUPE FUR SEALS. Based on our exposure analyses, each year we would expect about 184 instances in which Guadalupe fur seals might be exposed to mid-frequency active sonar associated with each major training exercise conducted in the Southern California Range Complex during the cold season . We would expect about 35 instances in which Guadalupe fur seals might be exposed to mid-frequency active sonar associated with major exercises

conducted during the warm season. In addition, we would expect another 144 exposure events involving Guadalupe fur seals during all unit-level training and maintenance activities conducted during the cold season (November to April) and about 27 exposure events during unit-level training and maintenance activities conducted in the warm season.

The 328 exposure events involving Guadalupe fur seals that we estimate would occur during the cold season is slightly lower than the 340 exposure events that we would expect to occur as part of the baseline condition (with current training schedules). The 62 exposure events that we estimate would occur during the warm season is about the same as the number of exposure events that we would expect to occur as part of the baseline condition (64 exposure events with current training schedules).

Like the whale species, during the cold season, about 85.6 percent of these exposure events are likely to occur at received levels between 140 and 160 dB (between 2.2 to 44 km from a transmitting vessel); during the warm season about 84.26 percent of exposure events would occur at received levels between 140 and 160 dB (between 500 meters to 8.3 km from a transmitting vessel). Small numbers of individuals might occur close enough to a transmitting vessel to be exposed at received levels greater than 190 dB.

The U.S. Navy identified 2 instances in which Guadalupe fur seals might be exposed to and behaviorally harassed by underwater detonations associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex. The U.S. Navy identified another 2 instances in which Guadalupe fur seals might experience temporary threshold shifts as a result of their exposure to underwater detonations, although we cannot estimate the magnitude of the threshold shift (how much a reduction in hearing sensitivity is likely to occur), the duration of the threshold shift (how long an animal would experience the loss in hearing sensitivity), or the frequency range that might be affected.

Because Guadalupe fur seals tend to forage further north as the waters become warmer and remain further south as surface water becomes colder, the abundance of these fur seals will vary widely and that variance would cause us to over-estimate the probable number of times these fur seals are likely to be exposed to active sonar. Because these fur seals form land-based rookeries and their pups remain on those rookeries for the first few months of their lives, we assume that any Guadalupe fur seals that occur in the action area would be pre- or post-reproductive adults or juveniles. Because adult males are territorial during the breeding season and adult females are likely to remain closer to rookeries when they are feeding pups than when they are not, we also assume that Guadalupe fur seals that occur in the action area during the summer months would be non-reproducing females or juvenile males.

At a minimum, we would assume that a Guadalupe fur seal that experienced a loss in hearing sensitivity would be aware of the impairment and would experience a stress response as a result. We assume that, like the whales discussed previously, these fur seals are likely to try to avoid being exposed to vessel traffic, active sonar, and sound-producing exercises such as gunnery exercises or sinking exercises. We do not have the information necessary to determine which of the many sounds associated with an exercise is likely to trigger avoidance behavior in Guadalupe fur seals (for example, engine noise, helicopter rotors, ordnance discharges, explosions, or some combination of these), but we assume that this avoidance will not prevent these fur seals from being exposed to

received levels of active sonar or explosions, but it would prevent the fur seals from being exposed at received levels that would be injurious, cause them physiological distress,or alter their reproductive success.

As discussed in the *Environmental Baseline* section of this Opinion, Guadalupe fur seals have been exposed to U.S. Navy training activities in the Southern California Range Complex, including vessel traffic, aircraft traffic, active sonar, and underwater detonations, for more than a generation. Although we do not know if more Guadalupe fur seals might have used the action area or the reproductive success of these fur seals in the Southern California Range Complex would be higher absent their exposure to these activities, the rate at which Guadalupe fur seals are increasing in their major rookery suggests that the number of these fur seals in the action area continue to increases despite exposure to earlier training regimes. Although the U.S. Navy proposes to increase the frequency of some of these activities, we do not believe those increases are likely to affect the rate at which the Guadalupe fur seal seal population is increasing.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual Guadalupe fur seals that are exposed to stressors produced by those training exercises or other activities. As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual fur seals would not be likely to reduce the viability of Guadalupe fur seals by reducing the population dynamics, behavioral ecology, and social dynamics of those populations (that is, we would not expect reductions in the reproduction, numbers, or distribution of those populations). As a result, we conclude that the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 would not be expected to appreciably reduce the Guadalupe fur seals' likelihood of surviving and recovering in the wild.

SEA TURTLES. The information available has not allowed us to estimate the probability of the different sea turtles being exposed to mid-frequency active sonar, vessel traffic, or explosions associated with the activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 .

Further, although the information on the hearing capabilities of sea turtles is limited, but the information available suggests that the auditory capabilities of sea turtles are centered in the low-frequency range (<1 kHz) (Ridgway *et al.* 1969; Lenhardt *et al.* 1983; Bartol *et al.* 1999, Lenhardt 1994, O'Hara and Wilcox 1990). Ridgway *et al.* (1969) studied the auditory evoked potentials of three green sea turtles (in air and through mechanical stimulation of the ear) and concluded that their maximum sensitivity occurred from 300 to 400 Hz with rapid declines for tones at lower and higher frequencies. They reported an upper limit for cochlear potentials without injury of 2000 Hz and a practical limit of about 1000 Hz. This is similar to estimates for loggerhead sea turtles, which had most sensitive hearing between 250 and 1000 Hz, with rapid decline above 1000 Hz (Bartol *et al.* 1999).

These hearing sensitivities are similar to the hearing sensitivities reported for two terrestrial species: pond turtles (*Pseudemys scripta*) and wood turtles (*Chrysemys inscuplta*). Pond turtles are reported to have best hearing responsiveness between 200 and 700 Hz, with slow declines below 100 Hz and rapid declines above 700 Hz and almost no sensitivity above 3000 Hz (Wever and Vernon 1956) the latter has sensitivities up to about 500 Hz,

followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Peterson 1966). We assume that these sensitivities to sound apply to the three hardshell turtles (i.e., green, loggerhead , and Olive ridley sea turtles). No audiometric data are available for leatherback sea turtles, but we assume that they have hearing ranges similar to those of other sea turtles (or at least, their hearing is more likely to be similar to other sea turtles than marine mammals). Based on this information sea turtles exposed to received levels of active mid-frequency sonar are not likely to hear mid-frequency sounds (sounds between 1 kHz and 10 kHz); therefore, they are not likely to respond physiologically or behaviorally to those received levels.

A recent study on the effects of airguns on sea turtle behavior also suggests that sea turtles are most likely to respond to low-frequency sounds. McCauley *et al.* (2000) reported that green and loggerhead sea turtles will avoid air-gun arrays at 2 km and at 1 km with received levels of 166 dB re 1 μPa and 175 db re 1 μPa, respectively. The sea turtles responded consistently: above a level of approximately 166 dB re 1 μPa $_{rms}$ the turtles noticeably increased their swimming activity compared to non-airgun operation periods. Above 175 dB re 1 μPa mean squared pressure their behavior became more erratic possibly indicating the turtles were in an agitated state. Because the sonar that would be used during the proposed exercises transmits at frequencies above hearing thresholds for sea turtles, sea turtles that are exposed to those transmissions are not likely to respond to that exposure.

Sea turtles in the Southern California Range Complex might encounter one or more parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. We cannot, however, determine whether such interactions are probable, given the relatively small number of sonobuoys that would be employed in each of the exercises, the relatively large geographic area involved, and the relatively low densities of sea turtles that are likely to occur in the Action Area. Given the large size of the Southern California Range Complex, the relatively small number of sonobuoys that would be employed in an exercise, and the relatively low densities of sea turtles, an interaction between sea turtles and parachutes seems to have a very small probability; however, despite a very small probability, an interaction could be fatal to the sea turtle if it was entangled and drowned or if it swallowed a parachute.

Nevertheless, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex over the twelve-month period beginning in January 2009 are not likely to reduce the fitness of individual sea turtles that are exposed to stressors produced by those training exercises or other activities. As a result, those activities would not be expected to appreciably reduce the viability of populations of these sea turtles or reduce the likelihood of green, leatherback, or loggerhead sea turtles surviving and recovering in the wild by reducing their reproduction, numbers, or distribution.

CONCLUSION

After reviewing the current status of endangered blue whales, fin whales, humpback whales, sei whales, sperm whales, Guadalupe fur seals, green sea turtles, leatherback sea turtles, loggerhead sea turtles, and Olive ridley sea turtles, the environmental baseline for the action area, the effects of the proposed research program, and the cumulative effects, it is NMFS' biological opinion that the Navy's proposal to conduct major training exercises, unit-level and intermediate-level training activities, and research, development, test and evaluation activities in the Southern California Range Complex over the twelve-month period beginning in January 2009 are likely to adversely affect but are not likely to jeopardize the continued existence of these threatened and endangered species under NMFS jurisdiction.

No critical habitat has been designated for endangered or threatened species in the action area, so the proposed actions are not likely to result in the destruction or adverse modification of designated critical habitat.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibits the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2) of the ESA, taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below, which are non-discretionary, must be implemented by NMFS' Permits, Conservation and Education Division so they become binding conditions of any permit issued to the U.S. Navy, as appropriate, in order for the exemption in section 7(o)(2) to apply. NMFS' Permits, Conservation, and Education Division has a continuing duty to regulate the activity covered by this Incidental Take Statement. If NMFS' Permits, Conservation and Education Division (1) fails to require the U.S. Navy to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to the permit or grant document, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

Amount or Extent of Take Anticipated

The section 7 regulations require NMFS to estimate the number of individuals that may be taken by proposed actions or the extent of land or marine area that may be affected by an action, if we cannot assign numerical limits for animals that could be incidentally taken during the course of an action (Federal Register 51, June 3, 1986, page 19953). The amount of take resulting from active sonar transmissions was difficult to estimate because we have no empirical information on (a) the actual number of listed species that are likely to occur in the different site, (b) the actual number of individuals of those species that are likely to be exposed to active sonar transmissions, (c) the circumstances associated with any exposure, and (d) the range of responses we would expect different individuals of the different species to exhibit upon exposure.

As discussed in the *Approach to the Assessment* section of this Opinion, we used empricial Bayesian analysis to estimate the the number of animals in the exposed population that might respond with particular responses, we multiplied our exposure estimates (which provided us with the number of instances of exposure) by the posterior

probabilities for these responses (which identify the probability of a particular response given an exposure). To estimate the number of animals that might be "taken" in this Opinion, we classified the suite of responses as one or more form of "take" and estimated the number of animals that might be "taken" by (1) multiplying the number of animals exposed the probability of particular responses given an exposure; (2) classifying particular responses as one or more form of "take" (as that term is defined by the ESA and implementing regulations that further define "harm"); then (3) adding the number of exposure events that are expected to produce responses that we would consider "take." The result represents our "take" estimate.

One limitation of this approach is that it estimates the number of animals that might be "taken" without explicitly incorporating the influence of the received level on those probabilities although received levels are almost certain to influence, if not determine, an animal's response to active sonar. To consider the potential effects of received level on these "take" estimates, we conducted logistic regression analyses to consider the relationship between received level and the probability of responses that would generally represent "behavioral disturbance" (see Appendix A for a detailed discussion of the data we used in these analyses, the analyses themselves, and the results of the analyses). The two approaches differed by about 1 percent resulting in the same estimated number of "take" or differences ranging from a low of 1 animal to a high of 33 "take" occurrences.

Table 14. Estimates of the number of instances in which endangered or threatened marine mammals that might be "taken," in the form of behavioral harassment as a result of exposure to the training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex from January 2009 through January 2010

Species	Number of Instances of Harassment Resulting From Exposure Events Involving			Totals
	Active Sonar or Other Environmental Cues from Surface Vessels[1]	Underwater Detonations		
		Harassment	Harm	
Blue whale	102	4		106
Fin whale	35	3	-	38
Humpback whale	1	0	-	1
Sperm whale	27	3	-	30
Guadalupe fur seal	870	4	-	874
Totals		**14**	**0**	

Notes **1** These estimates include animals that respond to vessels involved in major training exercises (rather than unit-level training or RDT&E activities) and that are between 600 meters and 2 kilometers of individual animals. The estimates assume the ships are moving at speeds of at least 10 knots and undergo frequent or periodic course changes

The instances of harassment identified in Table 14 would generally represent changes from foraging, resting, milling, and other behavioral states that require lower energy expenditures to traveling, avoidance, and behavioral states that require higher energy expenditures and, therefore, would represent significant disruptions of the normal behavioral patterns of the animals that have been exposed. We grouped responses to active sonar and responses to vessel traffic and other environmental cues associated with the surface vessels involved in major training exercises because we assume animals would respond to a suite of environmental cues that include sound fields produced by active sonar, sounds produced by the engines of surface vessels, sounds produced by displacement hulls, and other sounds associated with training exercises. That is, we assume endangered marine mammals will perceive and

respond to all of the environmental cues associated with an exercise rather than the single stimulus represented by active sonar. Further, we assume endangered marine mammals would recognize cues that suggest that ships are moving away from them rather than approaching them and they would respond differently to both situations.

Because of their hearing sensitivities, we generally expect fin and sei whales to change their behavior in response to cues from the vessels rather than to the sound field produced by active sonar and the estimates in Table reflect that expectation. However, we assume that humpback and sperm whales would changes their behavior in response to the sound field produced by active sonar and cues from the vessles involved in training exercises.

Effect of the Take

In the accompanying biological opinion, NMFS determined that the number of individuals that might be exposed to mid-frequency active sonar associated with the training exercises and other activities the U.S. Navy plans to conduct in the Southern California Range Complex and are likely to respond to that exposure in ways that NMFS would classify as "take" as that term is defined pursuant to section 3 of the Endangered Species Act is not likely to jeopardize the continued existence of blue, fin, humpback, sei, or sperm whales, Guadalupe fur seals, or endangered or threatened sea turtles. Although the biological significance of the animal's behavioral responses remains unknown, exposure to active sonar transmissions could disrupt one or more behavioral patterns that are essential to an individual animal's life history or to the animal's contribution to a population. For the proposed action, behavioral responses that result from active sonar transmissions and any associated disruptions are expected to be temporary and would not affect the reproduction, survival, or recovery of these species.

Reasonable and Prudent Measures

The National Marine Fisheries Service believes the following reasonable and prudent measures are necessary and appropriate to minimize the impacts of incidental take on threatened and endangered species:

1. The U.S. Navy shall submit reports that identify the general location, timing, number of sonar hours and other aspects of the training exercises and other activities they conduct in the Southern California Range Complex over the next twelve months.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Endangered Species Act of 1973, as amended, NMFS' Permits, Conservation and Education Division and the U.S. Navy must comply with the following terms and conditions, which implements the reasonable and prudent measures described above and outlines the reporting requirements required by the section 7 regulations (50 CFR 402.14(i)).

1. Annual Southern California Exercise Report - The Navy shall submit an Annual Southern California Exercise Report on October 1 of every year (covering data gathered through August 1 of the same year).

    (1) MFAS/HFAS Major Training Exercises - This section shall contain the following information for Major Training Exercises conducted in the Southern California Range Complex:

(i) Exercise Information (for each MTE):

(A) Exercise designator

(B) Date that exercise began and ended

(C) Location

(D) Number and types of active sources used in the exercise

(E) Number and types of passive acoustic sources used in exercise

(F) Number and types of vessels, aircraft, etc., participating in exercise

(G) Total hours of observation by watchstanders

(H) Total hours of all active sonar source operation

(I) Total hours of each active sonar source (along with explanation of how hours are calculated for sources typically quantified in alternate way (buoys, torpedoes, etc.)).

(J) Wave height (high, low, and average during exercise)

(ii) Individual marine mammal sighting info (for each sighting in each MTE)

(A) Location of sighting

(B) Species (if not possible – indication of whale/dolphin/pinniped)

(C) Number of individuals

(D) Calves observed (y/n)

(E) Initial Detection Sensor

(F) Indication of specific type of platform observation made from (including, for example, what type of surface vessel, i.e., FFG, DDG, or CG)

(G) Length of time observers maintained visual contact with marine mammal

(H) Wave height (in feet)

(I) Visibility

(J) Sonar source in use (y/n).

(K) Indication of whether animal is <200yd, 200-500yd, 500-1000yd, 1000-2000yd, or >2000yd from sonar source in (x) above.

(L) Mitigation Implementation – Whether operation of sonar sensor was delayed, or sonar was powered or shut down, and how long the delay was.

(M) If source in use (J) is hullmounted, true bearing of animal from ship, true direction of ship's travel, and estimation of animal's motion relative to ship (opening, closing, parallel)

(N) Observed behavior – Watchstanders shall report, in plain language and without trying to categorize in any way, the observed behavior of the animals (such as animal closing to bow ride, paralleling course/speed, floating on surface and not swimming, etc.)

(iii) An evaluation (based on data gathered during all of the MTEs) of the effectiveness of mitigation measures designed to avoid exposing to mid-frequency sonar. This evaluation shall identify the specific observations that support any conclusions the Navy reaches about the effectiveness of the mitigation.

(2) ASW Summary - This section shall include the following information as summarized from both MTEs and non-major training exercises (i.e., unit-level exercises):

(i) Total annual hours of each type of sonar source (along with explanation of how hours are calculated for sources typically quantified in alternate way (buoys, torpedoes, etc.))

(ii) Cumulative Impact Report - To the extent practicable, the Navy, in coordination with NMFS, shall develop and implement a method of annually reporting non-major (i.e., other than Exercises) training exercises utilizing hull-mounted sonar. The report shall present an annual (and seasonal, where practicable) depiction of non-major training exercises geographically across the SOCAL. The Navy shall include (in the SOCAL annual report) a brief annual progress update on the status of development until an agreed-upon (with NMFS) method has been developed and implemented.

(3) SINKEXs - This section of the report shall include the following information for each SINKEX completed that year:

(i) *Exercise information (gathered for each SINKEX):*

(A) Location

(B) Date and time exercise began and ended

(C) Total hours of observation by watchstanders before, during, and after exercise

(D) Total number and types of rounds expended / explosives detonated

(E) Number and types of passive acoustic sources used in exercise

(F) Total hours of passive acoustic search time

(G) Number and types of vessels, aircraft, etc., participating in exercise

(H) Wave height in feet (high, low and average during exercise)

(I) Narrative description of sensors and platforms utilized for marine mammal detection and timeline illustrating how marine mammal detection was conducted

(ii) *Individual marine mammal observation (by Navy lookouts) information (gathered for each marine mammal sighting)*

(A) Location of sighting

(B) Species (if not possible, indicate whale, dolphin or pinniped)

(C) Number of individuals

(D) Whether calves were observed

(E) Initial detection sensor

(F) Length of time observers maintained visual contact with marine mammal

(G) Wave height

(H) Visibility

(I) Whether sighting was before, during, or after detonations/exercise, and how many minutes before or after

(J) Distance of marine mammal from actual detonations (or target spot if not yet detonated) – use four categories to define distance: 1) the modeled injury threshold radius for the largest explosive used in that exercise type in that OPAREA (91 m for SINKEX in SOCAL); 2) the required exclusion zone (1 nm for SINKEX in SOCAL); (3) the required observation distance (if different than the exclusion zone (2 nm for SINKEX in SOCAL); and, (4) greater than the required observed distance. For example, in this case, the observer would indicate if < 91 m, from 91 m – 1 nm, from 1 nm – 2 nm, and > 2 nm.

(K) Observed behavior – Watchstanders will report, in plain language and without trying to categorize in any way, the observed behavior of the animal(s) (such as animal closing to bow ride, paralleling course/speed, floating on surface and not swimming etc.), including speed and direction.

(L) Resulting mitigation implementation – Indicate whether explosive detonations were delayed, ceased, modified, or not modified due to marine mammal presence and for how long.

(M) If observation occurs while explosives are detonating in the water, indicate munition type in use at time of marine mammal detection.

(4) IEER Summary. This section shall include an annual summary of the following IEER information:

(i) Total number of IEER events conducted in SOCAL

(ii) Total expended/detonated rounds (buoys)

(iii) Total number of self-scuttled IEER rounds

(5) Explosives Summary - To the extent practicable, the Navy will provide the information described below for all of their explosive exercises. Until the Navy is able to report in full the information below, they will provide an annual update on the Navy's explosive tracking methods, including improvements from the previous year.

(i) Total annual number of each type of explosive exercises (of those identified as part of the "specified activity" in this final rule) conducted in SOCAL

(ii) Total annual expended/detonated rounds (missiles, bombs, etc.) for each explosive type

3. Sonar Exercise Notification - The Navy shall submit to the NMFS Office of Protected Resources (specific contact information to be provided in LOA) either an electronic (preferably) or verbal report within fifteen calendar days after the completion of any major exercise (COMPTUEX, JTFEX. etc) indicating:

(1) Location of the exercise

(2) Beginning and end dates of the exercise

(3) Type of exercise (e.g., COMPTUEX, JTFEX, etc.)

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

The following conservation recommendations would provide information for future consultations involving the issuance of marine mammal permits that may affect endangered whales as well as reduce harassment related to research activities:

1. *Cumulative Impact Analysis.* The U.S. Navy should work with NMFS Endangered Species Division and other relevant stakeholders (the Marine Mammal Commission, International Whaling Commission, and the marine mammal research community) to develop a method for assessing the cumulative impacts of anthropogenic noise on cetaceans, pinnipeds, sea turtles, and other marine animals. This includes the cumulative impacts on the distribution, abundance, and the physiological, behavioral and social ecology of these species.

In order to keep NMFS Endangered Species Division informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Permits, Conservation and Education Division of the Office of

Protected Resources should notify the Endangered Species Division of any conservation recommendations they implement in their final action.

REINITIATION NOTICE

This concludes formal consultation on the U.S. Navy's proposal to undertake training activities in the Southern California Range Complex over the twelve-month period beginning in January 2009 and the National Marine Fisheries Service's Permits, Education, and Conservation Division's proposal to issue a Letter of Authorization for "take" of marine mammals in association with the U.S. Navy's activities. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, section 7 consultation must be reinitiated immediately.

Literature Cited

Abgrail, P., V. D. Moulton, and W. J. Richardson. 2008. Updated review of scientific information on impacts of seismic survey sound on marine mammals, 2004 - present. LGL Report SA973-1. Report prepared by LGL Limited, Environmental Research Associates for Canada Department of Fisheries and Oceans; Ottawa, Ontario, Canada.

Aburto, A., D.J. Rountry and J.L. Danzer. 1997. Behavioral response of blue whales to active signals. Technical Report 1746. U.S. Department of the Navy, Naval Command, Control, and Ocean Surveillance Center; San Diego, California.

Adler-Fenchel, H.S. 1980. Acoustically derived estimate of the size distribution for a sample of sperm whales (*Physeter catodon*) in the Western North Atlantic. Canadian Journal of Fisheries and Aquatic Sciences 37:2358-2361.

Advanced Research Projects Agency, and NOAA, National Marine Fisheries Service. 1995. Final Environmental Impact Statement/Environmental Impact Report for the Kauai Acoustic Thermometry of Ocean Climate Project and its associated Marine Mammal Research Program, Vols. I and II. Advanced Research Projects Agency, Arlington, Virginia; NOAA, National Marine Fisheries Service, Silver Spring, Maryland.

Agler, B.A., R.L. Schooley, S.E. Frohock, S.K. Katona, and I.E. Seipt. 1993. Reproduction of photographically identified fin whales, *Balaenoptera physalus*, from the Gulf of Maine. Journal of Mammalogy 74:577-587.

Aguayo L.A. 1974. Baleen whales off continental Chile. Pages 209-217. In: W.E. Schevill (editor) The whale problem: a status report. Harvard University Press, Cambridge, Massachusetts.

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.

Aicken, W., E. Clements, E. Harland, S. Healy, G. Smith, P. Ward, C. MacLeod, and C. Pierpont. 2005. STUFT2 Trial: Environmental protection data analysis report. Unpublished reported prepared by QuinetiQ Limited for the United Kingdom Ministry of Defense. QuinetiQ Limited, Hampshire, United Kingdom.

Alatalo, R.V., L. Gustafsson and A. Lundberg. 1990. Phenotypic selection on heritable size traits: environmental variance and genetic response. The American Naturalist 135(3): 464.

Allen, K.R. 1980. Conservation and management of whales. University of Washington Press; Seattle, Washington.

