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

Agencies: United States Navy

National Marine Fisheries Service

Activities Considered: The U.S. Navy conduct of training exercises in the Hawai'i Range Complex from January 2012 to January 2014

Letter of Authorization to the U.S. Navy to "take" marine mammals incidental to the conduct of training exercises in the Hawai'i Range Complex January 2012 to January 2014

Consultation Conducted by: Endangered Species Act Interagency Cooperation Division of the Office of Protected Resources, National Marine Fisheries Service

Approved by: ______________ **Date:** JAN 10 2012

Section 7(a)(2) of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1536(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 (NMFS) 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 (U.S. Navy), which proposes to undertake the training activities described in this Opinion, and NMFS' Office of Protected Resources – Permits and Conservation 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 Act Interagency Cooperation Division. This document represents NMFS biological opinion on the U.S. Navy's proposal to conduct training activities in the Hawai'i Range Complex over a twenty-four month period beginning January 15, 2012, and the Permits Division's 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.

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1 INTRODUCTION

Section 7(a)(2) of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1536(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 (NMFS) 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 concurs with that conclusion (50 CFR §402.14(b)).

For the actions described in this document, the action agencies are the United States Navy (U.S. Navy), which proposes to undertake military readiness activities in the Hawai'i Range Complex, and NMFS Office of Protected Resources – Permits and Conservation Division (Permits Division), which proposes to issue a Letter of Authorization (LOA) pursuant to the Marine Mammal Protection Act (MMPA) that would authorize the U.S. Navy to "take" marine mammals incidental to those military readiness activities. The consulting agency for these proposals is NMFS Office of Protected Resources - Endangered Species Act Interagency Cooperation (ESA IC) Division.

The biological opinion and Incidental Take Statement (ITS) portions of this consultation were prepared by NMFS ESA IC Division in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531, et seq.), and implementing regulations at 50 CFR §402. This document represents NMFS final biological opinion (Opinion) on the effects of these actions on endangered and threatened species and critical habitat that has been designated for those.

1.1 Background

This Opinion is related to NMFS' final programmatic biological opinion issued in December 2008, which assessed the effects of the U.S. Navy's conduct of training exercises (military readiness activities) in the Hawai'i Range Complex from December 2008 to January 2014 and the Permits Division's proposal to finalize regulations to authorize the U.S. Navy to "take" marine mammals incidental to the conduct of training exercises in the Hawai'i Range Complex over that five-year period (50 CFR §216.170; 74 FR 1456). That programmatic biological opinion considered the effects of the activities that would occur over the entire five-year period of the proposed regulations, while this Opinion considers the effects of the activities pursuant to a proposed LOA to be issued for the period from January 15, 2012 to January 5, 2014. This Opinion has been prepared in accordance with section 7 of the ESA and is based on: information provided in the application for the LOA and associated draft LOA; the U. S. Navy's final Environmental Impact Statement for the Hawai'i Range Complex; the 2009, 2010, and 2011 HRC and SOCAL Annual Monitoring and Exercise Reports provided under previous LOAs valid from 2009-2011; the NMFS Final Rule, other military readiness activities; published and unpublished scientific information on the biology and ecology of threatened and endangered whales, monk seals, and sea turtles in the action area; and, other sources of information.

There have been a number of consultations conducted and biological opinions issued for U.S. Navy activities in the Hawai'i Range Complex.

On June 27, 2006, NMFS issued a biological opinion on the U.S. Navy’s proposal to conduct Rim of the Pacific 2006 exercises.

On June 21, 2008, NMFS issued a biological opinion on the U.S. Navy’s proposal to conduct Rim of the Pacific Exercises in the Hawai'i Range Complex in July 2008 and other training activities in the Hawai'i Range Complex from July 2008 through the third week of January 2009.

On December 18, 2008, NMFS issued its programmatic biological opinion on the U.S. Navy’s proposal to conduct training exercises and other activities in the Hawai'i Range Complex from December 2008 to December 2013 and the Permits Division’s promulgation of regulations that would allow the Permits Division to authorize the “take” of marine mammals incidental to those training exercises and other activities in the Hawai’i Range Complex.