Allen, K.R. 1980. Size distribution of male sperm whales in the pelagic catches. Reports of the International Whaling Commission Special Issue 2: 51-56.

Allen, M.C. and A.J. Read. 2000. Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. Marine Mammal Science 16(4): 10.

Amaral, K.A. and C.A. Carlson. 2005. Scientific basis for whale watching guidelines: a review of current research. Unpublished paper submitted to the Scientific Committee of the International Whaling Commission SC/57/WW1; Cambridge, United Kingdom.

Anderson, J. J. 2000. A vitality-based model relating stressors and environmental properties to organism survival. Ecological Monographs 70:445-470.

Andre, M., C. Kamminga and D. Ketten. 1997. Are low-frequency sounds a marine hazard: a case study in the Canary Islands. Underwater Bio-sonar and Bioacoustics Symposium, Loughborough University.

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.

Andrews, R.C. 1916. The sei whale (*Balaenoptera borealis* Lesson). Memoir of the American Museum of Natural History New Series 1(6):291-388.

Angliss, R. P., and R. B. Outlaw. 2007. Alaska marine mammal stock assessments, 2006. NOAA Technical Memorandum NMFS-ASFC-168, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, Washington.

Angradi, A. M., C. Consiglio, and L. Marini. 1993. Behavior of striped dolphins (*Stenella coeruleoalba*) in the central Tyrrhenian Sea (Mediterranean Sea) in relation to commercial ships. Pages 77-79 *in* Proceedings of the 7th Annual Conference of the European Cetacean Society, 18-21 February 1993, Inverness, Scotland.

Anonymous. 2001. Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. Journal of Cetacean Research and Management Supplement 2: 1 - 60.

Apple, T.C. 2001. Spatial and temporal variation of sperm whale (*Physeter macrocephalus*) codas in the northern Gulf of Mexico. The Journal of the Acoustical Society of America 109(5 2): 2390.

Arnbom, T., V. Papstavrou, L.S. Weilgart and H. Whitehead. 1987. Sperm whales react to an attack by killer whales. Journal of Mammalogy 68(2): 450-453.

Ashford, J.R. and A.R. Martin. Interactions between cetaceans and longline fishery operations around South Georgia. Marine Mammal Science 12(3):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 Conservation., Washington D.C.

Au, D., and W. L. Perryman. 1982. Movement and speed of dolphin schools responding to an approaching ship. Fishery Bulletin 80:371-379.

Au, W. W. L. 1993. The sonar of dolphins. Springer Press; New York.

Au, W. W. L. 1997. Some hot topics in animal bioacoustics. The Journal of the Acoustical Society of America 101:10.

Au, W. W. L., A. Frankel, D. A. Helweg, and D. H. Cato. 2001. Against the humpback whale sonar hypothesis. IEEE Journal of Oceanic Engineering 26:5.

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

Au, W. W. L., and K. J. Benoit-Bird. 2003. Automatic gain control in the echolocation system of dolphins. Nature 423:861-863.

Au, W. W. L., and P. E. Nachtigall. 1997. Acoustics of echolocating dolphins and small whales. Marine Behavior and Physiology 29:36.

Au, W. W. L., L. N. Andersen, A. R. Rasmussen, H. L. Roitblat, and P. E. Nachtigall. 1995. Neural network modeling of a dolphin's sonar discrimination capabilities. The Journal of the Acoustical Society of America 98:8.

Au, W., and M. Green. 2000. Acoustic interaction of humpback whales and whale-watching boats. Marine Environmental Research 49:469-481.

Au, W.W.L., D.A. Carder, R.H. Penner, and B.L. Scronce. 1985. Demonstration of adaptation in beluga whale echolocation signals. The Journal of the Acoustical Society of America 77(2):726-730.

Au, W.W.L., J.L. Pawloski, T.W. Cranford, R.C. Gisner and P.E. Nachtigall. 1993. Transmission beam pattern of a false killer whale. The Journal of the Acoustical Society of America 93(4): 2358 - 2359.

Au, W.W.L., P. Nachtigall, and J.L. Pawloski. 1997. Acoustic effects of the ATOC signal (75 Hz, 195 dB) on dolphins and whales. Journal of the Acoustical Society of America 101:2973-2977.

Au, W.W.L., R.W. Floyd, R.H. Penner and A.E. Murchison. 1974. Measurement of echolocation signals of the Atlantic bottlenose dolphin, *Tursiops truncatus* Montagu, in open waters. The Journal of the Acoustical Society of America 64(2): 411 - 422.

Aurioles-Gamboa, D., C. J. Hernandez-Camacho, and E. Rodriguez-Krebs. 1999. Notes on the southernmost records of the Guadalupe fur seal, *Arctocephalus townsendi*, in Mexico. Marine Mammal Science **15**:3.

Babushina, Ye.S., G.L. Zaslavskii, and L.I. Yurkevich. 1991. Air and underwater hearing characteristics of the northern fur seal: audiograms, frequency, and differential thresholds. Biophysics 36(5):909-913.

Backus, R.H. and W.E. Schevill. 1966. Physeter clicks. p.510-528 In: K.S. Norris (editor) Whales, Dolphins, and Porpoises. University of California Press; Berkeley, California.

Baillie, J. and G. Groombridge (eds.). 1996. 1996 IUCN red list of threatened animals. International Union for the Conservation of Nature; Gland, Switzerland.

Bain, D. E., R. Williams, J. C. Smith, and D. Lusseau. 2006. Effects of vessels on behavior of southern resident killer whales (*Orcinus* spp) 2003 - 2006. NMFS Contract Report No. AB133F05SE3965. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington.

Baker, C. S., L.M. Herman, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Report prepared by the Kewalo Basin Marine Mammal Laboratory for U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington.

Baker, C.S and L.M. Herman. 1987. Alternative population estimates of humpback whales (*Megaptera novaeangliae*) in Hawai'ian waters. Canadian Journal of Zoology. 65:2818-2821.

Baker, C.S. 1985. The behavioral ecology and populations structure of the humpback whale (*Megaptera novaeangliae*) in the central and eastern Pacific. Unpublished Dissertation for the University of Hawai'i at Manoa. University Microfilms.

Baker, C.S. and L.M. Herman. 1981. Migration and local movement of humpback whales through Hawai'ian waters. Canadian Journal of Zoology 59:460-469.

Baker, C.S., A. Perry and L.M. Herman. 1987. Reproductive histories of female humpback whales (*Megaptera novaeangliae*) in the North Pacific. Marine Ecology Progress Series 41: 103-114.

Baker, C.S., A. Perry, J.L. Bannister, M.T. Weinrich, R.B. Abernethy, J. Calambokidis, J. Lien, R.H. Lambertsen, J. Urban Ramirez, O. Vasquez, P.J. Clapham, A. Alling, S.J. O'Brien and S.R. Palumbi. 1993. Abundant mitochondrial DNA variation and world-wide population structure in humpback whales. Proceedings of the National Academy of Science of the United States of America 90(17): 8239-8243.

Baker, C.S., D.A. Gilbert, M.T. Weinrich, R.H. Lambertsen, J. Calambokidis, B. McArdle, G.K. Chambers and J. O'Brien. 1993. Population characteristics of DNA fingerprints in humpback whales (*Megaptera novaeangliae*). Journal of Heredity 84: 281-290.

Baker, C.S., R.W. Slade, J.L. Bannister, B. Abernethy, M.T. Weinrich, J. Lien, J. Urban, P.J. Corkeron, J. Calambokidis, O. Vasquez and S.R. Palumbi. 1994. Hierarchical structure of mitochondrial DNA gene flow among humpback whales *Megaptera novaeangliae*, world-wide. Molecular Ecology 3: 313-327.

Baker, C.S., S.R. Palumbi, R.H. Lambertsen, M.T. Weinrich, J. Calambokidis and J. O'Brien. 1990. Influence of seasonal migration on geographic distribution of mitochondrial DNA haplotypes in humpback whales. Nature 344(15): 238-240.

Balazs, G. H., and M. Chaloupka. 2004. Thirty-year recovery trend in the once depleted Hawai'ian green sea turtle stock. Biological Conservation 117:491-498.

Balcomb, K. C., and D. E. Claridge. 2001. Mass whale mortality: U.S. Navy exercises cause strandings. Bahamian Journal of Science 8:1 - 12.

Ballance, L.T., R.C. Anderson, R.L. Pitman, K. Stafford, A. Shaan, Z. Waheed and R.L. Brownell, Jr. 2001. Cetacean sightings around the Republic of the Maldives, April 1998. Journal of Cetacean Research and Management 3(2): 213 - 218.

Bannister, J.L. 1994. Continued increase in humpback whales off Western Australia. Reports of the International Whaling Commission 44: 309-310.

Bannister, J.L. and E. Mitchell. 1980. North Pacific sperm whale stock identity: distributional evidence from Maury and Townsend charts. Reports of the International Whaling Commission Special Issue No. 2: 219-223

Bannister, J.L., G.P. Kirkwood and S.E. Wayte. 1991. Increase in humpback whales off western Australia. Reports of the International Whaling Commission 41: 461-465.

Baretta, L. and G.L. Hunt, Jr. 1994. Changes in the numbers of cetaceans near the Pribilof Islands, Bering Sea, between 1975-78 and 1987-89. Arctic 47: 321-326.

Barlow, J. 1994. Abundance of large whales in California coastal waters: a comparison of ship surveys in 1979/80 and in 1991. Reports of the International Whaling Commission 44:399-406.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall 1991. Fishery Bulletin 93: 1-14.

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 21:17.

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

Barlow, J., K. A. Forney, P. S. Hill, R. L. Brownell Jr, J. V. Carretta, D. P. DeMaster, F. Julian and others. 1997. U.S. Pacific marine mammal stock assessment: 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center; La Jolla, California.

Barlow, J., K. A. Forney, P. S. Hill, R. L. Brownell, Jr., J. V. Carretta, D. P. DeMaster, F. Julian, M. S. Lowry, T. Ragen, and R. R. Reeves. 1997. U.S. Pacific marine mammal stock assessment: 1996. U.S. Department of Commerce, NOAA Technical Memorandum nmfs-SWFSC-248. Southwest Fisheries Science Center; La Jolla, California.

Barlow, J., R.L. Brownell, D.P. DeMaster, K.A. Forney, M.S. Lowry, S. Osmek, T.J. Ragen, R.R. Reeves, and R.J. Small. 1995. U.S. Pacific marine mammal stock assessments 1995. NOAA Technical Memorandum NMFS-SWFSC-219. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center; La Jolla, California.

Barthol, S.M., J. Musick, and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). Copeia 1999(3): 836-840.

Bartholomew, G.A. 1970. A model for the evolution of pinniped polygyny. Evolution 24:546-559.

Bartol, S.M. and D.R. Ketten. 2006. Turtle and tuna hearing. In: Sea turtle and pelagic fish sensory biology: developing techniques to reduce sea turtle bycatch in longline fisheries. Edited by Y. Swimmer and R. Brill. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center; Honolulu, Hawai'i.

Bartol, S.M. and J.A. Musick. 2003. Sensory biology of sea turtles. Pages 79-102 *in* Lutz et al. 2003.

Bartol, S.M., J.A. Musick, and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle. Copeia 3: 836-840.

Bass, A.L., S.P. Epperly, J. Braun, D.W. Owens and R.M. Patterson. 1998. Natal origin and sex ratios of foraging sea turtles in the Pamlico-Albemarle Estuarine Complex. NOAA Technical Memorandum NMFS-SEFSC-415. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center; Miami, Florida.

Bauer, G.B. 1986. The behavior of humpback whales in Hawai'i and modification of behavior induced by human interventions. Unpublished doctoral dissertation; University of Hawai'i, Honolulu, Hawai'i.

Bauer, G.B. and L.M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawai'i. Report Submitted to NMFS Southwest Region, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center, Western Pacific Program Office; Honolulu, Hawai'i.

Bauer, G.B. and L.M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawai'i. Report Submitted to NMFS Southwest Region, Western Pacific Program Office; Honolulu, Hawai'i.

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(1):84-88.

Beale, C. M., and P. Monaghan. 2004. Human disturbance: people as predation-free predators? Journal of Applied Ecology 41:335-343.

Beamish P. and E. Mitchell. 1971. Ultrasonic sounds recorded in the presence of a blue whale (*Balaenoptera musculus*). Deep-Sea Research 18: 803-809.

Beauchamp, G. and B. Livoreil. 1997. The effect of group size on vigilance and feeding rate in spice finches (*Lonchura punctulata*). The Canadian Journal of Zoology 75(9): 6.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty and M. Kretzen. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology 20(6):1791-1798.

Bejder, L., S.M. Dawson and J.A. Harraway. 1999. Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. Marine Mammal Science 15(3):13.

Berger J., D. Daneke, J. Johnson, and S. H. Berwick. 1983. Pronghorn foraging economy and predator avoidance in a desert ecosystem: implications for the conservation of large mammalian herbivores. Biological Conservation 25:193-208.

Berta, A. 2002. Pinniped, Overview. Pages 903-911 *in* B. W. W. F. Perrin, and J. G. M. Thewissen (editors) Encyclopedia of Marine Mammals. Academic Press; San Diego, California.

Bérubé, M., A. Aguilar, D. Dendanto, F. Larsen, G. Notarbartolo Di Sciara, R. Sears, J. Sigurjonsson, J. Urban-R and P.J. Palsbøll. 1998. Population genetic structure of North Atlantic, Mediterranean Sea and Sea of Cortez fin whales, *Balaenoptera physalus*(Linnaeus 1758): analysis of mitochondrial and nuclear loci. Molecular Ecology 7: 585 - 599.

Berzin, A.A. 1971. "Kashalot [The sperm whale]". Izdat. "Pischevaya Promyshelennost." Moscow. English translation, 1972, Israel Program for Scientific Translations, Jerusalem.

Berzin, A.A. 2007. Subject No. 12. Whale stock status in the North Pacific in 1973. Pages: 26-27. In: Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. NOAA Technical Memorandum NMFS-AFSC-175. Edited by Y.V. Ivashchenko, P.J. Clapham and R.L. Brownell Jr. U.S. Department of

Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center; Seattle, Washington.

Berzin, A.A. 2007. Whale stock status in the North Pacific and Antarctica in 1977. Page 33. In: Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. NOAA Technical Memorandum NMFS-AFSC-175. Edited by Y.V. Ivashchenko, P.J. Clapham and R.L. Brownell Jr. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center; Seattle, Washington.

Berzin, A.A. 2007. Whale stock status in the North Pacific in 1975. Pages: 30-32. In: Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. NOAA Technical Memorandum NMFS-AFSC-175. Edited by Y.V. Ivashchenko, P.J. Clapham and R.L. Brownell Jr. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center; Seattle, Washington.

Berzin, A.A. and V.L. Vladimirov. 1981. Changes in abundance of whalebone whales in the Pacific and Antarctic since the cessation of their exploitation. Reports of the International Whaling Commission 31:495-498.

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. Izvestia TINRO 58:179-207.

Best, P.B. 1982. Whales, why do they strand? African Wildlife 36: 6.

Best, P.N. J.L. Bannister, R.L. Brownell, Jr., and G.P. Donovan (eds.). 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

Biassoni, N., P. J. O. Miller, and P. L. Tyack. 2001. Humpback whales, *Megaptera novaeangliae*, alter their song to compensate for man-made noise. *in* 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada.

Biassoni, N., P.J. Miller, and P.L. Tyack. 2000. Preliminary results of the effects of SURTASS-LFA sonar on singing humpback whales. Woods Hole Oceanographic Institute, Technical Report # 2000-06. Woods Hole, Massachusetts.

Blaylock, R.A., J.W. Hain, L.J. Hansen, D.L. Palka, and G.T. Waring. 1995. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments. NOAA Technical Memorandum NMFS-SEFSC-363. Miami, Florida.

Born, E.W., F.F. Riget, R. Dietz and D. Andriashek. 1999. Escape responses of hauled out ringed seals (*Phoca hispida*) to aircraft disturbance. Polar Biology 21(3): 171 - 178.

Bowles, A.E., M. Smultea, B. Wursig, D.P. DeMaster, D. Palka. 1994. Abundance of marine mammals exposed to transmissions from the Heard Island Feasibility Test. Journal of the Acoustical Society of America 96(4):2469-2482.

Bradshaw, C., S. Boutin and D. Hebert. 1998. Energetic implications of disturbance caused by petroleum exploration to woodland caribou. The Canadian Journal of Zoology 76(7): 6.

Braham, H.W., and D.W. Rice. 1984. The right whale, *Balaena glacialis*. Marine Fisheries Review 46(4):38-44.

Braham, H.W., R.D. Everitt, and D.J. Rugh. 1980. Northern sea lion decline in the eastern Aleutian Islands. Journal of Wildlife Management 44: 25-33.

Branch, T.A. and D.S. Butterworth. 2001. Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. Journal of Cetacean Research and Management 3(3): 251 - 270.

Brandon, R. 1978. Adaptation and evolutionary theory. Studies in the History and Philosophy of Science 9: 181 - 206.

Bräutigam, A. and K.L. Eckert. 2006. Turning the tide: exploitation, trade and management of marine turtles in the Lesser Antilles, Central America, Colombia and Venezuela. TRAFFIC International and the Secretariat of the Convention on International Trade in Endangered Species; Cambridge, United Kingdom.

Brodie, P.F. 1981. Energetic and behavioral considerations with respect to marine mammals and disturbance from underwater noise. Pages 287-290. In: N.M. Peterson (ed.), The questions of sound from icebreaker operations: The proceedings of a workshop. Arctic Pilot Project; Calgary, Alberta.

Brownell Jr., R.L., P.B. Best, and J.H. Prescott (eds.). 1986. Right whales: past and present status. Reports of the International Whaling Commission Special Issue No. 10. Cambridge, United Kingdom.

Brownell, R. L., T. Yamada, J. G. Mead, and A. L. van Helden. 2004. Mass strandings of Cuvier's beaked whales in Japan: US Naval acoustic link? International Whaling Commission, Cambridge, United Kingdom.

Brownell, R.L., Jr. 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: US Naval acoustic link? Unpublished paper SC/56/E37 presented to the International Whaling Commission's Scientific Committee, July 2004. International Whaling Commission; Cambridge, United Kingdom.

Browning, L. J., and E. J. Harland. 1999. Are bottlenose dolphins disturbed by fast ferries? Pages 92-98 *in* Proceedings of the 13th Annual Conference of the European Cetacean Society, 5 - 8 April 1999, Valencia, Spain.

Brumm, H. 2004. The impact of environmental noise on song amplitude in a territorial bird. Journal of Animal Ecology 73: 434-440.

Bryant, P. J., C. M. Lafferty and S. K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. Pages 375-387. In: M.L. Jones et al. (editors). The gray whale Eschrichtius robustus. Academic Press, Orlando, Florida.

Bryant, P. J., C. M. Lafferty, and S. K. Lafferty. 1984. Reoccupation of Laguna Guerro Negro, Baja California, Mexico, by gray whales. Pages 373-387*in* Bryant, P. J., C. M. Lafferty, and S. K. Lafferty, editors. The gray whale, *Eschrictius robustus*. Academic Press, Inc., Orlando, Florida.

Buck, J.R., and P.L. Tyack. 2000. Response of gray whales to low-frequency sound. Journal of the Acoustical Society of America 107 (5): 2744.

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 animal populations. Oxford University Press; Oxford, United Kingdom.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. and Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall; London, United Kingdom.

Burgner, R. L. 1991. Life history of sockeye salmon (Oncorhynchus nerka). Pages 3-116. In C. Groot and L. Margolis (editors). Pacific salmon life histories. University of British Columbia Press; Vancouver, British Columbia.

Calambokidis, J., E.A. Falcone, T.J. Quinn II, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R.G. LeDuc, D.K. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbân R, D.W. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K.R. 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 prepared by Cascadia Research for U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; Seattle, Washington.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, R.J. Urban, J.K. Jacobsen, O.V. Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P.P.L.D. Guevara, M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow and T.J. Quinn Ii. 2001. Movements and population structure of humpback whales in the North Pacific. Marine Mammal Science 17(4):769.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, M. Yamaguchi, F. Sato, J. Urbán, J. Jacobsen, O.V. Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dalheim, N. Higashi, S. Uchida, J.K.B. Ford, Y. Miyamura, P.L. Guevara, S.A. Mizroch, L. Schlender, and K. Rasumssen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. National Marine Fisheries Services, Southwest Fisheries Science Center; La Jolla, California.

Calambokidis, J., G.H. Steiger, J.M. Straley, T.J. Quinn II, L.M. Herman, S. Cerchio, D.R. Salden, M. Yamaguchi, F. Sato, R.J. Urbán, J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, N. Higashi, 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. Final Report prepared by Cascadia Research Collective for the National Marine Fisheries Service, Southwest Fisheries Science Center. U.S. Department of Commerce, National Marine Fisheries Service, Southwest Fisheries Science Center; La Jolla, California.

Calambokidis, J., T.E. Chandler, D.P. Costa, C.W. Clark, and H. Whitehead. 1998. Effects of the ATOC sound source on the distribution of marine mammals observed from aerial surveys off central California. WMMSC, Monaco. Jan. 1998.

Caldwell, D.K. and M.C. Caldwell. 1983. Whales and Dolphins. The Audubon Society Field Guide to North American Fishes, Whales and Dolphins. Alfred A. Knopf, Inc.; New York, New York.

Calkins, D.G. 1983. Marine mammals of lower Cook Inlet and the potential for impact from outer continental shelf oil and gas exploration, development, and transport. NOAA Outer Continental Shelf Environmental Assessment Program, Environmental Assessment of the Alaskan Continental Shelf. Final Report of the Principal Investigators 20:171-263.

Canadian Department of Fisheries and Oceans. 2004. Review of scientific information on impacts of seismic sound on fish, invertebrates, marine turtles and marine mammals. DFO Canadian Science Advisory Secretariat Habitat Status Report 2004/002. Canadian Department of Fisheries and Oceans; Ottawa, Ontario, Canada.

Carder, D.A. and S.H. Ridgway. 1990. Auditory brainstem response in a neonatal sperm whale *Physeter* spp. Journal of the Acoustical Society of America Supplement 1:88.

Carretta, J.V., and K.A. Forney. 1993. Report on two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter aircraft: March 9- April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS-SWFSC-185; La Jolla, California.

Caswell, H. 1980. On the equivalence of maximizing reproductive value and maximizing fitness. Ecology 6:19-24.

Caswell, H. 1982. Optimal life histories and the maximization of reproductive value: a general theorem for complex life cycles. Ecology 63:1218-1222.

Caswell, H. 2001, Matrix population models. Sunderland, Massachusetts, Sinauer Publishers, Inc.

Cato, D.H. and R.C. McCauley. 2001. Ocean ambient noise from anthropogenic and natural sources in the context of marine mammal acoustics. Journal of the Acoustical Society of America 110: 2751.

Caut, S., E. Guirlet, E. Angular, K. Das and M. Girondot. 2008. Isotope analysis reveals foraging area dichotomy for Atlantic leatherback turtles. Public Library of Science (PLoS) One 3(3):e1845.

Cetacean and Turtle Assessment Program [CETAP]. 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U.S. Outer Continental Shelf. Report prepared by the University of Rhode Island School of Oceanography for the U.S. Department of the Interior, Bureau of Land Management; Washington, D.C.

Charif, R.A., D.K. Mellinger, K.J. Dunsmore, and C.W. Clark. Submitted. Source levels and depths of fin whale (*Balaenoptera physalus*) vocalizations from the eastern North Pacific.

Cherfas, J. 1989. The hunting of the whale. Viking Penguin Inc.; New York, New York.

Chittleborough, R.G. 1965. Dynamics of two populations of humpback whale, *Megaptera novaeangliae* (Borowski). Australian Journal of Marine and Freshwater Research 16:33-128.

Christal, J. and H. Whitehead. 1997. Aggregations of mature male sperm whales on the Galapagos Islands breeding ground. Marine Mammal Science 13(1): 11.

Christal, J. and H. Whitehead. 2001. Social affiliations within sperm whale (*Physeter macrocephalus*) groups. Ethology 107(4): 18.

Christal, J., H. Whitehead and E. Lettevall. 1998. Sperm whale social units: variation and change. Canadian Journal of Zoology 76(8): 10.

Chrousos, G.P. 2000. The HPA axis and the stress response. Endocrine Research 26: 2.

Clapham, P. J., C. Good, S. E. Quinn, R. R. Reeves, J. E. Scarff, and R. L. Brownell, Jr. 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.

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. 1994. Maturational changes in patterns of association among male and female humpback whales. Journal of Zoology 71: 440-443.

Clapham, P.J. 1996. The social and reproductive biology of humpback whales: an ecological perspective. Mammal Review 26: 27-49.

Clapham, P.J. 1999. *Megaptera novaeangliae*. Mammalian Species 604: 1-9.

Clapham, P.J. and C.A. Mayo. 1987. Reproduction and recruitment of individually identified humpback whales, *Megaptera novaeangliae*, observed in Massachusetts Bay, 1979-1985. Canadian Journal of Zoology 65(12):2853-2863.

Clapham, P.J. and D.K. Mattila. 1993. Reaction of humpback whales to skin biopsy sampling on a West Indies breeding ground. Marine Mammal Science, 9(4):382-391.

Clapham, P.J., and R.L. Brownell, Jr. 1996. Potential for interspecific competition in baleen whales. Reports of the International Whaling Commission 46:361-367.

Clark, C.W. and K.M. Firstrup. 2001. Baleen whale responses to low-frequency human-made underwater sounds. Journal of the Acoustical Society of America 110: 2751.

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 R. Charif. 1998. Monitoring the occurrence of large whales off North and West Scotland using passive acoustic arrays. Society of Petroleum Engineers. SPE/UKOOA European Environmental Conference, Aberdeen, Scotland. April 1997.

Clark, C.W., C.J. Gagnon and D.K. Mellinger. 1993. Whales '93: Application of the Navy IUSS for low-frequency marine mammal research. Invited paper, abstract published in Tenth Biennial conference on the Biology of Marine Mammals abstracts, 11-15 November 1993, Galveston, Texas. (Abstract)

Clark, C.W., Tyack P., Ellison W.T. 1998. Low-frequency sound scientific research program. Phase I: Responses of blue and fin whales to SURTASS LFA, southern California Bight. Quick Look Report. Marine Acoustics Inc.; Washington, D.C.

Clarke, J.T. and S.A. Norman. 2005. Results and evaluation of the US Navy shock trial environmental mitigation of marine mammals and sea turtles. Journal of Cetacean Research and Management 7: 43 – 50.

Clarke, M.R. 1976. Observation on sperm whale diving. Journal of the Marine Biology Association UK 56: 809-810.

Clarke, M.R. 1979. The head of the sperm whale. Scientific American 240(1): 106-117.

Clarke, R. 1956. Marking whales from a helicopter. Norsk Hvalfangst-Tidende 45:311-318.

Clarke, R. 1956. Sperm whales of the Azores. Discovery Reports 28, 237-298.

Coakes, A. and H. Whitehead. 2004. Social structure and mating system of sperm whales off northern Chile. Canadian Journal of Zoology 82: 10.

Cody, M.L. and J.H. Brown. 1969. Song asynchony in neigboring bird species. Nature 222: 778-780.

Cole, L.C. 1954. The population consequences of life history phenomena. Quarterly Review of Biology 29: 103-137.

Cole, N.C., C.G. Jones and S. Harris. 2005. The need for enemy-free space: The impact of an invasive gecko on island endemics. Biological Conservation 125(4): 467-474.

Conner, R.C. and R.S. Smolker. 1985. Habituated dolphins (Tursiops sp.) in western Australia. Journal of Mammalogy 66(2):398-400.

Constantine, R., and D. Brunton. 2001. Boats and bottlenose dolphin (*Tursiops truncatus*) in the Bay of Islands, New Zealand. Pages 46 *in* 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada.

Cope, M., D. St. Aubin, and J. Thomas. 1999. The effect of boat activity on the behavior of bottlenose dolphin (*Tursiops truncatus*) in the nearshore waters of Hilton Head, South Carolina. Pages 37-38 *in* 13th Biennial Conference of the Society of Marine Mammalogy on the Biology of Marine Mammals, 28 November to 3 December 1999, Wailea, Maui, Hawai'i.

Couch, L.K. 1930. Humpback whale killed in Puget Sound, Washington. The Murrelet 11(3): 75.

Cowlishaw, g., M.J. Lawes, M. Lightbody, A. Martin, R. Pettifor and J.M. Rowcliffe. 2004. A simple rule for the costs of vigilance: empirical evidence from a social forager. Proceedings of the Royal Society of London, Series B: Biological Sciences 271:27-33.

Cox, T. M., T. J. Ragen, A. J. Read, E. Vos, R. W. Baird, K. C. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D. D'Spain, A. Fernandez, J. J. Finneran, R. L. Gentry, W. Gerth, F. M. D. Gulland, J. Hildebrand, D. Houser, T. Hullar, P. D. Jepson, D. R. Ketten, C. D. MacLeod, P. Miller, S. Moore, D. C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, P. L. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7:177 - 187.

Cranford, T.W. 1992. Directional asymmetry in the Odontocete forehead. American Zoologist 32(5): 140A.

Creel, S. 2005. Dominance, aggression, and glucocorticoid levels in social carnivores. Journal of Mammalogy 86(2): 255-264.

Croll, D.A., B.R. Tershy, A. Acevedo, and P. Levin. 1999. Marine vertebrates and low frequency sound. Unpublished technical report for the U.S. Navy's Environmental Impact Statement on Low Frequency Active Sonar. Marine Mammal and Seabird Ecology Group, Institute of Marine Sciences, University of California, Santa Cruz; Santa Cruz, California.

Croll, D.A., C.W. Clark, J. Calambokidis, W.T. Ellison and B.R. Tershy. 2001. Effect of anthropogenic low-frequency noise on the foraging ecology of *Balaenoptera* whales. Animal Conservation 4(1): 15.

Crouse, D.T. 1999. The consequences of delayed maturity in a human-dominated world. American Fisheries Society Symposium 23: 195-202.

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

Cudahy, E., and W.T. Ellison. 2001. A review of the potential for in vivo tissue damage by exposure to underwater sound. Unpublished report prepared for National Marine Fisheries Service, Office of Protected Resources. Silver Spring, Maryland.

Cummings, W.C. and J.F. Fish JF. 1972. Alpha Helix whale cruise, phase 1 (13-23 Oct 1971): bioacoustics of cetaceans. In: Alpha Helix Research program (1970-1971). pp 23-24. Scripps Institution of Oceanography, La Jolla, California.

Cummings, W.C. and P.O. Thompson. 1971. Underwater sounds from the blue whale *Balaenoptera musculus*. Journal of the Acoustical Society of America 50(4):1193-1198.

Cummings, W.C. and P.O. Thompson. 1977. Long 20-Hz sounds from blue whales in the northeast Pacific. Abstracts of the Second Conference on the Biology of Marine Mammals, San Diego, California, December 1977.

Cummings, W.C. and P.O. Thompson. 1994. Characteristics and seasons of blue and finback whale sounds along the U.S. west coast as recorded at SOSUS stations. Journal of the Acoustical Society of America 95: 2853.

Curtis, K.R., B.M. Howe, and J.A. Mercer. 1999. Low-frequency ambient sound in the North Pacific: long time series observations. Journal of the Acoustical Society of America 106: 3189-3200.

D'Amico, A., and W. Verboom. 1998. Summary record and report of the SACLANTCEN Bioacoustics, Marine Mammal Policy, and Mitigation Procedures Panels, 15-19 June 1998. SACLANTCEN Marine Mammal Environmental Policy and SACLANTCEN Marine Mammal and Human Divers: Risk Mitigation Rules. SACLANTCEN M-133, SACLANCT Undersea Research Center, La Spezia, Italy.

D'Spain, G. D., 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, 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.

Daan, S., C. Deerenberg, and C. Dijkstra. 1996. Increased daily work precipitates natural death in the kestrel. The Journal of Animal Ecology 65:539 - 544.

Darling, J.D. and K. Mori. 1993. Recent observations of humpback whales (*Megaptera novaeangliae*) in Japanese waters off Ogasawara and Okinawa. The Canadian Journal of Zoology 71(2): 325 - 333.

David, L. 2002. Disturbance to Mediterranean cetaceans caused by vessel traffic. Report prepared for the ACCOBAMS Secretariat, Monaco.

Davis, R, G. Scott, B. Würsig, G. Fargion, W. Evans, L. Hansen, R. Benson, K. Mullin, T. Leming, N. May, B. Mate, J. Norris, T. Jefferson, D. Peake, S.K. Lynn, T. Sparks, C. Schroeder. 1995. Distribution and abundance of marine mammals in the north-central and western Gulf of Mexico; draft final report. Volume II: Technical Report. OCS Study No. MMS95. Prepared by the Texas Institute of Oceanography and the National Marine Fisheries Service for the U. S. Minerals Management Service, New Orleans, Louisiana.

Dill, H.R., and W.A. Bryan. 1912. Report on an expedition to Laysan Island in 1911. U.S. Department of Agriculture Biological Survey Bulletin 42:1-30.

Dolphin, W.F. 1987. Ventilation and dive patterns of humpback whales *Megaptera novaeangliae*, on their Alaskan feeding grounds. Canadian Journal of Zoology 65(1):83-90.

Donovan, G. P. 1984. Blue whales off Peru, December 1982, with special reference to pygmy blue whales. Reports of the International Whaling Commission 34: 473-476.

Donovan, G.P. 1991. A review of IWC stock boundaries. Reports of the International Whaling Commission, Special Issue 13:39- 68.

Drouot, V., A. Gannier and J.C. Goold. 2004. Summer social distribution of sperm whales (*Physeter macrocephalus*) in the Mediterranean Sea. Journal of the Marine Biological Association of the UK 84(3): 6.

Drouot, V., M. Berube, A. Gannier, J.C. Goold, R.J. Reid and P.J. Palsboll. 2004. A note on genetic isolation of Mediterranean sperm whales (*Physeter macrocephalus*) suggested by mitochondrial DNA. Journal of Cetacean Research and Management 6(1): 29 - 32.

D'Spain, G. D., 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.

Dufault, S. and H. Whitehead. 1995. An encounter with recently wounded sperm whales (*Physeter macrocephalus*). Marine Mammal Science 11(4): 4.

Duncan, A. J., R. D. McCauley, and A. L. Maggi. 2004. Predicting the environmental impact of active sonar. AIP Conference Proceedings 728:280-287.

Ecolarge and Government of Australia. 2006. Pacific Islands whale watch tourism: 2006. An economic valuation. Unpublished paper submitted to the International Whaling Commission IWC/58/7. International Whaling Commission, Cambridge, United Kingdom.

Edds, P. L. 1988. Characteristics of finback *Balaenoptera physalus*vocalizations in the St. Lawrence Estuary. Bioacoustics 1: 131-149.

Edds, P.L. 1982. Vocalizations of the blue whale Balaenoptera musculus, in the St. Lawrence River. J.ournal of Mammalogy 63(2):345-347.

Edds, P.L. and J.A.F. MacFarlane. 1987. Occurrence and general behavior of balaenopterid cetaceans summering in the St. Lawrence Estuary, Canada. Canadian Journal of Zoology 65(6):1363-1376.

Edds-Walton, P.L. 1997. Acoustic communication signals of mysticete whales. Bioacoustics 8: 47-60.

Efroymson, R. A., W. H. Rose, S. Nemeth, and G. W. Suter, II. 2000. Ecological risk assessment framework for low-altitude overflights by fixed-wing and rotary-wing military aircraft. ORNL TM-2000/289. U.S. Department of Energy, Oak Ridge National Laboratory, Environmental Sciences Division; Oak Ridge, Tennessee.

Egnor, S. E. R., C. G. Iguina, and M. D. Hauser. 2006. Perturbation of auditory feedback causes systematic perturbation in vocal structure in adult cotton-top tamarins. Journal of Experimental Biology **209**:3652-3663.

Eldredge, L.G. 1991. Annotated checklist of the marine mammals of Micronesia. Micronesica 24(4): 217 - 230.

Eldredge, L.G. 2003. The marine reptiles and mammals of Guam. Micronesica 35 - 36: 653 - 660.

Erbe, C. 2000. Detection of whale calls in noise: Performance comparison between a beluga whale, human listeners and a neural network. Journal of the Acoustical Society of America108:297-303.

Erbe, C. 2002. Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. Marine Mammal Science 18(2): 25.

Erbe, C. and D.M. Farmer. 2000. Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. The Journal of the Acoustical Society of America 108(3): 1332.

Etnier, M. A. 2002. Occurrences of Guadalupe fur seals (*Arctocephalus townsendi*) on the Washington coast over the past 500 years. Marine Mammal Science **18**:6.

European Cetacean Society. 2003. Program for the Seventeenth Annual Conference: Marine Mammals and Sound. Las Palmas De Gran Canaria, Spain; 9 – 13 March 2003.

Evans, K., M. Morrice, M. Hindell and D. Thiele. 2002. Three mass strandings of sperm whales (*Physeter macrocephalus*) in southern Australian waters. Marine Mammal Science 18(3): 22.

Evans, P. G. H., P. J. Canwell, and E. J. Lewis. 1992. An experimental study of the effects of the pleasure craft noise upon bottlenose dolphins in Cardigan Bay, West Wales. Pages 60-64 *in* P. G. H. Evans, editor. European research on cetaceans 6: Proceedings of the European Cetacean Society. European Cetacean Society, Montpellier, France.

Faerber, M.M. and R.W. Baird. 2007. Beaked whale strandings in relation to military exercises: a comparison between the Canary and Hawai'ian Islands. Poster presentation. The 21st annual European Cetacean Society conference, 22 - 27 April 2007. San Sebastian, Spain.

Fagan, W.F. and E.E. Holmes. 2006. Quantifying the extinction vortex. Ecology Letters 9: 51 - 60.

Fagan, W.F., E. Meir and J.L. Moore. 1999. Variation thresholds for extinction and their implications for conservation strategies. The American Naturalist 154(5): 510-520.

Fagan, W.F., E. Meir, J. Prendergast, A. Folarin and P. Karieva. 2001. Characterizing population vulnerability for 758 species. Ecology Letters 4(2): 132 - 138.

Fair, P.A. and P.R. Becker. 2000. Review of stress in marine mammals. Journal of Aquatic Ecosystem Stress and Recovery 7: 335-354.

Fechter, L.D. and B. Pouyatos. 2005. Ototoxicity. Environmental Health Perspective 113(7):A443-444.

Félix, F. 2001. Observed changes of behavior in humpback whales during whalewatching encounters off Ecuador. 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada.

Ferber, D. 2005. Sperm whales bear testimony to worldwide pollution. Science 309(5738): 1166.

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 (Addendum). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center; La Jolla, California.

Fernandez, A. 2004. Pathological findings in stranded beaked whales during the naval military manoeuvers near the Canary Islands. Pages 37-40. European Cetacean Society Newsletter.

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.

Fernandez, A., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herraez, A. M. Pocknell, F. Rodriguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and P. D. Jepson. 2004. Beaked whales, sonar and decompression sickness. Nature 428:U1 - 2.

Fernandez, A., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herraez, A. M. Pocknell, F. Rodriguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and P. D. Jepson. 2004. Beaked whales, sonar and decompression sickness. Nature 428:U1 - 2.

Fernandez, A., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herraez, A. M. Pocknell, E. Rodriguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and P. D. Jepson. 2004. Pathology: Whales, sonar and decompression sickness (reply). Nature 428:

Ferrero, R. C., J. Hodder, and J. Cesarone. 1994. Recent strandings of rough-toothed dolphins (Steno bredanensis) on the Oregon and Washington coasts. Marine Mammal Science 10:114-115.

Ferrero, R.C., D.P. DeMaster, P.S. Hill and M. Muto. 2000. Draft Alaska marine mammal stock assessments. National Marine Mammal Laboratory, Seattle, Washington.

Ficken, R.W., M.S. Ficken and J.P. Hailman. 1974. Temporal pattern shifts to avoid acoustic interference in singing birds. Science 183: 762-763.

Fiedler P., S. Reilly, R. Hewitt, D. Demer, V. Philbrick, S. Smith, W. Armstrong, D. Croll, B. Tershy, Mate B 1998. Blue whale habitat and prey in the Channel Islands. Deep-Sea Res II 45: 1781-1801.

Finley, K.J. 1982. The estuarine habit of the beluga or white whale Delphinapterus leucas. Cetus 4(2):4-5.

Finneran, J. J. 2003. Whole-lung resonance in a bottlenose dolphin (Tursiops truncatus) and white whale (Delphinapterus leucas). The Journal of the Acoustical Society of America 114:7.

Finneran, J. J., and M. C. Hastings. 2000. A mathematical analysis of the peripheral auditory system mechanics in the goldfish (Carassius auratus). The Journal of the Acoustical Society of America 108:14.

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. The Journal of the Acoustical Society of America 112:7.

Finneran, J. J., C. E. Schlundt, R. Dear, D. A. Carder, and S. H. Ridgway. 2000. Masked temporary threshold shift (MTTS) in odontocetes after exposure to single underwater impulses from a seismic watergun. The Journal of the Acoustical Society of America 108:2515.

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. The Journal of the Acoustical Society of America 118:10.

Finneran, J.J. and C.E. Schlundt. 2004. Effects of pure tones on the behavior of trained odontocetes. Technical Report 1913. U.S. Department of the Navy, SPAWAR Systems Center; San Diego, California.

Forcada, J., A. Aguilar, P. Hammond and X. Pastor. 1996. Distribution and abundance of fin whales (*Balaenoptera physalus*) in the western Mediterranean sea during the summer. Journal of Zoology 238(1): 23.

Forney, K. A., J. Barlow, M. M. Muto, M. Lowry, J. Baker, G. Cameron, J. Mobley, C. Stinchcomb, and J. V. Carretta. 2000. U.S. Pacific Marine Mammal Stock Assessmemts: 2000 DRAFT. NOAA Technical Memorandum. Southwest Fisheries Science Center; La Jolla, California.

Forney, K. A., M. M. Muto, and J. Baker. 1999. U.S. Pacific marine mammal stock assessment: 1999. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-282, Southwest Fisheries Science Center; La Jolla, California.

Forney, K. A., M. M. Muto, and J. Baker. 1999. U.S. Pacific marine mammal stock assessment: 1999. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-282, Southwest Fisheries Science Center; La Jolla, California.

Forney, K.A., and R.L. Brownell, Jr. 1996. Preliminary report of the 1994 Aleutian Island marine mammal survey. paper SC/48/011 presented to the IWC Scientific Committee, June 1996 (unpublished). Available SW Fisheries Science Center, La Jolla, California.

Fowler, G. S. 1999. Behavioral and hormonal responses of Magellanic penguins (*Spheniscus magellanicus*) to tourism and nest site visitation. Biological Conservation 90:143-149.

Fox. G.A. 1991. Practical causal inference for ecoepidemiologists. Journal of Toxicology and Environmental Health 33: 359-379.

Frankel, A. S. and C. W. Clark. 1998. Results of low-frequency playback of M-sequence noise to humpback whales, *Megaptera novaeangliae*, 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(4).

Frankel, A. S., C. W. Clark, L. M. Herman, C. M. Gabriele, M. A. Hoffhines, T. R. Freeman, and B. K. Patterson. 1989. Acoustic Location and tracking of wintering humpback whales (*Megaptera novaeangliae*) off South Kohala, Hawai'i. In Proceedings of the Eighth Biennial Conference on the Biology of Marine Mammals

Frankel, A.S. 1994. Acoustic and visual tracking reveals distribution, song variability and social roles of humpback whales in Hawai'ian waters. Unpublished doctoral dissertation, University of Hawai'i. University Microfilms, Inc.

Frankel, A.S. 1994. Acoustic and visual tracking reveals distribution, song variability and social roles of humpback whales in Hawai'ian waters. Unpublished doctoral dissertation, University of Hawai'i. University Microfilms, Inc.

Frankel, A.S. and C.W. Clark. 1998. Results of low-frequency playback of M-sequence noise to humpback whales, *Megaptera novaeangliae*, 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(4).

Frankel, A.S., J. Mobley, L. Herman. 1995. Estimation of auditory response thresholds in humpback whales using biologically meaningful sounds. Pages 55-70. In: R.A. Kastelein, J.A. Thomas, P.E. Nachtigall (editors) Sensory Systems of Aquatic Mammals. De Spil Publication, Woerden, Netherlands.

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 P. G. H. Evans, and L. A. Miller, editors. Proceedings of the Workshop on Active Sonar and Cetaceans. European Cetacean Society's 17th Annual Conference, Auditorio Alfredo Kraus, Las Palmas, Gran Canaria.

Frantzis, A., J. C. Goold, E. K. Skarsoulis, M. I. Taroudakis, and V. Kandia. 2002. Clicks from Cuvier's beaked whales, Ziphius cavirostris (L). The Journal of the Acoustical Society of America 112:4.

Frantzis, A., O. Nikolaou, J. M. Bompar, and A. Cammedda. 2004. Humpback whale (*Megaptera novaeangliae*) occurrence in the Mediterranean Sea. Journal of Cetacean Research and Management 6:25 - 28.

Frantzis, A., P. Alexiadou, G. Paximadis, E. Politi, A. Gannier, and M. Corsini-Foka. 2003. Current knowledge of the cetacean fauna of the Greek Seas. Journal of Cetacean Research and Management 5: 3, 219-232.

Frazer, L.N. and E. Mercado III. 2000. A sonar model for humpback whale song. IEEE Journal of Oceanic Engineering 25(1): 23.

Frid, A. 2003. Dall's sheep responses to overflights by helicopter and fixed-wing aircraft. Biological Conservation 110:387-399.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:1 - 11.

Fristrup, K.M., L.T. Hatch, and C.W. Clark. 2003. Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts. Journal of the Acoustical Society of America 113(6): 3411-3424

Fritts, T.H. 1983. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. FWS/OBS-82/65. Report prepared for the U.S. Department of the Interior, Fish and Wildlife Service; Washington, D.C.

Fromm, D. 2004. Acoustic modeling results of the Haro Strait For 5 May 2003. Naval Research Laboratory Report, Office of Naval Research, 30 January 2004.

Frost, K.J. and L.F. Lowry. 1988. Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys. p. 15-25. In: W.M. Sackinger *et al*. (editors), Port and Ocean engineering under Arctic conditions, Vol II. Geophysical Institute of the University of Alaska; Fairbanks, Alaska.

Gagnon, C. J. and C. W. Clark. 1993. The use of U.S. Navy IUSS passive sonar to monitor the movement of blue whales. Abstracts of the 10th Biennial Conference on the Biology of Marine Mammals, Galveston, Texas. November 1993.

Gailey, G., B. Würsig, and T. L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. Environmental Monitoring and Assessment 134:75-91.

Gallo-Reynoso, J. P., and A.-L. Figueroa-Carranza. 1996. Size and weight of Guadalupe fur seals. Marine Mammal Science **12**:3.

Gallo-Reynoso, J.-P., and A.-L. Figueroa-Carranza. 1992. A cookiecutter shark wound on a Guadalupe fur seal male. Marine Mammal Science **8**:428-429.

Gambell, R. 1968. Aerial observations of sperm whale behavior. Norsk Hvalfangst-Tidende 57.

Gambell, R. 1976. World whale stocks. Mammal Review 6 (1): 41-53.

Gambell, R. 1985. Sei whale *Balaenoptera borealis* (Lesson, 1828). Pages 193-240. In: S.H. Ridgway and R. Harrison (editors). Handbook of marine mammals. Vol. 3: The sirenians and baleen whales. Academic Press; London, United Kingdom.

Gard, R. 1974. Aerial census of gray whales in Baja California lagoons, 1970 and 1973, with notes on behavior, mortality and conservation. California Fish and Game 60(3): 132-143.

Gaskin, D. E. 1972. Whales, dolphins, and seals; with special reference to the New Zealand region.

Gauthier, J and R. Sears. 1999. Behavioral response of four species of balaenopterid whales to biopsy sampling. Marine Mammal Science 15(1): 85-101.

Geraci, J.R., S.A. Testaverde, D.S. Staubin and T.H. Loop. 1976. A mass stranding of the Atlantic white-sided dolphin (*Lagenorhynchus acutus*): a study into pathobiology and life history. In: Report Number MMC 75/12. U.S. Marine Mammal Commission; Bethesda, Maryland.