On January 8, 2009, NMFS issued its biological opinion on the U.S. Navy’s proposal to conduct training exercises and other activities in the Hawai'i Range Complex from January 2009 to January 2010, and the Permits Division’s issuance of a Letter of Authorization that would authorize the U.S. Navy to “take” marine mammals incidental to those training exercises and other activities in the Hawai’i Range Complex.

In December 2009, NMFS determined that the activities the U.S. Navy proposed to conduct during training exercises and other activities in the Hawai'i Range Complex from January 15, 2010 to January 14, 2011, and the Permits Division’s issuance of a Letter of Authorization, were within the scope of activities analyzed in the December 18, 2008, programmatic biological opinion and issued an Incidental Take Statement for those activities.

On August 30, 2010, the U.S. Navy sent a letter to the NMFS Endangered Species Division requesting reinitiation of consultation on the U.S. Navy’s intention to request a Letter of Authorization that would authorize the U.S. Navy to “take” marine mammals incidental to those training exercises and other activities in the Hawai'i Range Complex from January 2011 to January 2012. Attached to that request was the application for renewal of the Letter of Authorization submitted to the Permits Division.

On December 2, 2010, The Permits Division sent a memorandum to the NMFS Endangered Species Division requesting consultation for the proposed issuance of a Letter of Authorization to the U.S. Navy to authorize the “take” of marine mammals incidental to the training exercises and other activities in the Hawai'i Range Complex. Attached to that request was a draft Letter of Authorization for the period January 15, 2011 to January 14, 2012.

On December 17, 2010 and December 20, 2010, NMFS Endangered Species Division notified the U.S. Navy and the Permits Division, respectively of the proposed endangered listing status of North Pacific loggerhead sea turtles and Hawai'i insular false killer whales which occur within the Hawai'i Range Complex and the requirements under section 7(a)(4) of the ESA. Both the U.S. Navy and the Permits Division have decided that they will determine whether their activities are likely to jeopardize the continued existence of these two proposed species and confer with NMFS ESA IC Division if warranted. Since that time, the North Pacific loggerhead sea turtles were listed as endangered under the ESA and are included in this consultation. The Hawai'i insular false killer whales remain as a species proposed for listing under the ESA. Consultation would be required if Hawai'i insular false killer whales are formally listed under the ESA.

On January 13, 2011, NMFS issued its biological opinion on the U.S. Navy's proposal to conduct training exercises and other activities in the Hawai'i Range Complex from January 2011 to January 2012, and the Permits Division's issuance of a Letter of Authorization that would authorize the U.S. Navy to "take" marine mammals incidental to those training exercises and other activities in the Hawai'i Range Complex.

1.2 Consultation History

On August 15, 2011, the U.S. Navy sent a letter to the NMFS Endangered Species Act Interagency Cooperation Division requesting initiation of formal consultation on the U.S. Navy change in proposed action for the Navy training in the Hawai'i Range Complex and for renewal of the MMPA LOA. The training exercises and other activities in the Hawai'i Range Complex would occur from January 2012 to January 2014.

On November 14, 2011, the Permits Division sent a memorandum to the ESA IC Division requesting consultation for the proposed issuance of a LOA to the U.S. Navy to authorize the "take" of marine mammals incidental to the proposed training exercises and other activities in the Hawai'i Range Complex. Attached to that request was a draft LOA for the period January 15, 2012 to January 14, 2014. The Hawai'i insular false killer whales remain as a species proposed for listing under the ESA. Consultation would be required if Hawai'i insular false killer whales are formally listed under the ESA.

On December 29, 2011, the ESA IC Division provided the Permits Division and the U.S. Navy with an electronic copy of its draft biological opinion. The Permits Division and the U.S. Navy each provided comments on the draft Opinion on January 5, 2012. The ESA IC Division has reviewed all comments submitted and revised the Opinion as warranted.

2 DESCRIPTION OF THE PROPOSED ACTION

The proposed action consists of two separate but related activities: (1) the U.S. Navy's proposal to conduct a suite of training activities in the Hawai'i Range Complex from January 15, 2012 to January 5, 2014 [1]; and (2) the NMFS Permits Division proposal to issue a LOA that would allow the U.S. Navy to take marine mammals incidental to those training activities.