Giese, M. 1996. Effects of human activity on Adelie penguin *Pygoscelis adeliae* breeding success. Biological Conservation 75:157.

Gill, J. A., K. Norris, and W. J. Sutherland. 2001a. Why behavioral responses may not reflect the population consequences of human disturbance. Biological Conservation 97:265-268.

Gill, J. A., W. J. Sutherland, and A. R. Watkinson. 1996. A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology 33:786-792.

Gill, J.A. and W.J. Sutherland. 2000. Predicting the consequences of human disturbance from behavioral decisions. Pages: 51 - 64. In: *Behavior and conservation*. Edited by L.M. Gosling and W.J. Sutherland. Cambridge University Press; Cambridge, United Kingdom.

Gill, J.A., K. Norris and W.J. Sutherland. 2001b. The effects of disturbance on habitat use by black-tailed godwits *Limosa limosa*. The Journal of Applied Ecology 38(4): 846-856.

Gilpatrick, J., W. Perryman, L. Lynn, and M.A. DeAngelis. 1997. Geographic populations of blue whales (*Balaenoptera musculus*) in the North Pacific Ocean investigated from whaling records and aerial photogrammetry. Paper SC/47/NP4 presented to the International Whaling Commission's Scientific Committee, May 1995 (unpublished).

Gisiner, R. C. 1998. Workshop on the effects of anthropogenic noise in the marine environment. U.S. Navy, Office of Naval Research, Marine Mammal Research Program, Washington, D.C.

Gitschlag, G. R. 2001. Biological impacts of underwater explosives used in platform salvage in the Gulf of Mexico, Pages 69-71 in M. McKay, J. Nides, W. Lang, and D. Vigil, eds., Gulf of Mexico marine protected species workshop - June 1999. New Orleans, Louisiana, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region.

Glockner, D. A. and S. Venus. 1983. Determining the sex of humpback whales (*Megaptera novaeangliae*) in their natural environment. Pages 447-464. In: R.S. Payne (editor). Communication and behavior of whales. AAAS Selected Symposia Series. Westview Press; Boulder, Colorado.

Glockner-Ferrari, D. A., and M. J. Ferrari. 1990. Reproduction in the humpback whale (*Megaptera novaeangliae*) in Hawai'ian waters 1975-1988: The life history, reproductive rates and behavior of known individuals identified through surface and underwater photography. Pages 161-170. In: P.S. Hammond, S.A. Mizroch and G.P. Donovan (editors) Individual Recognition of Cetaceans: Use of Photo-Identification and other Techniques to estimate population parameters. International Whaling Commission, Cambridge.

Goddard, P.C. and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. Marine Mammal Science 14(2):344-349.

Goold, J.C. 1999. Behavioral and acoustic observations of sperm whales in Scapa Flow, Orkney Islands. Journal of the Marine Biological Association of the UK 79(3): 10.

Goold, J.C. and S.E. Jones. 1995. Time and frequency domain characteristics of sperm whale clicks. Journal of the Acoustical Society of America 98: 1279-1291.

Goold, J.C., H. Whitehead and R.J. Reid. 2002. North Atlantic sperm whale, *Physeter macrocephalus*, strandings on the coastlines of the British Iles and eastern Canada. The Canadian field-naturalist 116(3): 18.

Gordon, J.C.D. 1987. Behavior and ecology of sperm whales off Sri Lanka. Ph.D. dissertation, University of Cambridge, Cambridge, England.

Gore, M.A., E. Ahmad, Q.M. Ali, R.M. Culloch, S. Hameed, S.A. Hasnain, B. Hussain, S. Kiani, N. Shaik, P.J. Siddiqui and R.F. Ormond. 2007. Sperm whale, *Physeter macrocephalus*, stranding on the Pakistani coast. Journal of the Marine Biological Association of the United Kingdom 87(1): 2.

Gosho, M.E., D.W. Rice, and J.M. Breiwick. 1984. Sperm whale interactions with longline vessels in Alaska waters during 1997. Unpublished report available Alaska Fisheries Science Center; Seattle, Washington.

Gotelli, N. J. 2001, A primer of ecology. Sunderland, Massachusetts, Sinauer Associates, Inc.

Government Printing Office. 1987. Endangered fish and wildlife; approaching humpback whales in Hawai'ian waters. Federal Register 52 (225, 23 Nov.):44912-44915.

Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnell, and K. C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington 1989-1990, Pages 1-100 in J. J. Brueggeman, ed., Oregon and Washington marine mammal and seabird surveys. Los Angeles, California, U.S. Department of the Interior, Minerals Management Service, Pacific Outer Continental Shelf Region.

Hain, J.H.W., M.J. Ratnaswamy, R.D. Kenney, and H.E. Winn. 1992. The fin whale, Balaenoptera physalus, in waters of the northeastern United States continental shelf. Reports of the International Whaling Commission 42: 653-669.

Hamilton, P.K., and C.A. Mayo. 1990. Population characteristics of right whales (Eubalaena glacialis) observed in Cape Cod and Massachusetts Bays, 1978-1986. Reports of the International Whaling Commission, Special Issue 12: 203-208.

Hamilton, P.K., G.S. Stone, and S.M. Martin. 1997. Note on a deep humpback whale (*Megaptera novaeangliae*) dive near Bermuda. Bulletin of Marine Science 61:491-494.

Hamilton, P.K., M.K. Marx, and S.D. Kraus. 1998. Scarification analysis of North Atlantic right whales (Eubalaena glacialis) as a method of assessing human impacts. Final report to the Northeast Fisheries Science Center, NMFS, Contract No. 4EANF-6-0004.

Hanni, K. D., D. J. Long, R. E. Jones, P. Pyle, and L. E. Morgan. 1997. Sightings and strandings of Guadalupe fur seals in central and northern California, 1988-1995. Journal of Mammalogy **78**:684-690.

Hansen, L.J., K.D. Mullin and C.L. Roden. 1995. Estimates of cetacean abundance in the northern Gulf of Mexico from vessel surveys. Contribution No. MIA-94/95-25. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center; Miami, Florida.

Harlow, H. J., F. G. Lindzey, W. D. Van Sickle, and W. A. Gern. 1992. Stress response of cougars to non-lethal pursuit by hunters. Canadian Journal of Zoology 70:136-139.

Harris, C. M., editor. 1998. Handbook of acoustical measurements and noise control. Acoustical Society of America, Woodbury, New York.

Herman, L. M. and R. C. Antinoja. 1977. Humpback whales in Hawai'ian waters: Population and pod characteristics. Scientific Reports of the Whales Research Institute (Tokyo) 29:59-85.

Herman, L. M., C. S. Baker, P. H. Forestell and R. C. Antinoja. 1980. Right whale Balaena glacialis - sightings near Hawai'i: a clue to the wintering grounds? 2:271-275.

Herman, L.M. 1979. Humpback whales in Hawai'ian waters: A study in historical ecology. Pacific Science 33: 1 - 15.

Heyning, J.E. and T.D. Lewis. 1990. Entanglements of baleen whales in fishing gear off southern California. Report of the International Whaling Commission 40: 427-431.

Hildebrand, J. A. 2004. Impacts of anthropogenic sound on cetaceans. Unpublished paper submitted to the International Whaling Commission Scientific Committee SC/56/E13. International Whaling Commission, Cambridge, United Kingdom.

Hildebrand, J. A. 2005. Annex K: Report of the standing working group on environmental concerns. Appendix 3. Introduction to acoustics. Journal of Cetacean Research and Management 7:284 - 286.

Hill, P.S. and D.P. DeMaster. 1999. Pacific marine mammal stock assessments, 1999. U.S. Department of Commerce, NOAA Technical Memorandum nmfs-AFSC-110. Alaska Fisheries Science Center; Auke Bay, Alaska.

Hill, P.S., and D.P. DeMaster. 1998. Draft Alaska marine mammal stock assessments 1998. National Marine Mammal Laboratory; Seattle, Washington.

Hill, P.S., D.P. DeMaster, and R.J. Small. 1997. Alaska stock assessments, 1996.U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC. Alaska Fisheries Science Center; Seattle, Washington.

Hohn, A. A., D. S. Rotstein, C. A. Harms, and B. L. Southall. 2006. Report on marine mammal unusual mortality event UME0501Sp Multispecies mass stranding of pilot whales (Globicephala macrorhynchus), minke whale (Balaenoptera acutiorostrata), and dwarf sperm whales (Kogia sima) in North Carolina on 15 - 16 January 2005. NOAA Technical Memorandum NMFS-SEFSC-537. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida.

Holberton, R. L., B. Helmuth, and J. C. Wingfield. 1996. The corticosterone stress response in gentoo and king penguins during the non-fasting period. The Condor 98:4.

Holling, C.S. 1959. Some characteristics of simple types of predation and parasitism. The Canadian Entomologist 91:385-398.

Holt, M.M., V. Veirs and S. Veirs. 2007. Noise effects on the call amplitude of southern resident killer whales (Orcinus orca) Poster presented at the International conference on the effects of noise on aquatic life, 13 - 17 August 2007. Nyborg, Denmark.

Hood, L. C., P. D. Boersma, and J. C. Wingfield. 1998. The adrenocortical response to stress in incubating magellanic penguins (Spheniscus magellanicus). The Auk 115:9.

Horwood, J. 1987. The sei whale: population biology, ecology and management. Croom Helm; Beckenham, Kent, United Kingdom.

Houser, D.S., R. Howard and S. Ridgway. 2001. Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals? Journal of Theoretical Biology 213: 183 - 195.

International Whaling Commission (IWC). 1980. Report of the sub-committee on protected species and aboriginal whaling. Reports of the International Whaling Commission 30:103-111.

International Whaling Commission (IWC). 2005. Annex K. Report of the standing working group on environmental concerns. Journal of Cetacean Research and Management 7 (Supplement):267 - 281.

International Whaling Commission [IWC]. 1998. Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. International Whaling Commission special workshop held 19-25 March 1998, in Cape Town, South Africa. SC/50/REP 4.

International Whaling Commission [IWC]. 2005. Annex K. Report of the standing working group on environmental concerns. Journal of Cetacean Research and Management 7 (Supplement): 267-281.

Jahoda, M., C. L. Lafortuna, N. Biassoni, C. Almirante, A. Azzelino, S. Panigada, M. Zanardelli et al. 2003. Mediterranean fin whale's (Balaenoptera physalus) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. Marine Mammal Science 19:15.

Jansen, G. 1998. Chapter 25. Physiological effects of noise. Pages 25.21 - 25.19 in C. M. Harris, editor. Handbook of acoustical*ƒ* measurements and noise control. Acoustical Society of America, Woodbury, New York.

Jaquet, N. 1996. How spatial and temporal scales influence understanding of sperm whale distribution. Mammal Review 26:51.

Jaquet, N., and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. Marine ecology progress series 135:10.

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, New York, New York.

Jefferson T.A., S. Leatherwood, M.A. Webber. 1993. FAO Species Identification Guide. Marine Mammals of the World. Food and Agriculture Organization; Rome, Italy.

Jefferson, T.A. and A.J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. Mammal Review 27(1): 27-50.

Jekel, J.F., D.L. Katz, and J.G. Elmore. 2001. Epidemiology, biostatistics, and preventive medicine, Second edition. W.B. Saunders Company, Philadelphia, Pennsylvania.

Jepson, P. D., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada et al. 2003. Gas-bubble lesions in stranded cetaceans. Nature 425:575-576.

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.

Jessop, T. S., A. D. Tucker, C. J. Limpus, and J. M. Whittier. 2003. Interactions between ecology, demography, capture stress, and profiles of corticosterone and glucose in a free-living population of Australian freshwater crocodiles. General and comparative endocrinology 132:10.

Jochens, A., D. Biggs, D. A. N. Engelhaupt, J. Gordon, N. Jaquet, M. Johnson, R. Leben et al. 2006. Sperm whale seismic study in the Gulf of Mexico, Summary Report 2002-2004. Pages: 1-100. OCS Study MMS 2006-034. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region; New Orleans, Louisiana.

Johnson, O.W. W.S. Grant, R.G. Kope. K. Neely, F.W. Waknitz, and R.S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Department of Commerce, National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NWFSC-32. Seattle, Washington.

Joint Nature Conservation Committee. 2004. Guidelines for minimizing acoustic disturbance to marine mammals from seismic surveys. Joint Nature Conservation Committee; Aberdeen, Scotland.

Jones, D. M., and D. E. Broadbent. 1998. Chapter 24. Human performance and noise. Pages 24.21 - 24.24 in C. M. Harris, editor. Handbook of acoustical measurements and noise control. Acoustical Society of America, Woodbury, New York.

Jones, D.M. and D.E. Broadbent. 1998. Chapter 24. Human peformance and noise. Pages: 24.1 - 24.24. In: *Handbook of acoustical measurements and noise control*. Edited by C.M. Harris. Acoustical Society of America; Woodbury, New York.

Jones, N. 2003. Is undersea noise harming whales? New Scientist.

Jonsgård, Å. and K. Darling. 1977. On the biology of the eastern North Atlantic sei whales, *Balaenoptera borealis* Lesson. Reports of the International Whaling Commission Special Issue 11: 123-129.

Jurasz, C.M. and V. Jurasz.1979. Feeding modes of the humpback whale, *Megaptera novaeangliae*, in southeast Alaska. Scientific Report of the Whales Research Institute of Tokyo 31:69-83.

Kamezaki, N., Y. Matsuzawa, O. Abe, H. Asakawa, T. Fujii, K. Goto, S. Hagino, M. Hayami, M. Ishii, T. Iwamoto, T. Kamata, H. Kato, J. Kodama, Y. Kondo, I. Miyawaki, K. Mizobuchi, Y. Nakamura, Y. Nakashima, H. Naruse, K. Omuta, M. Samejima, H. Suganuma, H. Takeshita, T. Tanaka, T. Toji, M. Uematsu, A. Yamamoto, T. Yamato, and I. Wakabayashi. 2003. Loggerhead turtles nesting in Japan. Pages210-217. In Loggerhead Sea Turtles. Edited by A.B. Bolten and B.E. Witherington. Smithsonian Institution.

Kastak, D. and R.J. Schusterman. 1996. Temporary threshold shift in a harbor seal (*Phoca vitulina*). The Journal of the Acoustical Society of America 100(3): 4.

Kastak, D. and R.J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise, and ecology. The Journal of the Acoustical Society of America 103(4): 13.

Kastak, D. and R.J. Schusterman. 2002. Changes in auditory sensitivity with depth in a free-diving California sea lion (Zalophus californianus). The Journal of the Acoustical Society of America 112(1): 5.

Kastak, D., R.J. Schusterman, B.L. Southall, and C. Reichmuth. 2000. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of the Acoustical Society of America 106(2):1142-1148.

Kasuya, T. 1991. Density dependent growth in North Pacific sperm whales. Marine Mammal Science 7(3):230-257.

Katona, S.K., and J.A. Beard. 1990. Population size, migrations, and feeding aggregations of the humpback whale (*Megaptera novaeangliae*) in the Western North Atlantic Ocean. Reports of the International Whaling Commission, Special Issue 12: 295-306.

Kawakami, T. 1980. A review of sperm whale food. Scientific Report of the Whales Research Institute Tokyo 32:199-218.

Kawamura, A. 1980. A review of food of balaenopterid whales. Scientific Report of the Whales Research Institute 32:155- 197.

Kawamura, A. 1982. Food habits and prey distributions of three rorqual species in the North Pacific Ocean. Scientific Report of the Whales Research Institute 34:59-91.

Kenney, R.D. 1992. Western North Atlantic Right Whales: Abundance and Trends from Great South Channel Aerial Surveys. Report of a workshop held on April 14-15, 1992. NOAA National Marine Fisheries Service Northeast Fisheries Science Center; Silver Spring, Maryland.

Kenney, R.D., H.E. Winn, and M.C. Macula. 1995. Cetaceans in the Great South Channel, 1979-1989: right whale (Eubalaena glacialis). Continental Shelf Research 15: 385-414.

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.

Ketten, D.R. 1994. Functional analyses of whale ears: adaptations for underwater hearing. IEEE Proceedings on Underwater Acoustics 1: 264-270.

Ketten, D.R. 1997. Structure and function 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 Technical Memorandum NOAA-TM-NMFS-SWFSC-256.

Kingsley, M.C.S. 1986. Distribution and abundance of seals in the Beaufort Sea, Amundsen Gulf, and Prince Albert sound, 1984. Environmental Studies Revolving Funds Rep. No. 025, Department of Fisheries and Oceans; Winnipeg, Alberta, Canada

Klima, E.F., G.R. Gitschlag, and M.L. Renaud. 1988. Impacts of the explosive removal of offshore petroleum platforms on sea turtles and dolphins. Marine Fisheries Review 50(3) 33-42.

Klinowska, M. 1985. Cetacean live 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(3): 109 - 119.

Klumov, S.K. 1962. The right whales in the Pacific Ocean. In P.I. Usachev (ed.), Biological Marine Studies. Trudy Institute of Okeanography 58:202-297.

Knowlton, A.R., S.D. Kraus, and R.D. Kenney. 1994. Reproduction in North Atlantic right whales (Eubalaena glacialis). Canadian Journal of Zoology 72: 1297-1305.

Korte, S. M., J. M. Koolhaas, J. C. Wingfield, and B. S. McEwen. 2005. The Darwinian concept of stress: benefits of allostasis and costs of allostatic load and the trade-offs in health and disease. Neuroscience and Biobehavioral Reviews 29:3 - 38.

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (Eubalaena glacialis). Marine Mammal Science 6(4):278-291.

Kraus, S.D. 1997. Right whale status in the North Atlantic. Pages 31-36 In: Knowlton, A.R., S.D. Kraus, D.F. Meck, and M L. Mooney-Seus (editors). Shipping/Right whale workshop. New England Aquarium Aquatic Forum Series Report 97-3. New England Aquarium, Boston, Massachusetts. 247 pp.

Kraus, S.D., and R.D. Kenney. 1991. Information on right whales (Eubalaena glacialis) in three proposed critical habitats in U.S. waters of the Western North Atlantic Ocean. Final report to the U.S. Marine Mammal Commission in fulfillment of Contracts T-75133740 and T-75133753.

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.

Krieger, K. J. and B. L. Wing. 1986. Hydroacoustic monitoring of prey to determine humpback whale movements. noaa Technical Memorandum nmfs F/NWC-98. NOAA National Marine Fisheries Service, Auke Bay, Alaska. National Technical Information Service PB86-204054.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. Pages 149-160*in* Kruse, S., editor. Dolphin societies. Discoveries and puzzles. University of California Press, Berkeley, California.

Kuczaj, S., R. Paulos, J. Ramos, R. Thames, G. Rayborn, G. Ioup and J. Newcomb. 2003. Anthropogenic noise and sperm whale sound production. Las Palmas de Gran Canaria, Canary Islands, Spain.

Kvadsheim, P.H., F. Benders, P.J.O. Miller, L. Doksaeter, F. Knudsen, P.L. Tyack, N. Nina, F.-P. Lam, F. Samarra, L. Kleivane and O.R. Godo. 2007. Herring (sild), killer whales (spekkhogger) and sonar - the 3S-2006

cruise report with preliminary results. FFI Report No. 2007/011189. Forsvarets Forskningsinstitutt Norwegian Defence Research Establishment; Kjellen, Norway.

Lafferty, K. D., and R. D. Holt. 2003. How should environmental stress affect the population dynamics of disease? Ecology Letters 6:654-664.

Lagueux, C.J. 1998. Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends. Doctoral Dissertation, University of Florida; Gainesville, Florida.

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(1): 35-75.

Lambertsen, R. H. B. A. Kohn, J. P. Sundberg, and C. D. Buergelt. 1987. Genital papillomatosis in sperm whale bulls. Journal of Wildlife Diseases. 23(3):361-367.

Lambertsen, R.H. 1986. Disease of the common fin whale (Balaenoptera physalus): Crassicaudiosis of the urinary system. Journal of Mammalogy 67(2): 353-366.

Landis, C.J. 1965. Research: A new high pressure research animal? Undersea Technology 6:21.

Landis, W. G., G.B. Matthews, R.A. Matthews, A. Sergeant. 1994. Application of multivariate techniques to endpoint determination, selection and evaluation in ecological risk assessment. Environmental Toxicology and Chemistry 13: 1917.

Landis, W. G., R. A. Matthews, and G. B. Matthews. 1997. Design and analysis of multispecies toxicity tests for pesticide registration. Ecological Applications 7:1111.

Lankford, S. E., T. E. Adams, R. A. Miller, and J. J. Cech, Jr. 2005. The cost of chronic stress: Impacts of a nonhabituating stress response on metabolic variables and swimming performance in sturgeon. Physiological and Biochemical Zoology 78:599-609.

Latishev, V.M. 2007. Scientific report from factory ships "Vladivostok" and "Dalniy Vostok" in 1967. Pages: 16-17. In: Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. NOAA Technical Memorandum NMFS-AFSC-175. Edited by Y.V. Ivashchenko, P.J. Clapham and R.L. Brownell Jr. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center; Seattle, Washington.

Leatherwood, S. L., D. K. Caldwell, and H. E. Winn. 1976. Whales, dolphins, and porpoises of the western North Atlantic: a guide to their identification. NOAA Technical Report, National Marine Fisheries Service, Circular 396.

Leatherwood, S., A.E. Bowles, and R.R. Reeves. 1986. Aerial surveys of marine mammals in the southeastern Bering Sea. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Final Report 42 (1986):147-490.

Leatherwood, S., R. R. Reeves, W. F. Perrin, and W. E. Evans. 1988. Whales, dolphins and porpoises of the eastern North Pacific and adjacent Arctic waters. Dover Publication, New York, New York.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent arctic waters: a guide to their identification. NOAA Technical Report National Marine Fisheries Service Circular 444.

Lenhardt, M.L. 1994. Auditory behavior of the loggerhead sea turtle (*Caretta caretta*). Page 89. In: K.A. Bjorndahl, A.B. Bolten, D.A. Johnson, and P.J. Eliazar (compilers), Proceedings of the 14th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-351.

Lettevall, E., C. Richter, N. Jaquet, E. Slooten, S. Dawson, H. Whitehead, J. Christal and P.M. Howard. 2002. Social structure and residency in aggregations of male sperm whales. Canadian Journal of Zoology 80(7): 8.

Levenson, C. 1974. Source level and bistatic target strength of the sperm whale (*Physeter catodon*) measured from an oceanographic aircraft. Journal of the Acoustical Society of America 55: 1100-1103.

LGL Environmental Research Associates Ltd. 1998. Marine Mammal and acoustical monitoring of BP exploration (Alaska) open-water seismic program in the Alaskan Beaufort Sea, 1997. Report prepared by LGL Environmental Research Associates, TA2150-3, page 5-89. Available from NMFS Office of Protected Resources, Silver Spring Maryland.

Lien, J. 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). Reports of the International Whaling Commission Special Issue 15: 149-157.

Lima, M., P. A. Marquet, and F. M. Jaksic. 1998. Population extinction risks of three Neotropical small mammal species. Oecologia 115:120-126.

Lipton, J., H. Galbraith, J. Burger, D. Wartenberg. 1993. A paradigm for ecological risk assessment. Environmental Management 17: 1-5.

Ljungblad DK, Clark CW, Shimada H (in press) Sounds attributed to pygmy blue whales (*Balaenoptera musculus brevicauda*) recorded south of the Madagascar Plateau in December 1996 as compared to sounds attributed to "true" blue whales (*Balaenoptera musculus*) recorded off Antarctica in January 1997.

Lockyer, C. 1978. The history and behavior of a solitary wild, but sociable bottlenose dolphin (*Tursiops truncatus*) on the west coast of England and Wales. Journal of Natural History 12:513-528.

Lockyer, C. 1981. Growth and energy budgets of large baleen whales from the Southern Hemisphere. Mammals in the Seas. Vol. 3. Food and Agricultural Organization Fisheries Series 5: 379-487.

Lockyer, C. 1984. Review of baleen whale (Mysticeti) reproduction and implications for management. Reports of the International Whaling Commission, Special Issue 6: 27-50.

Lohr, B., T.F. Wright and R.J. Dooling. 2003. Detection and discrimination of natural calls in masking noise by birds: estimating the active space of a signal. Animal Behavior 65(4): 16.

Lombard, E. 1911. Le signe de l'elevation de la voix. Annales Maladies Oreille, Larynx, Nez, Pharynx 37:101-119.

Loughlin, T.R., D.J. Rugh, and C.H. Fiscus. 1984. Northern sea lion distribution and abundance: 1956-80. Journal of Wildlife Management 48: 729-740.

Lowell, R.B. J.M. Culp, and M.G. Dube. 2000. A weight of evidence approach to northern river risk assessment: integrating the effects of multiple stressors. Environmental Toxicology and Chemistry 19: 1182-1190.

Lowry, L., D.W. Laist and E. Taylor. 2007. Endangered, threatened, and depleted marine mammals in U.S. waters. A review of species classification systems and listed species. Report prepared for the Marine Mammal Commission; Bethesda, Maryland.

Lütkebohle, T. 1996. Potential avoidance behavior of bottlenose dolphins to vessels in the Kessock channel, Moray Firth, Scotland. Pages 53-55 *in* Proceedings of the 10th Annual Conference of the European Cetacean Society, 11-13 March 1996, Lisbon, Portugal.

MacArthur, R.A., R.H. Johnson and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: A physiological approach to the study of wildlife harassment. Canadian Journal of Zoology 57(10):2010-2021.

Mackintosh, N.A. 1942. The southern stocks of whalebone whales. Discovery Reports 22:197-300.

Mackintosh, N.A. 1965. The stocks of whales. Fishing News (Books) Ltd., London.

Mackintosh, N.A. and J.F.G. Wheeler. 1929. Southern blue and fin whales. Discovery Reports 1: 257-540.

MacLeod, C. D., and A. D'Amico. 2006. A review of beaked whale behavior and ecology in relation to assessing and mitigating impacts of anthropogenic noise. Journal of Cetacean Research and Management 7:211 - 221.

MacLeod, C. D., G. J. Pierce, and M. B. Santos. 2004. Geographic and temporal variations in strandings of beaked whales (Ziphiidae) on the coasts of the UK and the Republic of Ireland from 1800-2002. Journal of Cetacean Research and Management 6:79 - 86.

Madsen, J. 1994. Impacts of disturbance on migratory waterfowl. Ibis 137:567-574.

Madsen, P. T., B. Moehl, B. K. Nielsen, and M. Wahlberg. 2002. Male sperm whale behavior during exposures to distance seismic survey pulses. Aquatic Mammals.

Madsen, P.T. and B. Mohl. 2000. Sperm whales (*Physeter catodon* L 1758) do not react to sounds from detonators. The Journal of the Acoustical Society of America 107: 668-671.

Magalhães, S., R. Prieto, M. A. Silva, J. Goncalves, M. Afonso-Dias, and R. S. Santos. 2002. Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. Aquatic Mammals 28:267-274.

Maldini, D., L. Mazzuca and S. Atkinson. 2005. Odontocete stranding patterns in the main Hawai'ian Islands (1937-2002): how do they compare with live animal surveys? Pacific Science 59(1): 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: Final Report for the Period of 7 June 1982 - 31 July 1983. Prepared for U.S. Department of the Interior Minerals Management Service, Alaska OCS Office by Bolt Beranek and Newman Inc. Cambridge: Bolt Beranek and Newman Inc., 1983.

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. 586. Rep. from Bolt, Beranek, & Newman, Inc. Cambridge, Massachusetts, for U.S. Minerals Management Service, Anchorage, Alaska.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. Report No. 5851, Unpublished report prepared by Bolt, Beranek and Newman Inc., Cambridge, USA, for U.S. Minerals Management Service, Alaska OCS Office, Anchorage, Alaska.

Mangels, K.F., and T. Gerrodette. 1994. Report of cetacean sightings during a marine mammal survey in the eastern Pacific Ocean and the Gulf of California aboard the NOAA ships "MacArthur" and "David Starr Jordan" July 28-November 6, 1993. NOAA Technical Memorandum NMFS- SWFSC-221.

Maravilla-Chavez, M. O., and M. S. Lowry. 1999. Incipient breeding colony of Guadalupe fur seals at Isla Benito del Este, Baja California, Mexico. Marine Mammal Science **15**:239-241.

Marcoux, M., L. Rendell and H. Whitehead. 2007. Indications of fitness differences among vocal clans of sperm whales. Behavioral Ecology and Sociobiology 61(7): 1093-1098.

Marine Mammal Commission. 2003. Annual Report to Congress 2002, Pages 264. Marine Mammal Commission; Bethesda, Maryland.

Marshall, G. J. 1998. Crittercam: an animal-borne imaging and data logging system. Marine Technology Science Journal. 32(1):11-17.

Masaki, Y. 1976. Biological studies on the North Pacific sei whale. Bulletin of the Far Seas Fisheries Research Laboratory (Shimizu) 14:1-104.

Masaki, Y. 1977. The separation of the stock units of sei whales in the North Pacific. Reports of the International Whaling Commission Special Issue No. 1: 71-79.

Masaki, Y. 1980. On the pregnancy rate of the North Pacific sperm whales. Reports of the International Whaling Commission Special Issue 2: 43-48.

Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dyrness. 1981. Natural history of Oregon coast mammals. US Department of Agriculture, Forest Service General Technical Report PNW-133, Portland, Oregon.

Mate B.R., Nieukirk S.L., Mesecar R.S., Martin T.J. 1992. Application of remote sensing for tracking large cetaceans: Atlantic right whales. Report Contract No. 14-12-0001-30411, U. S. Minerals Management Service.

Mate, B.R., K.M. Stafford and D.K. Ljungblad. 1994. A change in sperm whale (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. Journal of the Acoustical Society of America 96(2):3268-3269.

Mate, B.R., R. Gisiner, J. Mobley. 1998. Local and migratory movements of humpback whales tracked by satellite telemetry. Canadian Journal of Zoology 76(5): 863-868.

Maury, M.F. 1852. Whale chart of the world, (The wind and current charts), Series F, Washington, D.C.

Maury, M.F. 1853. A chart showing the favorite reports of the sperm and right whales by M.F. Maury, L.L.D. Lieutenant, U.S. Navy. Constructed from Maury's whale chart of the world by Robert H. Wayman, Lieutenant, U.S. Navy by Authority of the Commo. Bureau of Ordinance and Hydrography; Washington, D.C.

Maybaum, H.L. 1990. Effects of a 3.3 kHz sonar system on humpback whales, *Megaptera novaeangliae*, in Hawai'ian waters. EOS 71: 92.

Maybaum, H.L. 1993. Responses of humpback whales to sonar sounds. The Journal of the Acoustical Society of America 94(3):1848-1849.

Mayo, C.A., and M. K. Marx. 1990. Surface foraging behavior of the North Atlantic right whale (*Eubalaena glacialis*) and associated zooplankton characteristics. Canadian Journal of Zoology 68: 2214-2220.

McArdle, B.H. 1990. When are rare species not there? Oikos 57:276-277.

McCall Howard, M.P. 1999. Sperm whales *Physeter macrocephalus* in the Gully, Nova Scotia: Population, distribution, and response to seismic surveying. Unpublished Thesis prepared for a Batchelor of Science Degree. Dalhousie University, Halifax, Nova Scotia.

McCall Howard, M.P. 1999. Sperm whales *Physeter macrocephalus* in the Gully, Nova Scotia: Population, distribution, and response to seismic surveying. Thesis prepared for a Batchelor of Science Degree. Dalhousie University; Halifax, Nova Scotia.

McCarty, L. S., and M. Power. 1997. Environmental risk assessment within a decision-making framework. Environmental Toxicology and Chemistry 16:122.

McCauley, R. D., and D. H. Cato. 2001. The underwater noise of vessels in the Hervey Bay (Queensland) whale watch fleet and its impact on humpback whales. Journal of the Acoustical Society of America 109:2455.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M-N Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, 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. Centre for Marine Science and Technology, Curtin University of Technology, Western Australia.

McDonald, M. A., J. A. Hildebrand, and S. C. Webb. 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. and Fox, C.G. 1999. Passive acoustic methods applied to fin whale population density estimation. Journal of the Acoustical Society of America 105(5): 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. The Journal of the Acoustical Society of America 109(4): 1728 - 1735.

McDonald, M.A., J.A. Hildebrand, and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the northeast Pacific. Journal of the Acoustical Society of America 98: 712-721.

McEwen, B. S., and J. C. Wingfield. 2003. The concept of allostasis in biology and biomedicine. Hormones and Behavior 43:2 - 15.

McEwen, B. S., and T. Seeman. 2000. Overview - protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. Annals of the New York Academy of Sciences 896:18.

McKay, M., J. Nides, W. Lang, and D. Vigil. 2001. Gulf of Mexico marine protected species workshop - June 1999. New Orleans, Louisiana, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region.

Melin, S. R., and R. L. Delong. 1999. Observations of a Guadalupe fur seal (*Arctocephalus townsendi*) female and pup at San Miguel Island, California. Marine Mammal Science **15**:3.

Meredith, G.N. and R.R. Campbell. 1988. Status of the fin whale, *Balaenoptera physalus*, in Canada. Canadian Field-Naturalist 102: 351-368.

Mignucci-Giannoni, A.A., G.M. Toyos-González, J. Pâerez-Padilla, M.A. Rodríguez-Lopez and J. Overing. 2000. Mass stranding of pygmy killer whales (*Feresa attenuata*) in the British Virgin Islands. Journal of the Marine Biological Association of the UK 80(4): 2.

Mikhalev, Y.A. 1997. Humpback whales *Megaptera novaeangliae* in the Arabian Sea. Marine Ecology Progress Series 149: 13-21.

Miksis-Olds, J. L. 2006. Manatee response to environmental noise. Doctoral dissertation. University of Rhode Island, Providence, Rhode Island.

Miksis-Olds, J. L., J. H. Miller, and P. L. Tyack. 2004. The acoustic environment of the Florida manatee: Correlation with level of habitat use. The Journal of the Acoustical Society of America **115**:2558.

Miksis-Olds, J. L., P. L. Donaghay, J. H. Miller, and P. L. Tyack. 2005. Environmental noise levels affect the activity budget of the Florida manatee. The Journal of the Acoustical Society of America **118**:1.

Miksis-Olds, J. L., P. L. Donaghay, J. H. Miller, P. L. Tyack, and J. A. Nystuen. 2007. Noise level correlates with manatee use of foraging habitats. The Journal of the Acoustical Society of America **121**:18.

Mill, J.S. 1865. A system of logic ratiocinative and inductive: being a connected view of the principles of evidence and the methods of scientific investigation. Sixth Edition. Longmans and Company; London, United Kingdom.

Miller, C. T., S. Flusberg, and M. D. Hauser. 2003. Interruptibility of long call production in tamarins: implications for vocal control. Journal of Experimental Biology **206**:2629-2639.

Miller, P.J.O., N. Biassoni, A. Samuels and P.L. Tyack. 2000. Whales songs lengthen in response to sonar. Nature 405, 903

Mills, J.H. and J.A. Going. 1982. Review of environmental factors affecting hearing. Environmental Health Perspective 44:119-127.

Mills, S. K., and J. H. Beatty. 1979. The propensity interpretation of fitness. Philosophy of Science 46:263-286.

Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984. The blue whale, *Balaenoptera musculus*. Marine Fisheries Review 46(4):15-19.

Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984a. The fin whale, *Balaenoptera physalus*. Marine Fisheries Review 46(4):20-24.

Mizue, K. 1951. Food of whales (in the adjacent waters of Japan). Scientific Reports of the Whales Research Institute 5:81-90.

Moberg, G. P. 1985. Biological response to stress: key to assessment of animal well-being? Pages 27 - 49 in G. P. Moberg, editor. Animal stress. American Physiological Society, Bethesda, Maryland.

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.

Moberg, G.P. 1987. Influence of the adrenal axis upon the gonads. Pages: 456 - 496. In: *Oxford reviews in reproductive biology*. Edited by J. Clarke. Oxford University Press; New York, New York.

Mobley, J. R., L. M. Herman, A. S. Frankel. 1988. Responses of wintering humpback whales (*Megaptera novaeangliae*) to playback of recordings of winter and summer vocalizations and of synthetic sounds. Behavioral Ecology and Sociobiology 23: 211-223

Mobley, J. R., M. Smultea, T. Norris, and D. Weller. 1996. Fin whale sighting north of Kauai, Hawai'i. Pacific Science 50: 230-233.

Mobley, J. R., R. A. Grotefendt, P. H. Forestell, and A. S. Frankel. 1999a. Results of aerial surveys of marine mammals in the major Hawai'ian Islands (1993-1998): Report to the Acoustic Thermometry of Ocean Climate Marine Mammal Research Program. Cornell University Bioacoustics Research Program, Ithaca, New York.

Mobley, J.R., L. Mazzuca, A.S. Craig, M.W. Newcomer and S.S. Spitz. 2001. Killer whales (*Orcinus orca*) sighted west of Ni'ihau, Hawai'i. Pacific Science 55(3): 301-303.

Mohl, B. 2001. Sound transmission in the nose of the sperm whale *Physeter catodon*. A post mortem study. Journal of Comparative Physiology A Sensory Neural and Behavioral Physiology 187:335-340.

Mohl, B., M. Wahlberg, P. T. Madsen, A. Heerfordt, and A. Lund. 2003. The monopulsed nature of sperm whale clicks. The Journal of the Acoustical Society of America 114:12.

Mohl, B., M. Wahlberg, P. T. Madsen, L. A. Miller, and A. Surlykke. 2000. Sperm whale clicks: Directionality and source level revisited. Journal of the Acoustical Society of America 107:638.

Mohl, et al. 2000. Sperm Whale Clicks: Directionality and source level revisted. Journal of the Acoustical Society of America 107 (1), January 2000, pp. 638 -645.

Moore, K. E., W. A. Watkins, and P. L. Tyack. 1993. Pattern similarity in shared codas from sperm whales (*Physeter catodon*). Marine Mammal Science 9:1-9.

Moore, S. E., and J. T. Clarke. 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). Journal of Cetacean Research and Management 4:19–25.

Moore, S., and J. T. Clarke. 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). Journal of Cetacean Research and Management 4:19 - 25.

Morton, A.B. and H.K. Symonds. 2002. Displacement of *Orcinus orca* (L) by high amplitude sound in British Columbia, Canada. ICES Journal of Marine Science 59(1): 71-80.

Mullin, K.D. and G.L. Fulling. 2007. Abundance of cetaceans in the southern U.S. North Altantic Ocean during summer 1998. Fisheries Bulletin 101:603-613.

Mullins, J., H. Whitehead, and L.S. Weilgart. 1988. Behavior and vocalizations of two single sperm whales, *Physeter macrocephalus* off Nova Scotia. Canadian Journal of Fisheries and Aquatic Sciences 45(10):1736-1743.

Mullner, A., K. Eduard Linsenmair, and M. Wikelski. 2004. Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). Biological Conservation 118:549-558.

Murison, L. D., and D. E. Gaskin. 1989. The distribution of right whales and zooplankton in the Bay of Fundy, Canada. Canadian Journal of Zoology 67:1411-1420.

Myrberg, A.A., Jr. 1978. Ocean noise and behavior of marine animals: Relationships and implications. Pages 169-208. In: J.L. Fletcher and R.G. Busnel (eds.) Effects of Noise on Wildlife. Academic Press; New York, New York.

Nachtigall, P. E., A. Y. Supin, J. Pawloski, and W. W. L. Au. 2004. Temporary threshold shifts after noise exposure in the bottlenose dolphin (*Tursiops truncatus*) measured using evoked auditory potentials. Marine Mammal Science 20:15.

Nachtigall, P. E., J. L. Pawloski, and W. W. L. Au. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). The Journal of the Acoustical Society of America 113:5.

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.

Nasu, K. 1974. Movement of baleen whales in relation to hydrographic conditions in the northern part of the North Pacific Ocean and the Bering Sea. Pp. 345-361 in D.W. Hood and E.J. Kelley (editors) Oceanography of the Bering Sea. Institute of Marine Science, University of Alaska, Fairbanks.

National Marine Fisheries Service [NMFS]. 1991. Final recovery plan for the humpback whale (*Megaptera novaeangliae*). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1991. Final recovery plan for the northern right whale (*Eubalaena glacialis*). Prepared by the Right Whale Recovery Team for the National Marine Fisheries Service; Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1992. Environmental assessment of the effects of biopsy darting and associated approaches on humpback whales (*Megaptera novaeangliae*) and right whales (*Eubalaena glacialis*) in the North Atlantic. U.S. Department of Commerce, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1994. An assessment of whale watching in the United States. Prepared for the International Whaling Commission by U.S. Department of Commerce, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1998. Draft recovery plan for the fin whale *Balaenoptera physalus*and sei whale *Balaenoptera borealis*. Prepared by R.R. Reeves, G.K. Silber, and P. Michael Payne for the National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1998. Recovery plan for the blue whale (*Balaenoptera musculus*). Prepared by R.R. Reeves, P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber for the National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1998b. Recovery plan for the fin whale *Balaenoptera physalus*. Prepared by R.R. Reeves, G.K. Silber, and P. Michael Payne for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2000. Status review for smalltooth sawfish (Pristis pectinata). Unpublished report from the National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2001. Final biological opinion on the U.S. Navy's North Pacific Acoustic Laboratory Sound Source. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2002. Biological opinion on the U.S. Navy's Surveillance Towed Array Sensor System Low Frequency Active Sonar (SURASS LFA). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2002. Final biological opinion on the proposed letter of authorization to authorize the Navy to take marine mammals incidental to its employment of Surveillance Towed Array Sensor System Low Frequency Active Sonar for the period August 16, 2002, through August 15, 2003. Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2003. Final biological opinion on the proposed letter of authorization to authorize the Navy to take marine mammals incidental to its employment of Surveillance Towed Array Sensor System Low Frequency Active Sonar for the period August 16, 2003, through August 15, 2004. Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2004. Final biological opinion on the proposed letter of authorization to authorize the Navy to take marine mammals incidental to its employment of Surveillance Towed Array

Sensor System Low Frequency Active Sonar for the period August 16, 2004, through August 15, 2005. Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2005. Final biological opinion on the proposed letter of authorization to authorize the Navy to take marine mammals incidental to its employment of Surveillance Towed Array Sensor System Low Frequency Active Sonar for the period August 16, 2005, through August 15, 2006. Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2007. Biological opinion on the U.S. Navy's proposed 2007 USS Truman 07-1 Combined Carrier Strike Group Composite Training Unit/Joint Task Force exercise. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service and U.S. Fish and Wildlife Service [NMFS and USFWS]. 1998a. Recovery plan for U.S. Pacific population of the east Pacific green turtle (*Chelonia mydas*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources and U.S. Department of the Interior, U.S. Fish and Wildlife Service, Pacific Region; Silver Spring, Maryland.

National Marine Fisheries Service and U.S. Fish and Wildlife Service [NMFS and USFWS]. 1998c. Recovery plan for U.S. Pacific population of the leatherback turtle (*Dermochelys coriacea*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources and U.S. Department of the Interior, U.S. Fish and Wildlife Service, Pacific Region; Silver Spring, Maryland.

National Marine Fisheries Service and U.S. Fish and Wildlife Service [NMFS and USFWS]. 1998d. Recovery plan for U.S. Pacific population of the loggerhead turtle (*Caretta caretta*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources and U.S. Department of the Interior, U.S. Fish and Wildlife Service, Pacific Region; Silver Spring, Maryland.

National Marine Fisheries Service and U.S. Fish and Wildlife Service [NMFS and USFWS]. 1998e. Recovery plan for U.S. Pacific population of the olive ridley turtle (*Lepidochelys olivacea*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources and U.S. Department of the Interior, U.S. Fish and Wildlife Service, Pacific Region; Silver Spring, Maryland.

National Research Council [NRC]. 1994. Low-frequency sound and marine mammals, current knowledge and research needs. National Academy Press; Washington, D.C.

National Research Council [NRC]. 1996. Marine mammals and low frequency sound: Progress since 1994 - an interim report. National Academy Press; Washington, D.C.

National Research Council [NRC]. 1996a. The Bering Sea ecosystem. National Academy Press; Washington, D.C.

National Research Council [NRC]. 1996b. Marine mammals and low frequency sound: Progress since 1994 - an interim report. National Academy Press; Washington, D.C.

National Research Council [NRC]. 2003. Ocean noise and marine mammals. National Academy Press; Washington, D.C.

National Research Council 2005. Marine mammal populations and ocean noise: determining when noise causes biologically significant effects. National Academies Press, Washington, D.C.

Nelson, M., M. Garron, R.L. Merrick, R.M. Pace III and T. Cole. 2007. Mortality and serious injury determinations for baleen whale stocks along the United States eastern seaboard and adjacent Canadian Maritimes, 2001 - 2005. Northeast Fisheries Science Center Reference Document 07-05. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center; Woods Hole, Massachusetts.

Nemoto T. 1964. School of baleen whales in the feeding areas. Scientific Reports of the Whales Research Institute 18: 89-110.

Nemoto, T. 1957. Foods of baleen whales in the northern Pacific. Scientific Reports of the Whales Research Institute 12:33-89.

Nemoto, T. 1970. Feeding pattern of baleen whales in the oceans. Pages 241-252 in Steele, J.H. (ed.), Marine Food Chains. University of California Press, Berkeley, California.

Nemoto, T. 1978. Humpback whales observed within the continental shelf waters of the Bering Sea. Scientific Reports of the Whales Research Institute Tokyo 39:245-247.

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.

Newman, M. C., D. R. Ownby, L. C. A. Mezin, D. C. Powell, T. R. L. Christensen, S. B. Lerberg, and B. A. Anderson. 2000. Applying species-sensitivity distributions in ecological risk assessment: assumptions of distribution type and sufficient numbers of species. Environmental Toxicology and Chemistry 19:508.

Nikulin, P.G. 1946. Distribution of cetaceans in seas surrounding the Chukchi Peninsula. Trudy Inst. Okeanol. Akad. Sci. USSR 22:255-257.

Nishiwaki, M. 1952. On the age determination of Mystacoceti, chiefly blue and fin whales. Scientific Reports of the Whales Research Institute 7: 87-119.

Nishiwaki, M. 1966. Distribution and migration of the larger cetaceans in the North Pacific as shown by Japanese whaling results. Pages 171-191 in Norris, K.S., (ed.), Whales, Dolphins and Porpoises. University of California Press, Berkeley.

Nishiwaki, M. 1966. Distribution and migration of the larger cetaceans in the North Pacific as shown by Japanese whaling results. Pages: 171-191. In: *Whales, Dolphins and Porpoises.* Edited by K.S. Norris. University of California Press; Berkeley, California.

Nitta, E.T. 1991. The marine mammal stranding network for Hawai'i, an overview. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

Norrgard, J. 1995. Determination of stock composition and natal origin of a juvenile loggerhead turtle population (Caretta caretta) in Chesapeake Bay using mitochondrial DNA analysis. Thesis prepared in partial fulfillment of a Master's Degree in Arts. College of William and Mary; Williamsburg, Virginia

Norris K.S. and Harvey G.W. 1972. A theory for the function of the spermaceti organ of the sperm whale (*Physeter catodon* L.). In: Galler SR, Schmidt-Koenig K, Jacobs GJ, Belleville RE (eds) Animal Orientation and Navigation. pp 397-417. NASA Special Publications, Washington.

Norris, J. 2001. Human activities and natural events: impacts on Gulf of Mexico marine mammals. Part 2, Pages 85-92 in M. McKay, J. Nides, W. Lang, and D. Vigil, eds., Gulf of Mexico marine protected species workshop - June 1999. New Orleans, Louisiana, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region.

Norris, T.F. 1994. Effects of boat noise on the acoustic behavior of humpback whales. The Journal of the Acoustical Society of America 96(1):3251.

Norton, S. B., D. J. Rodier, J. H. Gentile, W. H. Van Der Schalie, and W. P. Wood. 1992. The framework for ecological risk assessment at the EPA. Environmental Toxicology and Chemistry 11:1663.

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 33:105-150.

Notobartolo di Sciara, G., M. Jahoda, N. Biassoni, and C. Lafortuna. 1996. Reactions of fin whales to approaching vessels assessed by means of a laser range finder. Pages 38-42 *in* Proceedings of the 10th Annual Conference of the European Cetacean Society, 11-13 March 1996, Lisbon, Portugal.

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 Biological Sciences Series B 271:227-231.