From January 2012 to January 2014, the U.S. Navy proposes to conduct a suite of activities annually in the Hawai'i Range Complex. Each year these activities include:

1. Six major exercises each year;
2. Other training exercises that would primarily represent intermediate- and unit-level training;
3. Research, Development, Test, and Evaluation (RDT&E) activities, which may be conducted by the U.S. Navy, U.S. Department of Defense's Missile Defense Agency, U.S. Army and U.S.

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[1] *The MMPA regulations at 50 CFR §216.171 define the effective date as ending on January 5, 2014.*

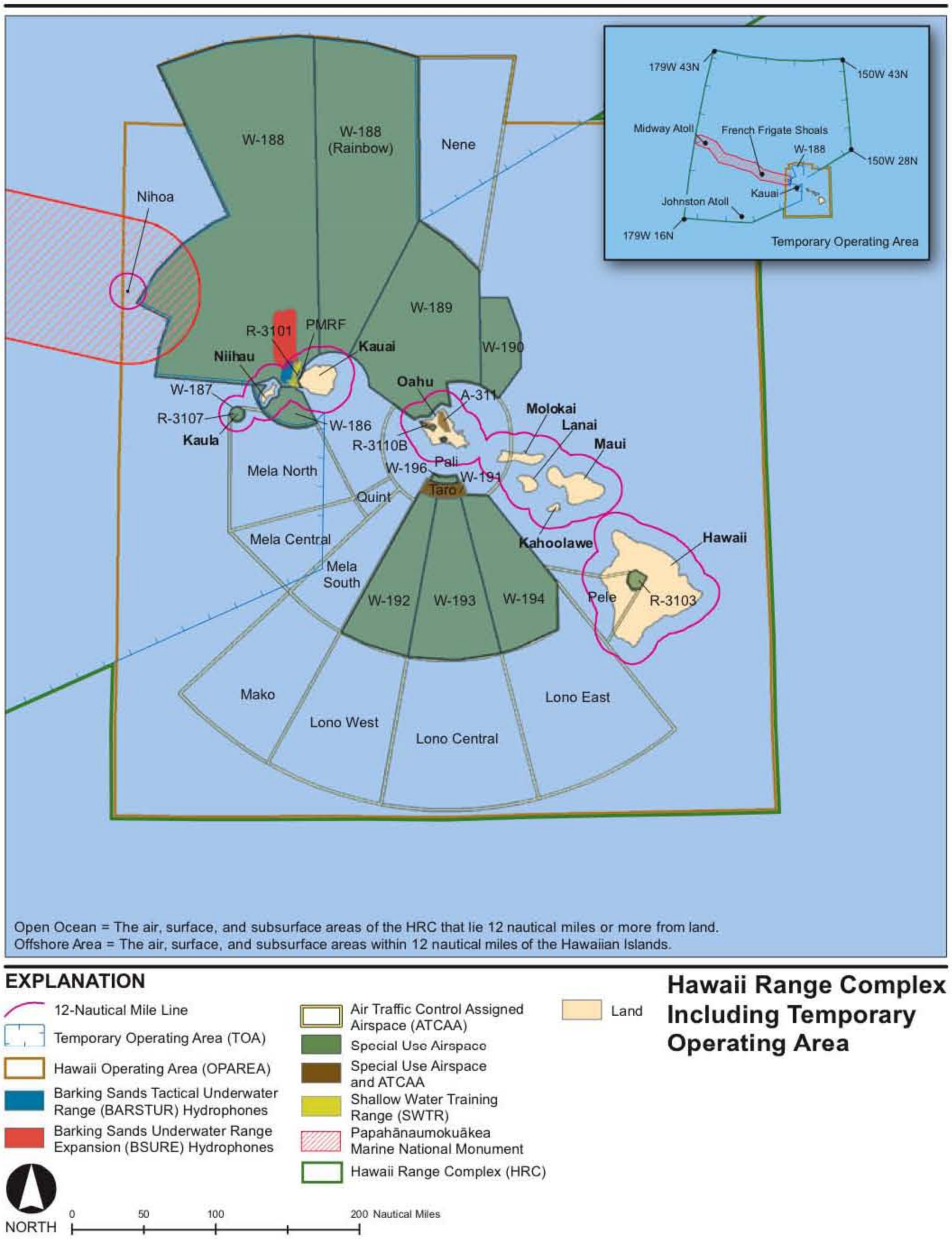
Army's Space and Missile Command, U.S. Air Force, U.S. Coast Guard, and National Oceanic and Atmospheric Administration (NOAA).

The major training exercises would consist of Undersea Warfare Exercises (USWEX). Every other year (even-numbered years, so in 2012), the Navy would engage in one Rim of the Pacific exercise. The LOA that NMFS Permits Division proposes to issue addresses the "take" of marine mammals associated with the annual operation of:

- 1,284 hours of AN/SQS-53
- 383 hours of AN/SQS-56
- 1010 dips of helicopter dipping sonar (AN/AQS-22 or AN/AQS-13)
- 2,423 sonobuoys
- 313 torpedoes (MK-48, MK-46 or MK-54)
- 200 hours of submarine mounted sonar (AN/BQQ-10 or AN/BQQ-5)
- up to four events (960 buoys: AN/SSQ-110A (IEER)/SSQ-125 (AEER)) per year combined of either AEER or EER/IEER.

The LOA would require the Navy to adjust the spatial location or the timing of training exercises in years when a Rim of the Pacific exercise would occur such that the total number of humpback whales exposed to sonar sound sources each year does not exceed the number authorized.

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 Hawai'i Range Complex (U.S. Navy 2008) (Figure 1).



Open Ocean = The air, surface, and subsurface areas of the HRC that lie 12 nautical miles or more from land.
Offshore Area = The air, surface, and subsurface areas within 12 nautical miles of the Hawaiian Islands.

Hawaii Range Complex Including Temporary Operating Area

Figure 1. The Hawai'i Range Complex.

2.1 Major Training Exercises

The U.S. Navy conducts three categories of major training exercises in the Hawai'i Range Complex: Rim of the Pacific exercises, which occur on alternate, even-numbered years, Undersea Warfare Exercises, and Multi-Strike Group Exercises. The U.S. Navy plans to conduct Undersea Warfare and Multi-Strike Group Exercises annually and one Rim of the Pacific Exercise during the period the LOA would be valid. These exercises are described in more detail below.

2.1.1 Rim of the Pacific Exercises

Since 1968, the U.S. Navy has conducted biennial, sea control and power projection fleet exercises in the Hawai'i Islands Operating Area called Rim of the Pacific (RIMPAC) exercises. These exercises, which historically have lasted for about a month, have involved forces from various nations on the Pacific Rim including Australia, Canada, Chile, Japan, and the Republic of Korea. These exercises have historically included a series of anti-submarine warfare training events that employ mid-frequency sonar.

Rim of the Pacific exercises encompass in-port operations, command and control, aircraft operations, ship maneuvers, amphibious landings, troop movements, gunfire and missile exercises, submarine and antisubmarine exercises, mining and demolition activities, hulk sinking exercise, salvage, special warfare, and humanitarian operations. The following narratives discuss only those aspects of future RIMPAC exercises that are necessary to understand the potential effects of those exercises on threatened and endangered species under the jurisdiction of NMFS and critical habitat that has been designated for them. For a complete description of all aspects of the proposed exercises, readers should refer to the U.S. Navy's 2002 Rim of the Pacific (RIMPAC) Programmatic Environmental Assessment, the 2006 Supplement to that environmental assessment, and the U.S. Navy's Final Environmental Impact Statement on the Hawai'i Range Complex (Navy 2002; Navy 2006a; Navy 2006c).

Rim of the Pacific exercises consist of scenarios in which one "country" (designated "Green") is attacked by another "country" (designated "Orange"). The scenarios assume that "Green" has requested and received support from allied countries among the Pacific Rim nations. The allies then use military force to eliminate military hostilities and restore peace to the region. The military activities that occur during RIMPAC exercises vary from year-to-year and are based on the participants' training needs and desires and may be based in part on anticipated operations that may be required under real world conditions. Allied forces opposing Orange are usually split into multinational and bilateral forces, depending on which Pacific Rim allies participate. Multinational Forces typically consist of units from various RIMPAC nations. In the past, these nations have included Australia, Canada, Chile, the Republic of Korea, and the United States. Bilateral Forces typically consist of units from Japan and the United States.