Nowacek, D. P., M. P. Johnson, P. L. Tyack, K. A. Shorter, W. A. McLellan, and D. A. t. Pabst. 2001. Buoyant balaenids: The ups and downs of buoyancy in right whales. Proceedings of the Royal Society Biological Sciences Series B 268:1811-1816.

Nowacek, D., 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. Series B. Biological Sciences 271: 227-231.

Nowacek, S. M., R. S. Wells, and A. R. Solow. 2001. Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. Marine Mammal Science 17:16.

O'Hara, J. and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, Caretta caretta, to low frequency sound. Copeia 1990: 564-567.

O'Hara, T.M., M.M. Krahn, D. Boyd, P.R. Becker, and L.M. Philo. 1999. Organochlorine contaminant levels in Eskimo harvested bowhead whales of arctic Alaska. Journal of Wildlife Diseases 35(4): 741-52.

O'Shea, T.J. and R.L.J. Brownell. 1994. Organochlorine and metal contaminants in baleen whales: A review and evaluation of conservation implications. Science of the Total Environment 154 (2-3): 179-200.

Odell, D.K., E. Asper, J. Baucom and L. Cornell. 1980. A recurrent mass stranding of false killer whales, *Pseudorca crassidens*, in Florida. Fishery Bulletin 78: 171 - 177.

Ohsumi, S. 1980. Criticism of Japanese fishing effort for sperm whales in the North Pacific. Reports of the International Whaling Commission Special Issue 2: 19-30.

Ohsumi, S. 1980. Population assessment of the sperm whale in the North Pacific. Reports of the International Whaling Commission Special Issue 2: 31-42.

Ohsumi, S., and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. Reports of the International Whaling Commission 24:114-126.

O'Keefe, D.J. and G.A. Young. 1984. Handbook on the environmental effects of underwater explosions. NAVSWC Technical Report 83-240. U.S. Navy, Naval Surface Warfare Center; Silver Spring, Maryland.

Oleson, E. M., J. Calambokidis, J. Barlow, and J. A. Hildebrand. 2007. Blue whale visual and acoustic encounter rates in the southern California Bight. Marine Mammal Science **23**:574-597.

Omura, H. 1958. North Pacific right whales. Scientific Reports of the Whales Research Institute 13:1-52.

Omura, H., S. Ohsumi, T. Nemota, k. Nasu, and T. Kasuya. 1969. Black right whales in the North Pacific. Scientific Reports of the Whales Research Institute 21:1-87.

Owens, D. W. 2001. Human activities and natural events: impacts on Gulf of Mexico sea turtles, Pages 93-97 in M. McKay, J. Nides, W. Lang, and D. Vigil, eds., Gulf of Mexico marine protected species workshop - June 1999. New Orleans, Louisiana, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region.

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(4): 6.

Palumbi, S.R. and J. Roman. 2006. The history of whales read from DNA. Pages: 102-115. In: Whales, whaling, and ocean ecosystems. Edited by J.A. Estes, D.P. DeMaster, D.F. Doak, T.M. Williams and R.L. Brownell Jr. University of California Press; Berkeley and Los Angeles, California.

Panigada, S., G. Pesante, M. Zanardelli, F. Capoulade, A. Gannier and M.T. Weinrich. 2006. Mediterranean fin whales at risk from fatal ship strikes. Marine Pollution Bulletin 52(10): 1287-1298.

Papouchis C., F. J. Singer, and W. B. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. Journal of Wildlife Management 65:573-582.

Parks, S.E. and C.W. Clark. 2007. Short- and long-term changes in right whale calling behavior: the potential effects of noise on acoustic communication. Journal of the Acoustic Society of America 122(6): 3725-3731.

Patricelli, G.L. and J.L. Blickley. 2006. Avian communication in urban noise: causes and consequences of vocal adjustment. The Auk 123(3):639-649.

Payne R.S. 1970. Songs of the humpback whale. Catalog No. ST-620. Capital Records, Hollywood, California.

Payne, R. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. Annals of the New York Academy of Sciences 188:0110-141.

Payne, R. S. 2005. Annex K: Report of the standing working group on environmental concerns. Appendix 2. Long-range communication in large whales, ocean noise, and synergistic impacts. Journal of Cetacean Research and Management 7:282 - 283.

Perez, M.A. 1990. Review of marine mammal population and prey information for Bering Sea ecosystem studies. U.S. Department of Commerce, NOAA Technical Memorandum NMFS F/NWC-186. Northwest Fisheries Science Center; Seattle, Washington.

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.

Philo, L.M., J.C. George and T.F. Albert. 1992. Rope entanglement of bowhead whales (*Balaena mysticetus*). Marine Mammal Science 8(3): 306-311.

Piantadosi, C. A., and E. D. Thalmann. 2004. Pathology: Whales, sonar and decompression sickness. Nature 428:n.

Piatt, J. F. and D. A. Methven. 1992. Threshold foraging behavior of baleen whales. Marine Ecology Progress Series 84:205-210.

Piatt, J. F., D. A. Methven, A. E. Burger, R. L. McLagan, V. Mercer and E. Creelman. 1989. Baleen whales and their prey in a coastal environment. Canadian Journal of Zoology 67:1523-1530.

Pike G.C., MacAskie I.B. 1969. Marine mammals of British Columbia. Bulletin of the Fisheries Research Board of Canada 171: 1-54.

Polmar, N. 2001. The Naval Institute guide to the ships and aircraft of the U.S. fleet. Naval Institute Press; Annapolis, Maryland.

Polovina, J. J., G. H. Balazs, E. A. Howell, D. M. Parker, M. P. Seki, and P. H. Dutton. 2004. Forage and migration habitat of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific Ocean. Fisheries Oceanography 13:36-51.

Posner, M.I. 1994. Attention: the mechanism of consciousness. Proceedings of the National Academy of Science of the United States of America 91:7398-7403.

Potter, J.R. 2004. A possible mechanism for acoustic triggering of decompression sickness symptoms in deep-diving marine mammals. Underwater Technology April 2004: 20-23.

Poulter, T.C. and D.G. DelCarlo. 1971. Echoranging signals: sonar of the Steller sea lion *Eumetopias jubata*. Journal of Auditory Research 11: 43-52.

Prevalichin, V.I. 2007. Scientific report for "Dalniy Vostok" and "Vladivostok" for the 1973 season. Pages: 20-22. In: Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. NOAA Technical Memorandum NMFS-AFSC-175. Edited by Y.V. Ivashchenko, P.J. Clapham and R.L. Brownell Jr. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center; Seattle, Washington.

Pryor, K. 1990. Non-acoustic communication in small cetaceans: glance, touch, position, gesture, and bubbles. In: J.A. Thomas and R.A. Kastelein (eds.), Sensory Abilities in Cetaceans - Laboratory and Field Evidence. p.537-544. NATO ASI Series, Plenum Press, New York.

Rankin, S. 1999. The potential effects of sounds from seismic exploration on the distribution of cetaceans in the northern Gulf of Mexico, Texas A&M University, College Station, Texas.

Rankin, S. and J. Barlow. 2007. Vocalizations of the sei whale *Balaenoptera borealis* off the Hawai'ian Islands. Bioacoustics 16: 137-145.

Rankin, S., and W. E. Evans. 1998. Effect of low-frequency seismic exploration signals on the cetaceans of the Gulf of Mexico. Journal of the Acoustic Society of America 103:2908.

Rankin-Baransky, K.C. 1997. Origin of loggerhead turtles (*Caretta caretta*) in the western North Atlantic as determined by mt DNA analysis. Thesis prepared in partial fulfillment of a Master's Degree in Science. Drexel University; Philadelphia, Pennsylvania

Ray, G. C., E. Mitchell, D. Wartzok, V. Koxicki, and R. Maiefski. 1978. Radio tracking of a fin whale (Balaenoptera physalus). Science 202: 521-524.

Reeves, R. R. 1977. The problem of gray whale (*Eschrichtius robustus*) harassment at the breeding lagoons and during migration. U.S. Marine Mammal Commission Report MMC-76/06. Bethesda, Maryland.

Reeves, R. R. 1992. Whale responses to anthropogenic sounds: a literature review. New Zealand Department of Conservation, Wellington, New Zealand.

Reeves, R. R., B. S. Stewart, and S. Leatherwood. 1992. The Sierra Club handbook of seals and sirenians. Sierra Club Books; San Francisco, California.

Reeves, R. R., D. K. Ljungblad, and J. T. Clarke. 1984. Bowhead whales and acoustic seismic surveys in the Beaufort Sea. Journal of the Acoustic Society of America 62:271–280.

Reeves, R.R. and Whitehead, H. 1997. Status of the sperm whale, *Physeter macrocephalus*, in Canada. Canadian Field-Naturalist 111(2): 293-307

Reeves, R.R., B.D. Smith, E.A. Crespo, G. Notarbartolo di Sciara. 2002. Dolphins, whales and porpoises. 2002 – 2010 Conservation action plan for the world's cetaceans. The World Conservation Union, Cetacean Specialist Group. IUCN; Gland, Switzerland and Cambridge, United Kingdom.

Reilly, S. B. and V. G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. Marine Mammal Science 6: 265-277.

Reiner, F., M.E. Dos Santos and F.W. Wenzel. 1996. Cetaceans of the Cape Verde archipelago. Marine Mammal Science 12(3): 10.

Relyea, R. A. 2003. Predator cues and pesticides: A double dose of danger for amphibians. Ecological Applications 13:7.

Relyea, R. A. 2004. Synergistic impacts of malathion and predatory stress on six species of North American tadpoles. Environmental Toxicology and Chemistry 23:5.

Relyea, R. A. 2005. The lethal impacts of roundup and predatory stress on six species of North American tadpoles. Archives of Environmental Contamination and Toxicology 48:7.

Relyea, R. A., and N. Mills. 2001. Predator-induced stress makes the pesticide carbaryl more deadly to gray treefrog tadpoles (*Hyla versicolor*). Proceedings of the National Academy of Sciences of the United States of America 98:6.

Rendell, L. and H. Whitehead. 2004. Do sperm whales share coda vocalizations? Insights into coda usage from acoustic size measurement. Animal Behavior 67(5): 10.

Rendell, L. and H. Whitehead. 2005. Coda playbacks to sperm whales in Chilean waters. Marine Mammal Science 21(2): 10.

Rendell, L. E., and J. C. D. Gordon. 1999. Vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Ligurian Sea. Marine Mammal Science **15**:198-204.

Rendell, L., H. Whitehead and A. Coakes. 2005. Do breeding male sperm whales show preferences among vocal clans of females? Marine Mammal Science 21(2): 6.

Reneerkens, J., R. I. G. Morrison, M. Ramenofsky, T. Piersma, and J. C. Wingfield. 2002. Baseline and stress-induced levels of corticosterone during different life cycle substages in a shorebird on the high arctic breeding grounds. Physiological and Biochemical Zoology 75:200-208.

Rice, D. W. 1978. Blue whale. In: D. Haley (editor) Marine mammals of the Eastern North Pacific and Arctic waters.

Rice, D.W. 1974. Whales and whale research in the eastern North Pacific . Pp. 170-195. In W.E. Schevill, (editor), The Whale Problem: A Status Report. Harvard University Press, Cambridge, Massachusetts.

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 No. 1:92-97.

Rice, D.W. 1986. Sperm whales. Pages 94-101 in D. Haley (ed.), Marine Mammals of the Eastern North pacific and Arctic Waters, 2nd ed. Pacific Search Press, Seattle, Washington.

Rice, D.W. 1989. Sperm whale, *Physeter macrocephalus* (Linneaus, 1758). In: Handbook of marine mammals. Volume 4. River dolphins and the larger toothed whales. Edited by S.H. Ridgeway and R.J. Harrison. Academic Press, Inc.; New York, New York.

Richard, K.R., M.C. Dillon, H. Whitehead and J.M. Wright. 1996. Patterns of kinship in groups of free-living sperm whales (*Physeter macrocephalus*) revealed by multiple molecular genetic analyses. Proceedings of the National Academy of Science of the United States of America 93(16): 8792-8795.

Richardson W.J., C.R. Greene Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press; San Diego, California.

Richardson W.J., R.A. Davis, C.R. Evans, P. Norton. 1985. Distribution of bowheads and industrial activity, 1980-84. In: Richardson W.J. (ed) Behavior, disturbance responses and distribution of bowhead whales Balaena

mysticetus in the eastern Beaufort Sea. 1980-84. OCS Study MMS 85-0034. Unpublished reported prepared by LGL Ecological Research Associates, Inc. for U. S. Minerals Management Service, Reston, Virginia.

Richardson, W. J., and B. Würsig. 1997. Influences of man-made noise and other human actions on cetacean behavior. Marine and Freshwater Behavior and Physiology 29:183-209.

Richardson, W. J., B. Wursig and C.R. Greene, Jr. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. Marine Environmental Research 29(2):135-160.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme and D. H. Thompson. 1991. Effects of noise on marine mammals. OCS Study MMS-90-0093; LGL Rep. TA834-1. Report prepared by LGL Ecological Research Associates, Inc. for U.S. Minerals Management Service, Atlantic OCS Reg., Herndon, Virginia. NTIS PB91-168914.

Richardson, W.J. 1995b. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska—1991 and 1994 phases: sound propagation and whale responses to playbacks of icebreaker noise. Outer Continental Shelf Study. Report prepared by LGL Limited Environmental Research Associates and Greeneridge Sciences Inc. for United States Department of the Interior, Minerals Management Service; Herndon, Virginia.

Richardson, W.J., C.R. Greene, Jr., W.R. Koski and M.A. Smultea. 1991a. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska -- 1990 phase. OCS Study MMS 91-0037; LGL Rep. TA848-5. Unpublished Report prepared by LGL Ltd., for U.S. Minerals Management Service, Herndon, Virginia. NTIS PB92-170430.

Richter, C., S. Dawson and E. Slooten. 2006. Impacts of commercial whale watching on male sperm whales at Kaikoura, New Zealand. Marine Mammal Science 22(1): 18.

Richter, C., S.M. Dawson and E. Slooten. 2003. Sperm whale watching off Kaikoura, New Zealand: effects of current activities on surfacing and vocalization patterns. Science for Conservation 219. New Zealand Department of Conservation; Wellington, New Zealand.

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., B. L. Scronce, and J. Kanwisher. 1969. Respiration and deep diving in the bottlenose porpoise. Science 166:1651-1654.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin, and J.H. Anderson. 1960. Hearing in the giant sea turtle, *Chelonia mydas*. Proceedings of the National Academy of Sciences 64(3):884-890.

Ritter, F., and B. Brederlau. 1999. Behavioral observations of dense beaked whales (*Mesoplodon densirostris*) off La Gomera, Canary Islands (1995-1997). Aquatic Mammals **25**:55-61.

Rivers, J.A. 1997. Blue whale, *Balaenoptera musculus*, vocalizations from the waters off central California. Marine Mammal Science 13: 186-195.

Rivier, C. 1985. Luteinizing-hormone-releasing hormone, gonadotropins, and gonadol steroids in stress. Annals of the New York Academy of Sciences 771: 187 - 191.

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.

Romero, A., K.T. Hayford and J. Romero. 2002. The marine mammals of Grenada, W.I., and their conservation status. Mammalia 66(4): 479-494.

Romero, L. M. 2004. Physiological stress in ecology: lessons from biomedical research. Trends in Ecology and Evolution 19:249-255.

Romero, L. M., and M. Wikelski. 2001. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. Proceedings of the National Academy of Sciences of the United States of America 98:5.

Romero, L. M., and M. Wikelski. 2002. Exposure to tourism reduces stress-induced corticosterone levels in Galapagos marine iguanas. Biological conservation 108:371-374.

Rommel, S.A., A.M. Costidis, A. Fernandez, P.D. Jepson, D.A. Pabst, W.A. McLellan, D.S. Houser, T.W. Cranford, A.L. van Helden, D.M. Allen and N.B. Barros. 2006. Elements of beaked whale anatomy and diving physiology, and some hypothetical causes of sonar-related stranding. Journal of Cetacean Research and Management 7(3): 189 - 209.

Ruud, J.T. 1956. The blue whale. Scientific American 195: 46-50.

Sakhalin Energy Investment Company Limited. 2002. Western gray whale protection plan: framework for monitoring and mitigation measures related to Sakhalin energy oil and gas operations on the northeast coast of Sakhalin Island, Russia. Unpublished report prepared by Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Salden, D. R. 1987. An observation of apparent feeding by a sub-adult humpback whale off Maui. Eighth Biennial Conference on the Biology of Marine Mammals. Pacific Grove, California.

Salden, D.R. 1988. Humpback whale encounter rates offshore at Maui, Hawai'i. The Journal of Wildlife Management 52(2): 301-304.

Sandgren, F.E. 1970. Breeding and maternal behavior of the Steller sea lion (*Eumetopias jubatus*) in Alaska. The Zoological Institute, University of Stockholm, Swedish Museum of Natural History.

Sapolsky, R. M., L. M. Romero, and A. U. Munck. 2000. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews 21:55 – 89.

Scarff, J.E. 1986. Historic and present distribution of the right whale (*Eubalaena glacialis*) in the eastern North Pacific south of 50ºN and east of 180ºW. Pp. 43-63. In Brownell Jr., R.L., P.B. Best, and J.H. Prescott (eds.), Right Whales: Past and Present Status. Reports of the International Whaling Commission; Special Issue No. 10. Cambridge, United Kingdom.

Scheidat, M., C. Castro, J. Gonzalez, and R. Williams. 2004. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to whalewatching boats near Isla de la Plata, Machalilla National Park, Ecuador. Journal of Cetacean Research and Management 61:63 - 68.

Scheifele, P. M. 2003. Investigation into the response of the auditory and acoustic communications systems in the Beluga whale (*Delphinapterus leucas*) of the St. Lawrence River Estuary to noise, using vocal classification. Dissertation Abstracts International **65**:1-123.

Scheifele, P. M., S. Andrew, R. A. Cooper, and M. Darre. 2005. Indication of Lombard vocal response in the in the St. Lawrence River beluga. Journal of the Acoustic Society of America **117**:1486-1492.

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, *Delphinapterus leucas*, after exposure to intense tones. The Journal of the Acoustical Society of America 107(6): 3496.

Schmidly, D.J. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. Biological Services Program FWS/OBS-80/41. U.S. Department of the Interior, Bureau of Land Management and U.S. Fish and Wildlife Service; Slidell, Louisiana.

Schoenherr, J.R. 1991. Blue whales feeding on high concentrations of euphausiids in around Monterey Submarine Canyon. Canadian Journal of Zoology 69: 583-594.

Scott, T.M. and S. Sadove. 1997. Sperm whale, *Physeter macrocephalus*, sightings in the shallow shelf waters off Long Island, New York. Marine Mammal Science 13(2): 4.

Sears, C.J. 1994. Preliminary genetic analysis of the population structure of Georgia loggerhead sea turtles. NOAA Technical Memorandum NMFS-SEFSC-351. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center; Miami, Florida.

Sears, C.J., B.W. Bowen, R.W. Chapman, S.B. Galloway, S.R. Hopkins-Murphy and C.M. Woodley. 1995. Demographic composition of the feeding population of juvenile loggerhead sea turtles (*Caretta caretta*) off Charleston, South Carolina: evidence from mitochondrial DNA markers. Marine Biology 123:869-874.

Sease, J.L., and T.R. Loughlin. 1999. Aerial and land-based surveys of Steller sea lions (*Eumetopias jubatus*) in Alaska, June and July 1997 and 1998. U.S. Department of Commerce, noaa Technical Memorandum nmfs-AFSC. Alaska Fisheries Science Center; Seattle, Washington.

Seminoff, J. A., A. Resendiz, and W. J. Nichols. 2002. Home range of green turtles *Chelonia mydas* at a coastal foraging area in the Gulf of California, Mexico. Marine Ecology Progress Series 242:14.

Seminoff, J.A., A. Resendiz and W.J. Nichols. 2002. Home range of green turtles *Chelonia mydas* at a coastal foraging area in the Gulf of California, Mexico. Marine Ecology Progress Series 242: 14.

Sergeant, D. E. 1977. Stocks of fin whales, *Balaenoptera physalus*, in the North Atlantic Ocean. Reports of the International Whaling Commission 27: 460-473.

Seyle, H. 1950. Stress and the general adaptation syndrome. The British Medical Journal:1383-1392.

Shallenberger, E. E. 1978. Activities possibly affecting the welfare of humpback whales. p. 81-85 In: K.S. Norris and R.R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawai'i. Unpublished report prepared by Sea Life Inc., for the U.S. Marine Mammal Commission, Bethesda, Maryland. MMC-77/03. NTIS PB-280794

Shallenberger, E. E. 1981. The status of Hawai'ian cetaceans. U.S. Marine Mammal Commission, Bethesda, Maryland.

Shallenberger, E.E. 1981. The status of Hawai'ian cetaceans. In: Contract No. MM7A C028. U.S. Marine Mammal Commission; Bethesda, Maryland.

Shane, S.H., R.S. Wells, and B. Wursig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. Marine Mammal Science 2(1):34-63.

Sharpe F.A., L.M. Dill. 1997. The behavior of Pacific herring schools in response to artificial humpback whale bubbles. Canadian Journal of Zoology 75: 725-730

Sigurjonsson, J. and T. Gunnlaugsson. 1990. Recent trends in abundance of blue whales (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeangliae*) off west and southwest Iceland with a note on occurrence of other cetacean species. Report of the International Whaling Commission 40: 557-551.

Sigurjønsson, J., A.S. Blix, L. Walloe and O. Ulltang. 1995. On the life history and autecology of North Atlantic rorquals. Pages: 425-441. In: *Developments in Marine Biology*. *Volume 4*. Edited Elsevier Science.

Sih, A., A. M. Bell, and J. L. Kerby. 2004. Two stressors are far deadlier than one. Trends in Ecology and Evolution 19:274-276.

Silber, G. K. 1986. The relationship of social vocalizations to surface behavior and aggression in the Hawai'ian humpback whale (*Megaptera novaeangliae*). Canadian Journal of Zoology 64:2075-2080.

Silber, G. K. 1986. The relationship of social vocalizations to surface behavior and aggression in the Hawai'ian humpback whale (*Megaptera novaeangliae*). Canadian Journal of Zoology 64:2075-2080.

Simmonds, M. P. 2005. Whale watching and monitoring: some considerations. Unpublished paper submitted to the Scientific Committee of the International Whaling Commission, Cambridge, United Kingdom.

Simmonds, M. P., and L. F. Lopez-Jurado. 1991. Whales and the military. Nature 351:448.

Simmonds, M.P. 2005. Whale watching and monitoring: some considerations. SC/57/WW5. Unpublished paper submitted to the Scientific Committee of the International Whaling Commission; Cambridge, United Kingdom.

Simmonds, M.P. and L.F. Lopez-Jurado. 1991. Whales and the military. Nature 351(6 June 1991): 448.

Slabbekoorn, H. and M. Peet. 2003. Birds sing at a higher pitch in urban noise: Great Tits hit the high notes to ensure that their mating calls are heard above the city's din. Nature 424:267.

Slabbekoorn, H., and E. A. Ripmeister. 2008. Birdsong and anthropogenic noise: implications and applications for conservation. Molecular Ecology 17:72-83.

Sleptsov, M.M. 1955. Biology of whales and the whaling fishery in Far Eastern seas. >Pishch. Prom.', Moscow [In Russian] (Translated with comments and conclusions only by Fisheries Research Board of Canada Translation Series 118, 6 pp.)

Sleptsov, M.M. 1955. Biology of whales and the whaling fishery in Far Eastern seas. >Pishch. Prom.', Moscow [In Russian] (Translation with comments and conclusions only by Fisheries Research Board of Canada, Translation Series 118)

Slijper E. 1962. Whales. Basic Books; New York, New York.

Sloger, W. 2001. Navy explosives testing, Pages 72-79 in M. McKay, J. Nides, W. Lang, and D. Vigil, eds., Gulf of Mexico marine protected species workshop - June 1999. New Orleans, Louisiana, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region.

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? The Journal of Experimental Biology 207:12.

Smith, S.C. and H. Whitehead. 1993. Variations in the feeding success and behavior of Galapagos sperm whales (*Physeter macrocephalus*) as they relate to oceanographic conditions. Canadian Journal of Zoology 71(10): 1991-1996.

Smith, S.C. and H. Whitehead. 2000. The diet of Galapagos sperm whales *Physeter macrocephalus* as indicated by fecal sample analysis. Marine Mammal Science 16(2): 11.