The Multinational Force typically has up to nine days of briefings and preparations in Pearl Harbor. They then move to various onshore, nearshore, and open-ocean areas for up to 21 days of work-up training exercises including amphibious insertions, and covert reconnaissance, which typically includes up to 6 days of advanced weapon firings at the Pacific Missile Range Facility (PMRF) and the PMRF Warning Areas and underwater ranges (see Table 1, previous page).

The Bilateral Force typically engages in up to 5 days of briefings at Pearl Harbor, Hawaii (see Table 1). Up to 11 days of work-up exercises are typically conducted by the Bilateral Force at onshore, nearshore, and open-ocean areas. The Bilateral Force then returns to Pearl Harbor for an additional 6 days of briefings followed by up to 15 days of work-up exercises. The work-up exercises typically include up to 6 days of advanced weapon firings at

Pacific Missile Range Facility and the PMRF Warning Areas and underwater ranges for an average total of 14 days, or a maximum of 26 days.

The next phase of RIMPAC exercises typically consists of up to 14 days of complex scenario-driven tactical exercises intended to represent real-life conflict situations. An amphibious landing assault of PMRF by allied forces ends the scripted phase of exercises. The timing, phases, and scope of the different exercises are modified or rearranged depending on the final objectives of the overall exercise.

In 2010, fourteen nations and more than 20,000 military personnel, including a U.S. fleet of 25 Navy ships and submarines and a Coast Guard cutter, participated in the biennial RIMPAC training off Hawaii that military officials have billed as the world's largest maritime exercise. Three other nations have sent teams of observers for the exercises, which also includes. The exercise also included ground and combat support forces and nearly 180 jets, helicopters, patrol craft and transport and refueling aircraft.

Anti-Submarine Warfare Training Operations during RIMPAC

Anti-submarine exercises have typically occurred on 21 days during this overall schedule of Rim of the Pacific exercises. As a combined force, submarines, surface ships and aircraft typically conduct anti-submarine warfare against opposition submarine targets. Submarine targets typically include real submarines, target drones that simulate the operations of an actual submarine, and a virtual surface action group — typically consisting of between one and five surface ships equipped with sonar — with one or more helicopters, and P-3 aircraft searching for submarines.

Active Acoustic Devices

Tactical military sonars are designed to search for, detect, localize, classify, and track submarines. The Navy plans to employ two types of sonars with future RIMPAC exercises, 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.

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 RIMPAC exercises include:

Sonar Systems Associated with Surface Ships

A variety of surface ships participate in Rim of the Pacific 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 analysis, all surface ship sonars were modeled as equivalent to AN/SQS-53C having a nominal source level of 235 decibels (dB_{rms}) re 1 µPa-s at 1 m.

Sonar Systems Associated with Submarines

Submarines are equipped with a variety of active and passive sonar systems 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 would operate during Rim of the Pacific exercises include sonobuoys and dipping sonar. Aircraft (P-3) 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. Most sonobuoys are passive, but some can generate active acoustic signals, as well as listen passively. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets. During Rim of the Pacific exercises, these systems active modes are only used briefly for localization of contacts and are not used in primary search capacity.

Torpedoes

Torpedoes 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. All torpedoes used for anti-submarine warfare during Rim of the Pacific exercises would be located in the range area managed by PMRF and would be non-explosive and recovered after use.

Acoustic Device Countermeasures

These countermeasures 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. Based on the operational characteristics (source output level and/or frequency) of these acoustic sources, they are not likely to affect threatened or endangered marine mammals and have not been modeled for the Navy’s assessments.

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).

Other Training Exercises

In addition to the anti-submarine warfare exercises, future Rim of the Pacific exercises would include the following:

Surface-To-Air Missile Exercise

Surface-to-air missile exercise (SAMEX) which is designed to provide realistic training and evaluation of surface ships and their crews in defending against enemy aircraft and missiles. For this exercise, target drones representing enemy aircraft or missiles are flown or towed into the vicinity of the surface ship. The crew must identify the incoming object and respond with surface-to-air missiles as appropriate. Two types of missiles are typically used with this exercise. One missile is equipped with an instrumentation package, while the other type is equipped with a warhead. Recoverable target drones are refurbished and reused.

The exercise consists of one or more surface ships and/or submarines; one or more (20 to 50) target drones; and a helicopter and weapons recovery boat for target recovery. The surface-to-air missiles are launched from ships and/or submarines located within PMRF Warning Area. Targets are launched from an existing ground-based target launch site at PMRF Launch Complex and/or Kauai Test Facility, PMRF; from a Mobile Aerial Target Support System located in the open ocean within the PMRF Warning Areas; or released from an aircraft. The exercise requires approximately 2 to 5 hours, but could range from 8 to 60 hours.

Air-To-Air Missile Exercise

Air-to-air missile exercise (which the Navy abbreviated as AAMEX in documents supporting the 2006 RIMPAC exercise and now abbreviates as A-A MISSILEX), which is designed to provide aircrews with experience in using aircraft missile firing systems, and to develop new firing tactics. For this exercise jet target drones are launched from PMRF Launch Complex, Kauai Test Facility, or an aircraft controlled by PMRF. The targets are engaged by aircraft equipped with air-to-air missiles. The 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 exercise includes 1 to 6 jet target drones, 2 to 20 aircraft, 2 to 20 missiles and a weapons recovery boat for target recovery. The exercise is conducted within PMRF Warning Area. Targets are launched from an existing ground-based target launch site at PMRF Launch Complex and/or Kauai Test Facility, PMRF; from a Mobile Aerial Target Support System located in the open ocean within the PMRF Warning Areas; or released from an aircraft. Each exercise typically lasts 2 to 6 hours, but could range from 2 to 30 hours.

Air-To-Surface Missile Exercise

Air-to-surface missile exercise (ASMEX), which is designed to provide a basic training situation for U.S. Air Force, U.S. Navy, U.S. Marine and multinational air groups in air-to-surface missile firing; conventional ordnance delivery including bombing (MK-80 series bombs, live and inert), gunnery, and rocket and precision guided munitions firing; and close air support techniques. The exercise consists of 1 to 16 aircraft, carrying missiles and/or bombs (live and inert), rockets, precision guided munitions, or flying without ordnance (dry runs) are used during the exercise. At sea, Seaborne Powered Targets (occasionally a live bomb target), Improved Surface Towed Targets, excess ship hulks (live bombs), and a computer-generated island that is located within the Barking Sands Underwater Range Expansion are used as targets for inert bomb drops. The Naval Gunfire Scoring System gathers data for scoring of surface ships and aircraft conducting gunnery and bombardment exercises within the Barking Sands Tactical Underwater Range. On land, terrain features, constructed props, and/or tank hulks are used as targets. During recent Rim of the Pacific exercises, the Navy used three to four environmentally-cleaned ex-USS ships as sinkable targets. When an exercise is scripted to use a combination of missiles to sink a target, the Navy calls the exercise a SINKEX.

The exercise involves helicopters and/or 1 to 16 fixed wing aircraft with air-to-surface missiles, anti-radiation missiles (electromagnetic radiation source seeking missiles), high-speed radiation missiles (electromagnetic radiation producing missiles that simulate radar and radio transmitters), and/or bombs (live and inert), rockets, or precision-guided munitions. The exercise is typically conducted within PMRF Warning Area and last about 4 hours. However, a SINKEX typically lasts 10 to 12 hours per target, but may include a separate day per hulk (4 to 6) extending the duration out as far as 40 to 72 hours.

Surface-To-Surface Missile Exercise

Surface-to-surface missile exercise (SSMEX), which is designed to provide basic training for fleet units in firing surface-to-surface missiles. The exercise involves one or more surface ships, submarines, and Seaborne Powered Target (SEPTARs). The surface ships and/or submarines can operate as a single unit or as multiple fire units against the SEPTARs.