Smith, T.D., J. Allen, P.J. Clapham, P.S. Hammond, S. Katona, F. Larsen, J. Lien, D. Mattila and P.J. Palsbøll. 1999. An ocean-basin-wide mark-recapture study of the North Atlantic humpback whale (*Megaptera novaeangliae*). Marine Mammal Science 15(1): 1-32.

Sonobuoy Tech Systems. No date. an/ssq-63E dicass sonobuoy. Brochure of specifications. Columbia City, Indiana and Deleon Springs, Florida.

Southall, B. L., R. Braun, F. M. D. Gulland, A. D. Heard, R. W. Baird, S. M. Wilkin, and T. K. Rowles. 2006. Hawai'ian melon-headed whale (*Peponacephala electra*) mass stranding event of July 3 - 4, 2004. NOAA Technical Memorandum NMFS-OPR-31. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland.

Southall, B. L., R. J. Schusterman, and D. Kastak. 2000. Masking in three pinnipeds: Underwater, low-frequency critical ratios. Journal of the Acoustical Society of America 108:1322.

Southall, B.L. 2007. Mid-frequency active sonar - marine mammal behavioral response functions. Scientific peer-review process - December 2007. Memorandum to Mr. James Lecky, Director, Office of Protected Resources. U.S. Department of Commerce, National Oceanic and Atmospheric Administrration, National Marine Fisheries Service; Silver Spring, Maryland.

Spaulding, G.C. 1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Fisheries Research Board of Canada, Bulletin No. 146.

Spero, D. 1981. Vocalizations and associated behavior of northern right whales Eubalaena glacialis. Abstracts of the Fourth Biennial Conference on the Biology of Marine Mammals, San Francisco, USA, December 1981.

St. Aubin, D.J. and J.R. Geraci. 1988. Capture and handling stress suppresses circulating levels of thyroxine (T4) and triiodothyronine (T3) in beluga whales Delphinapterus leucas. Physiological Zoology 61(2): 170-175.

Stafford, K.M. 2007. Baleen whale acoustic activity in the North Pacific: historical analysis and current occurrence. Unpublished report prepared through the Naval Postgraduate School, Monterey, California, for the Office of the Chief of Naval Operations (N45); Washington, D.C.

Stark, J. D., J. E. Banks, and R. Vargas. 2004. How risky is risk assessment: The role that life history strategies play in susceptibility of species to stress. Proceedings of the National Academy of Sciences of the United States of America 101:732-736.

Stark, J.D., J.E. Banks and R. Vargas. 2004. How risky is risk assessment: The role that life history strategies play in susceptibility of species to stress. Proceedings of the National Academy of Sciences of the United States of America 101: 732-736.

Stearns, S. C. 1992. The evolution of life histories. New York, New York, Oxford University Press.

Stearns, S.C. 1977. The evolution of life history traits: a critique of the theory and a review of the data. Annual Review of Ecology and Systematics 8: 145-171.

Stensland, E., and P. Berggren. 2007. Behavioral changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism. Marine Ecology Progress Series **332**:225-234.

Stevick, P.T., J. Allen, M. Berube, P.J. Clapham, S.K. Katona, F. Larsen, J. Lien, D.K. Mattila, P.J. Palsboll, J. Robbins, J. Sigurjonsson, T.D. Smith, N. Oien and P.S. Hammond. 2003a. Segregation of migration by feeding ground origin in North Atlantic humpback whales (*Megaptera novaeangliae*). Journal of Zoology 259(3): 231-237.

Stevick, P.T., J. Allen, P.J. Clapham, N.A. Friday, S.K. Katona, F. Larsen, J. Lien, D.K. Matilla, P.J. Palsbøll, J. Sigurjonsson, T.D. Smith, N. Olen and P.S. Hammond. 2003b. North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. Marine Ecology Progress Series 258: 263-273.

Stone, C.J. 1997. Cetacean observations during seismic surveys in 1996. Joint Nature Conservation Committee, Rep. 228, Aberdeen, Scotland.

Stone, C.J. 1998. Cetacean observations during seismic surveys in 1997. Joint Nature Conservation Committee Rep. 278, Aberdeen, Scotland..

Stone, C.J. 2000. Cetacean observations during seismic surveys in 1998. Joint Nature Conservancy, Aberdeen, Scotland.

Stone, C.J. 2001. Marine mammal observations during seismic surveys in 1999. JNCC Report 316. Joint Nature Conservation Committee Rep. 316, Aberdeen, Scotland.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters, 1998-2000 JNCC Report No. 323.

Strong, C.S. 1990. Ventilation patterns and behavior of balaenopterid whales in the Gulf of California, Mexico. Unpublished master's thesis, San Francisco State University, California.

Sun, J.W.C. and P.M. Narins. 2005. Anthropogenic sounds differentially affect amphibian call rate. Biological Conservation 121:419-427.

Swartz, S.L., T. Cole, M.A. McDonald, J.A. Hildebrand, E.M. Oleson, A. Martinez, P.J. Clapham, J. Barlow and M.L. Jones. 2003. Acoustic and visual survey of humpback whale (*Megaptera novaeangliae*) distribution in the eastern and southeastern Caribbean Sea. Caribbean Journal of Science 39(Part 2): 195-208.

Swift, R. 1998. The effects of array noise on cetacean distribution and behavior. Department of Oceanography. University of Southampton; Southampton, United Kingdom

Swingle, W. M., S. G. Barco, and T. D. Pitchford.1993. Appearance of juvenile humpback whales feeding in the nearshore waters of Virginia. Marine Mammal Science 9: 309-315.

Tarasevich, M.N. 1968. Pishchevye svyazi kasholotov v severnoi chasti Tikhogo Okeana. [Food connections of the sperm whales of the Northern Pacific.] [In Russian.] Zool. Zhur. 47:595-601. (Translated by K. Coyle, University of Alaska, Fairbanks, 1982, 11 pp.)

Taub, F. B. 1997. Are ecological studies relevant to pesticide registration decisions? Ecological Applications 7:1083.

Taylor, B., J. Barlow, R. Pitman, L. Ballance, T. Klinger, D. DeMaster, J. Hildebrand, J. Urban, D. Palacios, and J Mead. 2004. A call for research to assess risk of acoustic impact on beaked whale populations. Unpublised paper submitted to the International Whaling Commission, Scientific Committee SC/56/E36. Cambridge, United Kingdom.

Tershy, B.R., G. A. Acevedo, D. Breese, C.S. Strong. 1993. Diet and feeding behavior of fin and Bryde's whales in the central Gulf of California, Mexico. Rev Inv Cient 1 (No Esp SOMEMMA 1): 31-38.

Thomas, J. A., R. A. Kastelein and F. T. Awbrey. 1990. Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. Zoo Biology 9(5): 393-402.

Thompson P.O., L.T. Findley, O. Vidal, W.C. Cummings. 1996. Underwater sounds of blue whales, *Balaenoptera musculus*, in the Gulf of California, Mexico. Marine Mammal Science 288-293.

Thompson P.O., W.C. Cummings, 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. Pages 403-431. In: H.E. Winn and B.L. Olla (editors). Behavior of Marine Animals. Vol. 3. Cetaceans. Plenum Press; New York, New York.

Thompson, D. R., and K. C. Hamer. 2000. Stress in seabirds: causes, consequences and diagnostic value. Journal of Aquatic Ecosystem Stress and Recovery 7:19.

Thompson, P.O. and W.A. Friedl. 1982. A long term study of low frequency sounds from several species of whales off Oahu, Hawai'i. Cetology 45: 1-19.

Thompson, P.O., L.T. Findley, and O. Vidal. 1992. 20-Hz pulses and other vocalizations of fin whales, *Balaenoptera physalus*, in the Gulf of California, Mexico. Journal of the Acoustical Society of America 92: 3051-3057.

Thomson, C.A. and J.R. Geraci. 1986. Cortisol, aldosterone, and leucocytes in the stress response of bottlenose dolphins, Tursiops truncatus. Canadian Journal of Fisheries and Aquatic Sciences 43(5): 1010-1016.

Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. Reports of the International Whaling Commission Special Issue No. 1:98-106.

Todd S., P. Stevick, J. Lien, F. Marques, D. Ketten. 1996. Behavioral effects of exposure to underwater explosions in humpback whales *Megaptera novaeangliae*. Canadian Journal of Zoology 74: 1661-1672.

Tomich, P.Q. 1986. Mammals in Hawai'i. A synopsis and notational bibliography. Second edition. Bishop Museum Press; Honolulu, Hawai'i.

Tomilin, A. G. 1957. Cetacea. In: Heptner, V. G. (ed.). Mammals of the USSR and adjacent countries. Vol. 9. Israel Program for Scientific Translations, Jerusalem, 1967.

Tønnessen, J.N. and O. Johnsen 1982. The history of modern whaling. University of California Press; Berkeley, California.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica (N.Y.) 19:1-50.

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 behavior of nesting osprey. The Journal of Applied Ecology 35:9.

Turl, C.W. 1980. Literature review on: I. Underwater noise from offshore oil operations and II. Underwater hearing and sound productions of marine mammals. Naval Ocean Systems Center Report, San Diego, California.

Tyack P. and H. Whitehead. 1983. Male competition in large groups of wintering humpback whales. Behavior 83: 132-154.

Tyack, P. 1981. Interactions between singing Hawai'ian humpback whales and conspecifics nearby. Behavioral Ecology and Sociobiology 8: 105-116.

Tyack, P.L. 2000. Functional aspects of cetacean communication. Pages 270-307. In: J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead (eds.) Cetacean societies: field studies of dolphins and whales. The University of Chicago Press; Chicago, Illinois.

Tyack, P.L. and C.W. Clark. 1997. Long range acoustic propagation of whale vocalizations. In: Taborsky M, Taborsky B (eds) Advances in Ethology, 32. pp 28. Contributions to the XXV International Ethological Conference, Vienna.

U.S. Department of Commerce. 1983. Draft management plan and environmental impact statement for the proposed Hawai'i Humpback Whale National Marine Sanctuary. NOAA, Office of Ocean and Coastal Resource management, Sanctuary Programs Division, and Hawai'i Department of Planning and Economic Development, Washington, D.C.

U.S. Department of the Navy [Navy]. 1999a. Biological Assessment for the Employment of the Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 1999b. Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Technical Report 1: Low Frequency Sound Scientific Research Program Technical Report (Responses of four species of whales to sounds of SURTASS LFA sonar transmissions). U.S. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2001a. Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2001b. Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Technical Report 2: Acoustic Modeling Results. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2006a. Biological Assessment for the Employment of the Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2006b. Operation of the Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) sonar onboard the R/V *Cory Chouest* and USNS impeccable (T-AGOS 23) under the National Marine Fisheries Service Letters of Authorization of 12 August 2005. Annual Report Number 4. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy Pacific Fleet. 2007d. Final comprehensive report for the operation of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar onboard the *R/V Cory Chouest* and USNS IMPECCABLE (T-AGOS 23) under the National Marine Fisheries Service Regulations 50 CFR 216 Subpart Q. U.S. Navy, Chief of Naval Operations, Washington, D.C.

U.S. Department of the Navy. 2005. Operation of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar onboard the R/V *Cory Chouest* and USNS impeccable (T-AGOS 23) under the National Marine Fisheries Service Letters of Authorization of 13 August 2004. Annual Report No. 3. Unpublished report prepared by the Department of the Navy, Chief of Navy Operations for the National Marine Fisheries Service, Office of Protected Resources. Silver Spring, Maryland.

U.S. Department of the Navy. 2005. Operation of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar onboard the R/V Cory Chouest and USNS Impeccable (T-AGOS 23) under the National Marine Fisheries Service Letters of Authorization of 13 August 2004. Annual Report No. 3. Unpublished report prepared by the U.S. Department of the Navy, Chief of Navy Operations for the National Marine Fisheries Service, Office of Protected Resources. Silver Spring, Maryland.

U.S. Environmental Protection Agency [EPA]. 1998. Guidelines for ecological risk assessment. Federal Register 63(93); 26846-26924.

van Rij, N.G. 2007. Implicit and explicit capture of attention: what it takes to be noticed. A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Arts in Psychology. University of Canterbury; Canterbury, United Kingdom

Vladimirov, V.L. 2007. Scientific report for "Dalniy Vostok" and "Slava" for the 1969 season. Page 19. In: Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. NOAA Technical Memorandum NMFS-AFSC-175. Edited by Y.V. Ivashchenko, P.J. Clapham and R.L. Brownell Jr. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center; Seattle, Washington.

von Ziegesar, O. 1984. A survey of the humpback whales in southeastern Prince William Sound, Alaska: 1980, 1981, and 1983. Report to the Sate of Alaska, Alaska Council on Science and Technology.

Wada, S. 1980. Japanese whaling and whale sighting in the North Pacific 1978 season. Reports of the International Whaling Commission 30:415-424.

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.

Waite, J.M. and R. C. Hobbs. 1999. Small cetacean aerial survey of Prince William Sound and the western Gulf of Alaska in 1998 and preliminary abundance harbor porpoise estimates for the southeast Alaska and the Gulf of Alaska stocks. Annual Report 1998, noaa National Marine Fisheries Service; Silver Spring, Maryland.

Walker, R.J., E.O. Keith, A.E. Yankovsky and D.K. Odell. 2005. Environmental correlates of cetacean mass stranding sites in Florida. Marine Mammal Science 21(2): 9.

Walsh, M. T., R. Y. Ewing, D. K. Odell, and G. D. Bossart. 2001. Mass strandings of cetaceans. Pages 83 - 96 in L. Dierauf, and F. M. D. Gulland, editors. Marine mammal medicine. CRC Press, Boca Raton, Florida.

Watkins W.A., W.E. Schevill. 1972. Sound source location by arrival-times on a non-rigid three-dimensional hydrophone array. Deep-Sea Research 19: 691-706.

Watkins, W. A. 1977. Acoustic behavior of sperm whales. Oceanus. 2:50-58.

Watkins, W. A., K. E. Moore, D. Wartzok, and J. H. Johnson. 1981. Radio tracking of finback (Balaenoptera physalus) and humpback (*Megaptera novaeangliae*) whales in Prince William Sound, Alaska. Deep-Sea Research 28A(6): 577-588.

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(6): 1901-1912.

Watkins, W.A. 1980. Acoustics and the behavior of sperm whales. Pages 283-290. In: R.G. Busnel and J.F. Fish (editors). Animal Sonar Systems. Plenum Press; New York, New York.

Watkins, W.A. 1981. Activities and underwater sounds of fin whales. Scientific Reports of the International Whaling Commission 33: 83-117.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Marine Mammal Science 2(4): 251-262.

Watkins, W.A. and W.E. Schevill. 1975. Sperm whales (*Physter catodon*) react to pingers. Deep-Sea Research 22: 123-129.

Watkins, W.A. and W.E. Schevill. 1977. Spatial distribution of *Physeter catodon* (sperm whales) underwater. Deep-Sea Research 24:693-699.

Watkins, W.A. and Wartzok, D. 1985. Sensory biophysics of marine mammals. Marine Mammal Science 1(3): 219-260.

Watkins, W.A., K.E. Moore, and P. Tyack. 1985. Codas shared by Caribbean sperm whales. In: Abstracts of the Sixth Biennial Conference on the Biology of Marine Mammals, November 1985; Vancouver, British Columbia.

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., M.A. Daher and J.E. George. 2001. Numbers of calling whales in the North Pacific. WHOI-2001-16. Woods Hole Oceanographic Institution; Woods Hole, Massachusetts.

Watkins, W.A., M.A. Daher, J.E. George and S. Haga. 2000. Distribution of calling blue, fin, and humpback whales in the North Pacific. WHOI-2001-12. Woods Hole Oceanographic Institution; Woods Hole, Massachusetts.

Watkins, W.A., M.A. Daher, J.F. George and D. Rodriguez. 2004. Twelve years of tracking 52-Hz whale calls from a unique source in the North Pacific. Deep-Sea Research, Part I 51:1889-1901.

Watkins, W.A., M.A. Dahr, K.M. Fristrup and T.J. Howald 1993. Sperm whales tagged with transponders and tracked underwater by sonar. Marine Mammal Science 9(1):55-67.

Watkins, W.A., P.L. 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(6): 1901-1912.

Weilgart, L. and H. Whitehead. 1993. Coda communication by sperm whales (*Physeter macrocephalus*) off the Galapagos Islands. Canadian Journal of Zoology 71(4): 744-752.

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.

Weilgart, L.S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. Canadian Journal of Zoology 85:1091-1116.

Weilgart, L.S. and H. Whitehead. 1988. Distinctive vocalizations from mature male sperm whales (*Physeter macrocephalus*). Canadian Journal of Zoology 66:1931-1937.

Weinrich, M.T., H. Rosenbaum, C. Scott Baker, A.L. Blackmer and H. Whitehead. 2006. The Influence of maternal lineages on social affiliations among humpback whales (*Megaptera novaeangliae*) on their feeding grounds in the southern Gulf of Maine. Journal of Heredity 97(3): 226-234.

Weinrich, M.T., R.H. Lambertsen, C.R. Belt, M.R. Schilling, H.J. Iken and S.E. Syrjala. 1992. Behavioral reactions of humpback whales *Megaptera novaeangliae* to biopsy procedures. Fisheries Bulletin 90(3): 588-598.

Weinrich, M.T., R.H. Lambertsen, C.S. Baker, M.R. Schilling and C.R. Belt. 1991. Behavioral responses of humpback whales (*Megaptera novaeangliae*) in the southern Gulf of Maine to biopsy sampling. Reports of the International Whaling Commission (Special Issue 13): 91-97.

Weller, D.W., A.J. Schiro, V.G. Cockcroft and W. Ding. 1996. First account of a humpback whale (*Megaptera novaeangliae*) in Texas waters, with a re-evaluation of historical records from the Gulf of Mexico. Marine Mammal Science 12(1): 5.

Wells, J.V. and M.E. Richmond. 1995. Populations, metapopulations, and species populations: what are they and who should care? Wildlife Society Bulletin 23(3): 458-462.

Wentsel, R. S. 1994. Risk assessment and environmental policy. Environmental Toxicology and Chemistry 13:1381.

Wetherall, J.A. 1983. Assessment of the stock of green turtles at East Island, French Frigate Shoals. Southwest Fisheries Center, Honolulu Laboratory, National Marine Fisheries Service, NOAA Administrative Report H-83-8.

Whitehead, H. 1982. Population of humpback whales in the northwest Atlantic. Reports of the International Whaling Commission 32: 345-353.

Whitehead, H. 1987. Updated status of the humpback whale, *Megaptera novaeangliae*, in Canada. Canadian Field-Naturalist 101(2): 284-294.

Whitehead, H. 1993. The behavior of mature male sperm whales on the Galapagos Islands breeding grounds. Canadian Journal of Zoology 71(4): 689-699.

Whitehead, H. 1996. Babysitting, dive synchrony, and indications of alloparental care in sperm whales. Behavioral Ecology and Sociobiology 38: 237-244.

Whitehead, H. 1996. Variation in the feeding success of sperm whales: temporal scale, spatial scale, and relationship to migrations. The Journal of Animal Ecology 65(4): 429-438.

Whitehead, H. 1999. Variation in the visually observable behavior of groups of Galapagos sperm whales. Marine Mammal Science 15(4): 17.

Whitehead, H. 2002. Sperm whale (*Physeter macrocephalus*). Pages 1165 - 1172 in W. F. Perrin, B. Wursig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, Inc., San Diego, California.

Whitehead, H. 2003, Sperm whales. Chicago, Illinois, University of Chicago Press.

Whitehead, H. and C. Glass. 1985. Orcas (killer whales) attack humpback whales. Journal of Mammalogy 66(1): 183-185.

Whitehead, H. and F. Nicklin. 1995. Sperm Whales. National geographic 188(5): 18.

Whitehead, H. and L. Rendell. 2004. Movements, habitat use and feeding success of cultural clans of South Pacific sperm whales. Journal of Animal Ecology 73(1): 190-196.

Whitehead, H. and L. Weilgart. 1991. Patterns of visually observable behavior and vocalizations in groups of female sperm whales. Behavior 118(Parts 3-4): 275-296.

Whitehead, H. and L. Weilgart. 2000. The sperm whale: social females and roving males. Pages: 154-172. In: Cetacean societies. Field studies of dolphins and whales. Edited by J. Mann, R.C. Connor, P.L. Tyack and H. Whitehead. University of Chicago Press; Chicago, Illinois.

Whitehead, H. and P.L. Hope. 1991. Sperm whalers off the Galapagos Islands and in the western North Pacific, 1830-1850: Ideal free whalers? Ethology and sociobiology 12(2): 147-162.

Whitehead, H. and T. Arnbom. 1987. Social organization of sperm whales off the Galapagos Islands, February-April 1985. Canadian Journal of Zoology 65(4): 913-919.

Whitehead, H., J. Christal and S. Dufault. 1997. Past and distant whaling and the rapid decline of sperm whales off the Galápagos Islands. Conservation Biology 11(6): 1387-1396.

Whitehead, H., J. Gordon, E. A. Mathews and K. R. Richard. 1990. Obtaining skin samples from living sperm whales. Marine Mammal Science 6(4):316-326.

Whitehead, H., L. Rendell and M. Marcoux. 2006. Coda vocalizations recorded in breeding areas are almost entirely produced by mature female sperm whales (*Physeter macrocephalus*). Canadian Journal of Zoology 84: 5.

Whitehead, H., M. Dillon, S. Dufault, L. Weilgart and J. Wright. 1998. Non-geographically based population structure of South Pacific sperm whales: dialects, fluke-markings and genetics. Journal of Animal Ecology 67(2): 253-262.

Whitehead, H., S. Waters and T. Lyrholm. 1992. Population structure of female and immature sperm whales (*Physeter macrocephalus*) off the Galapagos Islands. Canadian Journal of Fisheries and Aquatic Science 49(1): 78-84.

Wiley, D.N., R.A. Asmutis, T.D. Pitchford and D.P. Gannon. 1995. Stranding and mortality of humpback whales, *Megaptera novaeangliae*, in the mid-Atlantic and southeast United States, 1985-1992. Fisheries Bulletin 93: 196-205.

Wilkinson, D. M. 1991. Program review of the Marine Mammal Stranding Network. Report prepared for the Assistant Administrator for Fisheries. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland.

Williams, R.M., A.W. Trites and D.E. Bain. 2002. Behavioral responses of killer whales (*Orcinus orca*) to whale-watching boats: Opportunistic observations and experimental approaches. Journal of Zoology 256(2): 255-270.

Wingfield, J. C., K. M. O'Reilly, and L. B. Astheimer. 1995. Modulation of the adrenocortical responses to acute stress in Arctic birds: A possible ecological basis. American Zoologist 35:10.

Winn H.E., J.D. Goodyear, R.D. Kenney, R.O. Petricig. 1994. Dive patterns of tagged right whales in the Great South Channel. Continental Shelf Research 15: 593-611.

Winn, H.E, P.J. Perkins, L. Winn. 1970. Sounds and behavior of the northern bottlenosed whale. Pages 53-59. In: Proceedings of the 7th Annual Conference on the Biology, Sonar and Diving of Mammals. Stanford Research Institute; Menlo Park, California.

Winn, H.E. and N.E. Reichley. 1985. Humpback whale *Megaptera novaeangliae* (Borowski, 1781). Pages: 241-273. In: *Handbook of marine mammals. Volume 3. The sirenians and baleen whales*. Edited by S.H. Ridgeway and R.J. Harrison. Academic Press, Inc.; London, United Kingdom.

Winn, H.E., C.A. Price, and P.W. Sorensen. 1986. The distributional biology of the right whale (*Eubalaena glacialis*) in the western North Atlantic. Reports of the International Whaling Commission Special Issue No. 10:129- 138.

Winn, H.E., P.J. Perkins and L. Winn. 1970. Sounds and behavior of the northern bottlenosed whale. Pages: 53-59. In: Proceedings of the 7th Annual Conference on the Biology, Sonar and Diving of Mammals. Edited Menlo Park, California. Stanford Research Institute.

Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. Fishery Bulletin 97:200-211.

Wolman, A.A. and C.M. Jurasz. 1977. Humpback whales in Hawai'i: Vessel census, 1976. Marine Fisheries Review 39(7):1-5.