These exercises include 4 to 20 surface-to-surface missiles, a weapons recovery boat, and a helicopter for environmental and photo evaluation. When a Harpoon anti-ship missile is used, the exercise is called a HARPOONEX. At sea, SEPTARs, ISTTs, excess ship hulks, and a computer-generated island that is located within the BSURE are used as targets for aircraft bomb drops. The Naval Gunfire Scoring System gathers data for scoring of surface ships and aircraft conducting gunnery and bombardment exercises within Barking Sands Tactical Underwater Range. On land, terrain features, constructed props, and/or tank hulks are used as targets. During recent Rim of the Pacific exercises there have been three to four environmentally cleaned ex-USS ships utilized as sinkable targets. When an exercise is scripted to utilize a combination of missiles to sink a target, the exercise is called a SINKEX. All missiles are equipped with instrumentation packages or a warhead. Surface-to-air missiles can also be used in a surface-to-surface mode. These exercises are conducted within PMRF Warning Area. Each exercise typically lasts 2 hours, but could range from 4 to 35 hours.

Anti-Submarine Warfare Exercise

Anti-submarine warfare exercise (ASWEX) which is designed to provide crews of anti-submarine ships, aircraft (including airships), submarines, and helicopters experience in locating and pursuing underwater targets and dropping inert torpedo weapons. The exercise involves locating and pursuing underwater targets and dropping inert torpedoes and inert air-dropped mines from anti-submarine aircraft and helicopters. Weapon recovery boats and helicopters are used to locate and recover the targets, torpedoes, and mines.

The exercise includes ships, fixed wing aircraft, helicopters, torpedo targets, 1 to 10 submarines, and weapons recovery boats and/or helicopters. Weapons used encompass inert air-dropped mines, lightweight and heavyweight wire-guided inert long-range torpedoes launched from helicopters, aircraft, surface ships, and submarines. Sensors include sonars, non-acoustic sensors (sonobuoys), and airborne early warning radars. These exercises are conducted within PMRF Warning Area, the Oahu Warning Areas or the open ocean. Each ASWEX typically runs for 7 days but could range from 1 to 50 days.

The use of sonobuoys is generally limited to areas greater than 183 meters (100 fathoms, or 600 feet) in depth. Before dropping sonobuoys, the crew visually determines that the area is clear. Although the altitude varies at which buoys are dropped, the potential for drift during descent generally favors release at lower altitudes, where visual searches for marine mammals or sea turtles are more effective. When the sonobuoy is released, a small parachute (about 4 feet in diameter) retards its entry into the ocean. For operational reasons, the sonobuoy is designed to float on the surface and, after a controlled period of time (no longer than 8 hours), the complete package (with the parachute) will sink to the bottom.

Aerial and Submarine Mining Exercise

Aerial and submarine mining exercise (MINEX) which is designed to provide practice with techniques for submarine-launched mobile mines and to provide a basis for crew qualification in aerial mining. The exercise involves one or more aircraft and both computer-simulated and inert exercise mines. Mine warfare exercises are limited to either the simulated laying of aircraft-deployed mines, where no actual mine ordnance is dropped, or the use of inert exercise mines or inert exercise submarine-deployed mines.

Aerial mining requires one or more aircraft. Submarine mining involves one or more submarines, divers, and a weapons recovery boat to recover the mines, and one or more helicopters. Aerial mining lines are generally developed off the southwest coast of Kauai and the southeast coast of Niihau, within PMRF Warning Areas W-186 and W-188. Submarine mining exercises are conducted within PMRF Warning Area W-188 and aircraft operations are conducted within R3101. These exercises last about 1 to 3 hours. Submarine MINEX may last from 1 to 4 days.

Ship Mine Warfare Exercise

Ship mine warfare exercise (SMWEX) which is designed to allow surface ship sonar operators to train in shallow-water environments. Mine detection helicopter sonar operators can also train in this area. Two types of exercises are included. The first type is a structured exercise where PMRF tracking systems would monitor passing ships. Tracking data combined with shipboard or helicopter acquired data would provide the basis for analysis of the exercise. In the second type of exercise, a ship would traverse seaward of the buoy field and attempt to detect the buoys without monitoring. This type of exercise would occur when ships enter or depart PMRF instrumented areas for other exercises.