Wood, W.E. and S.M. Yezerinac. 2006. Song sparrow (*Melospiza melodus*) song varies with urban noise. The Auk 123:650-659.

Wu, C. and J. Schaum. 2000. Exposure assessment of trichloroethylene. Environmental Health Perspectives. Supplements 108: 359-364.

Würsig, B. 2001. Human activities and natural events: impacts on Gulf of Mexico marine mammals. Part 1, Pages 80-84 in M. McKay, J. Nides, W. Lang, and D. Vigil, eds., Gulf of Mexico marine protected species workshop - June 1999. New Orleans, Louisiana, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region.

Würsig, B., S. K. Lynn, T. A. Jefferson, and K. D. Mullin. 1998. Behavior of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. Aquatic Mammals 24:41-50.

Yeung, C. 1999. Estimates of marine mammal and marine turtle bycatch by the U.S. Atlantic pelagic longline fleet in 1998. NOAA Technical Memorandum NMFS-SEFSC-430. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center; Miami, Florida.

Yochem, P. K. and S. Leatherwood. 1985. Blue whale *Balaenoptera musculus* (Linnaeus, 1758). In: S.H Ridgway and R. Harrison (editors) Handbook of marine mammals. Volume 3. The sirenians and baleen whales. Academic Press, Inc.; London, United Kingdom.

Young, G.A. 1973. Guide-lines for evaluating the environmental effects of underwater explosion tests. U.S. Department of the Navy, Naval Ordnance Laboratory; Silver Spring, Maryland.

Young, G.A. 1991. Concise methods for predicting the effects of underwater explosions on marine life. NAVSWC No. 91-220. U.S. Navy, Naval Surface Warfare Center; Silver Spring, Maryland.

Appendix A: Logistic Regression Analyses

As discussed in the *Incidental Take Statement* sections of this Opinion, the information available left us with two options for estimating the number of marine mammals that might be "taken" as result of their exposure to active sonar associated with the proposed training exercises: (1) estimate the number of animals that might be "taken" by first estimating the probability of particular responses given exposure to active sonar, without explicitly incorporating the influence of the received level on those probabilities, then estimate the number "taken" by classifying particular responses as "take"; or (2) estimate the number of animals that might be "taken" by estimating the probability of responses that would generally represent "behavioral disturbance," without identifiying the particular responses, then treat all "behavioral disturbance" as "harassment" for the purposes of the incidental take statement. A better alternative would have combined both approaches and estimated the probability of particular responses given the received level, but the sample sizes were too small to pursue that approach.

As discussed in the *Incidental Take Statement* sections of this Opinion, we used the first of the two approaches discussed in the preceding paragraph to estimate the number of marine mammals that might be "taken" in the form of "harassment" as a result of their exposure to active sonar. However, to consider the potential effects of received level on these "take" estimates, we compared the estimates produced by the two approaches. In this instance, the estimates produced by the two approaches differed by about 1 percent (resulting in the same estimated number of "take" or differences ranging from a low of 1 animal to a high of 33 "take" occurrences).

This appendix describes the data and logistic regression analyses we conducted to estimate the number of animals that might be "taken," in the form of harassment, as a result of their exposure to active sonar. Regression analyses are one of the most basic statistical methods for establishing associations, correlations, or other relationships between explanatory or independent variables (in this case, received levels of sound) and response or dependent variables (in this case, "significantly-altered" behavior). When the response variable is discrete — that is, when the data for response variables consists of of "0s" and "1s" — logistic regression and probit regression are standard methods for examining relationships between explanatory variables and discrete response variables (Hosmer and Lemeshow 2000, Menard 2002).

In general, logistic and probit models produce similar results (multiplying a probit estimate by 1.6 produces a results that approximates the value of a logit estimate, Amemiya 1981); in some cases, however, the two models produce substantially different results. For example, when there are a large number of observations in the tails of distributions, logit models are more appropriate than probit models. In addition, we recognize that response variables we use in the future may not be dichotomous (for example, we may want to use an ordinal scale that represents the severity of different behavioral responses); logit models have been extended to handle polytomous response

variables while extending probit models to handle such variables is considered impractical (Aldrich and Nelson 1984). As a result, we chose to analyze the data available using logistic models rather than probit models primarily to allow consistency with any similar analyses conduct in the future in case those future analyses need to use datasets that are concentrated in the tails of the distribution and want to analyze polytomous response variables.

Anyone interested in detailed and technical treatments of generalized linear models and logistic regression models should refer to texts such as Dobson (2002), Hoffman (2004), Hosmer and Lemeshow (2000), McCullagh and Nedler (1989), McCulloch and Searle (2001), and Nedler and Wedderburn (1972).

Outputs of the Logistic Regression Analyses

The data we used for our analyses represented observations of the behavioral responses of baleen whales exposed to low-frequency active sonar associated with the SURTASS LFA sonar system (Biassoni *et al*. 2000, Croll *et al*. 2001), baleen whales exposed to seismic surveys and airgun arrays (Ljungblad *et al*. 1988, Richardson *et al*. 1986), and baleen whales exposed to alert stimuli (Nowacek *et al*. 2004).

We collected the data in a single worksheet in Microsoft Excel in which records were entered as rows. Each record consisted of columns whose cells contained the following information (1) the marine mammal species identified in a report or observation; (2) a frequency or frequency range for the acoustic source; (3) a measured or estimated received level in sound pressure level (re: 1 μPa^2); (4) the behavioral response or responses of the individual marine mammal that had been exposed; (5) the circumstances of the exposure to distinguish between controlled experiments on captive animals, experiments of animals in the wild, and different study designs; (6) the reference that was the source of the data in a record; and (7) additional notes that capture information that would help interpret the results of the analyses.

All logistic regression analyses reported in this memorandum were conducted using XLStat™ software (version 2007.7 from Addinsoft Software 2007). Maximum likelihoods were estimated using 100 iterations while implementing Firth's penalized likelihood function (maximized using the Newton-Raphson algorithm) to avoid the probability of separation that is common with sample sizes as small as those of the seven datasets we analyzed (Heinze and Schemper 2002). Like SPSS, XLStat estimates the probability of the dependent variable equals 1 [that is, Prob(y = 1)]. With the seven models presented in this memorandum, Prob(y = 1) means the probability of a significantly altered behavioral response given an exposure at a particular received level.

Assessing the Fit of the Logistic Regression Equations

It is common practice to assess the performance of logistic models by considering a model's calibration (the degree to which a model fits the data used to generate the model) and the model's discrimination (the degree to which a model distinguishes between 0s and 1s). Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model in question.

Most measures of the goodness-of-fit of logistic models are designed to help users decide which of a suite of explanatory variables produce the most calibrated model. In this instance, the primary dataset (the observations from the Navy's SPAWAR experiments) consisted of only one response variable (whether or not an animal's behavior was

"significantly altered") and one explanatory variable (the received level in decibels 1μPa rms). Because we did not have the option of adding additional explanatory variables to improve the fit of the logistic regression models we developed for the mysticete dataset, we could not develop alternative models that might fit the data better. Because there are no alternative models, we do not report goodness-of-fit statistics for the models we report in this memorandum.

One consequence of using only one explanatory variable is that the logistic regression models may be misspecified as a result. Model specification is based on two characteristics of models: the first is that the functional form of a model should be correct and the second is that a model should include all relevant explanatory variables and no irrelevant explanatory variables. If the logistic model is misspecified, it might produce logistic regression coefficients that are systematically overestimated or underestimated. Received levels of a sound source are almost certainly relevant when we try to explain the behavioral response of marine mammals given an exposure, but received levels are not the only relevant explanatory variable. Other variables (covariates) that are probably relevant to the behavioral responses of marine mammals to sound exposures include whether the animal perceives itself to near or far from the sound source; whether the animal perceives the sound source to represent a potential threat given the circumstances of an exposure; the age, health, and reproductive condition of the animal, and the effect of the exposure on the animal's ability to process information from its auditory scene, among numerous other potential explanatory variables. Because each of the seven models were produced using only one explanatory variable, the different models might not include all of the relevant explanatory variables and the models may be misspecified.

Classification Tables

Classification tables provide information about the predictive accuracy of logistic model by summarizing the frequency with which the model would correctly and incorrectly classify observations as "events" or "nonevents" (in this case, "events" are significantly altered behavioral responses). Although classification tables are not suitable for assessing how well a model fits the data, they provide the information necessary to assess the reliability of logistic regression models as predictive tools. Specifically, with any model we might want to use in an assessment we would want to estimate the number of true positive, true negative, false positive, and false negative results that might be associated with a logistic regression model.

Classification tables are produced by cross-classifying the outcome variable, y, with a dichotomous variable whose values are derived from probabilities estimated from a logistic model. To produce classification tables, logistic regression software requires users to define a cut-point, *c*, and compare each estimated probability to *c*. If the estimated probability exceeds *c* the derived variable is equal to 1; otherwise it is equal to 0. we used the most commonly used value for cut-points: 0.5.

Using the different classification tables produced by the logistic regression equations, we calculated and report five additional diagnostics that measure the models' ability to classify observations:

a. *Number of true positive results*: the number of the observations contained in the data that a logistic model would correctly classify as "significantly altered behavior" assuming a particular cut-off (all of the results reported in this technical memorandum are for a cut-off of 0.50).

b. *Number of true negative results*: the number of the observations contained in the data that a logistic model would correctly classify as "not significantly altered behavior" assuming a particular cut-off (all of the results reported in this technical memorandum are for a cut-off of 0.50).

c. *Percent correct*: the percent of the observations contained in the data that a logistic model would correctly classify as "significantly altered behavior" or "not significantly altered behavior."

d. *Diagnostic sensitivity*: the proportion of observations of "significantly altered behavior" contained in the data that a logistic model would correctly classify as "significantly altered behavior." If a model is not sensitive, it will fail to detect an outcome when the outcome is present. In this case, the model would fail to detect "significantly altered" behavioral responses when such responses are present (this is the percent false-negative outcomes reported in Table A.1)

e. *Diagnostic specificity*: the proportion of observations of "not significantly altered behavior" contained in the data that a logistic model would correctly classify as "not significantly altered behavior." If a model is not specific, it will incorrectly indicate the presence of an outcome when an outcome is not present. In this case, the model would indicate that "significantly altered" behavioral responses have occurred when, in fact, such responses are absent (this is the percent false-positive outcomes reported in Table A.1).

Receiver Operating Characteristic Curves

Receiver operating characteristic (ROC) curves graphically depict the predictive accuracy of logistic regression equations by plotting a model's sensitivity (*sensitivity* is the proportion of true positive results produced by a model) against 1 – the model's specificity (s*pecificity* is the proportion of true negative results produced by a model; 1 – specificity is a model's rate of producing false positive results). The area under a ROC curve, which ranges from zero to one, provides a measure of a model's ability to discriminate between those subjects (in this case, marine mammals) who experience the outcome of interest (in this case, altered behavior) compared with those subjects who do not experience the outcome of interest.

The area under the ROC curve, which ranges from zero to one, estimates a model's ability to discriminate between those subjects who experience the outcome of interest and those who do not. Hosmer and Lemeshow (2000) suggest that if the area under the ROC curve is between 0.8 and 0.9, the model has excellent discrimination; if the area under the curve is between 0.7 and 0.8, the model has acceptable discrimination; and if the area under the curve is 0.5, the model has no discrimination and is no better than tossing a fair coin.

Results

Logistic regression analyses of the relationship between the behavioral responses of baleen whales exposed to different received levels (in sound pressure level measured as dB_{rms} re: 1 μPa sec) of several low frequency sound sources were conducted on a sample size of 48 observations compiled from published reports of the behavioral responses of baleen whales exposed to low-frequency sound sources in the wild. Of these, 22 observations (45.83% of the total) resulted from experiments conducted with bowhead whales (*Balaena mysticetus*) in the Beaufort Sea, 11 observations (22.92% of the total) resulted from experiments conducted with humpback whales (*Megaptera novaeangliae*), and the remaining observations were from experiments conducted with right whales (*Eubalaena*

glacialis) in the western north Atlantic Ocean, and blue or fin whales (*Balaenoptera musculus* and *B. physalus*, respectively.

The minimum exposure (received level in dB) in this dataset was 107 dB, the maximum exposure was 178 dB. The lowest exposure that produced an "altered behavioral response" (the lowest observed adverse effect level or LOAEL) for this frequency range was 133 dB; the highest exposure that produced an "altered behavioral response" for this frequency was 178 dB (Figure A.1). The logistic regression equation or model for the probability of altered behavior in baleen whales given exposure to low-frequency sound sources given a received level (in dB) is:

Probability of Altered Behavior = 1 / (1 + exp(-(-15.1005885208061+0.0976849488833056*Exposure)))

Discrimination and Classification Using This Model. The area under the ROC curve for the Mysticete model produced using low-frequency data for baleen whales is 0.8316, which suggests that this logistic regression equation acceptably discriminates between the proportion of an exposed population that might experience significantly altered behavior from the proportion that would not experience altered behavior (Figure A.2).

Figure A.1. Plot of the logistic regression model produced using data on the response of baleen whales to low frequency sound sources. The x-axis represents the explanatory variable which is exposure as received level in decibels (sound pressure level). The y-axis represents the response variable or the proportion of a population of marine mammals that would be expected to exhibit significantly altered behavioral responses given an exposure to a low-frequency sound source. The red-line represents the exposure-response relationship. The blue diamonds represent the distribution of 0s (along the x-axis) and 1s (along the upper axis) in the data.

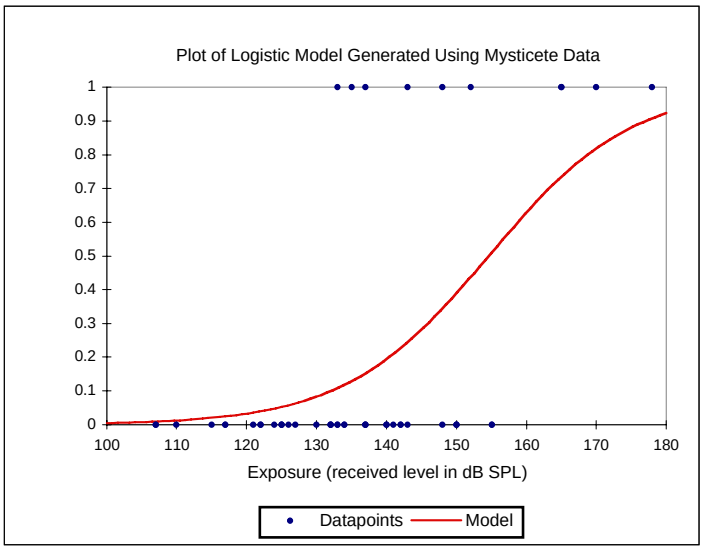
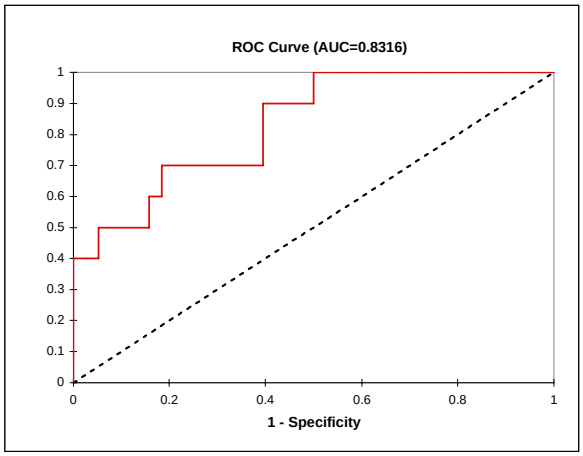


Figure A.2. Receiver operating characteristic curve for the logistic regression model developed using data on the behavioral responses of baleen whales low frequency sound sources. "Sensitivity" represents the percentage of significantly altered behavioral responses that the model would correctly classify as "significantly altered behavior." "1-Specificity" is the percentage of "significantly altered" behavioral responses that the model would incorrectly classify as "not significantly altered behavior." The dashed line represents correct classifications that would occur as a result of chance.



The Mysticete model would be expected to classify 83.33% of the responses correctly, which is also the highest value of any of the models reported here. The specificity of this model is substantially higher than its sensitivity (0.9474 and 0.4000, respectively). That is, the model would correctly classify "not significantly altered behavior" with substantially greater reliably than it would classify "significantly altered behavior." Because of this bias toward specificity, the model would produce a much lower percentage (5.26%) of false negative classifications (behaviors that are "not significantly altered" that the model would correctly classify as "not significantly altered behavior") and a higher percentage of false positive classifications (60.00%).

Table 1. Classification table for the logistic regression equation discussed in this appendix. The data are based on classification tables generated from logistic regression analyses. The column labeled "sensitivity" refers to the proportion of behavioral responses in the data that a logistic regression equation would correctly classify as "altered behavior." The column labeled "specificity" estimates the proportion of behavioral responses in the data that a logistic regression equation would correctly classify as "not altered behavior." The column labeled "false positive rate" estimates the proportion of behavioral responses that a logistic regression equation would incorrectly classify as "altered behavior." The column labeled "false negative rate" estimates the proportion of behavioral responses that a logistic regression equation would incorrectly classify as "not altered behavior." The column labeled "AUC" represents the area under a Receiver Operating Characteristic (ROC) curve

Model for Source Frequency	Number Correct		Number incorrect		Percent Correct	Sensitivity	Specificity	Percent False Positive	Percent False Negative	AUC
	True Positive	True Negative	False Positive	False Negative						
Mysticete data	4	36	6	2	83.33	0.4000	0.9474	0.6000	0.0526	0.8316

Interpretation and Application of the Model

The exposure – response model for mysticetes made it possible to estimate the probability of marine mammals exhibiting significantly-altered behavioral responses given exposure to different received levels of active acoustic sources. The model only considers the probable effects of exposure to active sonar and ignores other covariates that are relevant to these relationships (for example, the distance between animals and a sound source, other acoustic and visual cues that co-occur with the sonar, the behavioral activities the animals were engaged in when exposed to active sonar, the animals' physiological state and health condition at the time of an exposure event, the context of the

exposure, and the animals' age, among other variables). These variables remain important when interpreting the results of this model.

For example, a marine mammal exposed to mid-frequency active sonar at a received level of 160 dB would be several kilometers from the source of the sonar and in a setting where the sonar's ping would have to compete for the animal's attentional resources with other stimuli in the animal's acoustic field (studies in perceptual psychology suggest that stimuli compete for attentional resources within sensory modalities, not between sensory modalities, so animals have a finite ability to process a suite of sounds). We do not know if a sonar ping would be salient to animals several kilometers from its source, if animals would dedicate attentional resources to the ping, if they would respond behaviorally to the ping, and if such responses would be "significant" for an animal. Therefore, the results of this model needs to be interpreted after considering the circumstances of exposures as they are likely to occur *in situ*.

Similarly, the model estimates the probability of significant changes in behavior, but does not identify the kinds of behavioral response those changes connote. These changed behaviors include vocal adjustments, avoidance responses (primarily horizontal movement away from a sound source), evasive responses (which include the dive reflex, sudden changes in swim speed, linearity, and directness), and changes from one behavioral state to another (for example, from resting or milling to traveling) among other behavioral responses that have been reported.

Literature Cited

Amemiya, T. 1981. Qualitative response models: a survey. Journal of Economic Literature 19:1483 - 1536.

B. Richardson, W.J., C.R. Greene Jr., W.R. Koski, C.I. Malme, G.W. Miller, M.A. Smultea, and B. Würsig. 1990b. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska ─ 1989 phase. Report prepared by LGL Environmental Research Associates Ltd. for the U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska. NTIS Pb91-105486.

Baker, C. S., L.M. Herman, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Report prepared by the Kewalo Basin Marine Mammal Laboratory for U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington.

Biassoni, N., P.J. Miller, and P.L. Tyack. 2000. Preliminary results of the effects of SURTASS-LFA sonar on singing humpback whales. Woods Hole Oceanographic Institute, Technical Report # 2000-06. Woods Hole, Massachusetts.

Borrooah, V. K. 2002. Logit and probit. Ordered and multinomial models. SAGE Publications, Inc., Newbury Park, California.

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

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 USS SHOUP (DDG 86) in the Haro Strait on or about 5 May 2003. U.S. Department of the Navy, Washington, D.C.

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

Eliason, S. R. 1993. Maximum likelihood estimation. Logic and practice. SAGE Publications, Inc., Newbury Park, California.

Frankel, A. S. and C.W. Clark. 1998. Results of low-frequency playback of M-sequence noise to humpback whales, *Megaptera novaeangliae*, in Hawai'i. Canadian Journal of Zoology, 76: 521-535.

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.

Heinze, G, and M. Schemper. 2002. A solution to the problem of separation in logistic regression. Statistics in Medicine 21: 2409 – 2419.

Hoffman, J. P. 2004. Generalized linear models. An applied approach. Pearson Education, Inc., Boston, Massachusetts.

Hosmer, D. W., and S. Lemeshow. 2000. Applied logistic regression. Second Edition. John Wiley and Sons, Inc., New York, New York.

Liao, T. F. 1994. Interpreting probability models. Logit, probit, and other generalized linear models. SAGE Publications, Inc., Newbury Park, California.

Ljungblad, D. K., Würsig, B., Swartz, S. L., & Keene, J. M. 1988. Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic, 41: 183-194.

Malme, C. I., P.R. Miles, C.W. Clark, P.L. Tyack, and J. E. Bird. 1983. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Report No. 5366. prepared by Bolt Beranek and Newman Inc. for U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska. NTIS PB86-174174.

Malme, C.I., B. Würsig, J.E. Bird, and P.L. Tyack. 1986. Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling. National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Final Report of the Principal Investigators, Anchorage, Alaska: BBN Report No. 6265. OCS Study MMS 88-0048; NTIS PB88-249008.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. 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. Report No. 5586 prepared by Bolt Beranek and Newman, Inc. for U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J. E. Bird. 1985. Investigations of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. Report No. 5851

prepared by Bolt Beranek & Newman, Inc. for the U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska.

McCauley, R. D., D.H. Cato, and A.F. Jeffery. 1996. A study of the impacts of vessel noise on humpback whales in Hervey Bay, Australia: Report prepared by the Department of Marine Biology of the James Cook University for the Queensland Department of Environment and Heritage, Maryborough Office; Maryborough, Queensland, Australia.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdock, and K. McCabe. 2000a. Marine seismic survyes: 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.

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. 2000b. Marine seismic surveys-a study of environmental implications. Australian Petroleum Production and Exploration Association Journal 2000: 692-708.

McCauley, R.D., M.N. Jenner, C. Jenner, K. McCabe, and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: Preliminary results of observations about a working seismic vessel and experimental exposures. Australian Petroleum Production and Exploration Association Journal 1998: 692-707.

McCullagh, P. and J.A. Nedler. 1989. Generalized linear models. Second Edition. Chapman and Hall; London, United Kingdom.

McCulloch, C.E. and S.R. Searle. 2001. Generalized, linear, and mixed models. John Wiley and Sons, Inc.; New York, New York.

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.

Miller, G.W., J.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillvray, and D. Hannay. 2005. Monitoring seismic effects on marine mammals – southeastern Beaufort Sea, 2001-2002. Pages 511 – 542. *In:* S. L. Armsworthy, P. J. Cranford and K. Lee (eds.) Offshore oil and gas environmental effects monitoring: approaches and technologies. Battelle Press; Columbus, Ohio.

Nedler, J.A. and T.W.M. Wedderburn. 1972. Generalized linear models. Journal of the Royal Statistical Society, Series A, 135: 370 – 384.

Nowacek, D., 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. Series B. Biological Sciences 271: 227-231.

Pampel, F. C. 2000. Logistic regression. A primer. SAGE Publications, Inc., Newbury Park, California.

Richardson, W. J., C.R. Greene Jr., W.R. Koski, M.A. Smultea, G. Cameron, C. Holdsworth, G. Miller, T. Woodley, and B. Würsig. 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 LGL Environmental Research Associates Ltd. for the U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska. NTIS PB92-170430.

Richardson, W.J., B. Würsig, and C.R. Greene, Jr. 1990a. Reactions of bowhead whales, *Balaena mysticetes*, to drilling and dredging noise in the Canadian Beaufort Sea. Marine Environmental Research 29: 135-160.

Richardson, W.J., B. Würsig, and C.R. Greene, Jr.. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. Journal of the Acoustical Society of America 79: 1117-1128.