The mine warfare training area is approximately 1.6 kilometer (1 mile) off shore and consists of 10 buoys in 2 columns oriented north-south. Each buoy is 94 centimeters (37 inches) in diameter and moored to the sea floor by a wire rope. The ocean depth varies between 45.7 and 107 meters (150 and 350 feet), and the buoys are at least 15 meters (50 feet) below the ocean surface. Various marine and aerial assets, capable of tracking underwater objects over a 2,590-square-kilometer (1,000-square-mile) area, would be used during the structured exercise. In the second type of exercise, only shipboard assets would be used. The mine warfare training area is located between 1.2 and 2 kilometers (0.75 and 1.25 miles) from shore and is adjacent to the PMRF Shallow Water Training Area. This exercise can take from 3 to 72 hours.

Strike Warfare Exercise

Strike warfare exercise (STWEX) and close air support exercise (CASEX) which is designed to provide a basic training situation for U.S. Air Force, U.S. Navy, U.S. Marine and multinational air groups in air-to-surface missile firing; conventional ordnance delivery including bombing (MK80 series bombs, live and inert), gunnery, and rocket and precision guided munitions firing; and close air support techniques.

The exercise can involve 1 to 16 aircraft, carrying missiles and/or bombs (live and inert), rockets, precision guided munitions, or flying without ordnance (dry runs) are used during the exercise. At sea, excess ship hulks and a computer-generated island that is located within the Barking Sands Underwater Range Expansion are used as targets for aircraft missile firing and bomb drops. The Naval Gunfire Scoring System gathers data for scoring of surface ships and aircraft conducting gunnery and bombardment exercises within the Barking Sands Tactical Underwater

Range. On land, terrain features, constructed props, and/or tank hulks are used as targets. Air crews conduct STWEX in conjunction with ground or airborne forward air controllers.

The STWEX assets include helicopters and/or 1 to 16 fixed wing aircraft with air-to-surface missiles, anti-radiation missiles (electromagnetic radiation source seeking missiles), high-speed radiation missiles (electromagnetic radiation producing missiles that simulate radar and radio transmitters), and/or bombs (live and inert), rockets, or precision-guided munitions. Targets include excess ship hulks, and simulated electronic targets at the Barking Sands Tactical Underwater Range and Barking Sands Underwater Range Expansion Ranges operated by PMRF. The Barking Sands Tactical Underwater Range and Barking Sands Underwater Range Expansion Ranges consist of passive bottom-mounted hydrophones, which receive signals from pingers mounted internally on the exercise rounds and submarines. The underwater tracking system detects the water impacts and directs the data to the Naval Gunfire Scoring System.

The STWEX, and CASEX exercises are conducted within Oahu Restricted Airspace R-3107 and Warning Area W-187 (at Kaula only inert missiles would be used) and PMRF Warning Area, and the Pohakuloa Training Area on Hawaii. The exercise would last about 4 hours; although strike warfare exercises could last from 4 to 35 hours.

Gunnery Exercise

Gunnery exercise (GUNNEX) which is designed to provide gunnery practice for surface vessel crews against both stationary and moving targets. Gunnery training operations involve the use of highly automated guns against surface (land, excess vessel hulks [see SINKEX], and simulators) or aerial targets. Crews respond to threats from air attack and surface-skimming missiles that require extremely fast reaction times and a heavy volume of fire. Ships fire inert exercise rounds, and aircraft fire inert exercise rounds and drop inert exercise bombs at stationary targets on Kaula and at the computer-generated island located within Barking Sands Underwater Range Expansion (PMRF Warning Area W-188).

The exercise involves 1 to 10 surface vessels, observation helicopters, SEPTARs, ISTTs, orange buoys, towed aerial targets, excess ship hulks, jet aerial targets, and the Barking Sands Underwater Range Expansion. Ship-deployed and air-deployed weapons systems are used, ranging from 20-millimeter to 5-inch caliber guns.

These exercises would be conducted within PMRF Warning Areas W-186 and W-188, Oahu Warning Areas W-187 (Kaula), W-194, and Restricted Airspace R-3107 (Kaula). The exercises could involve from 5 to 50 events taking from 1 to 100 hours.

Sinking Exercise

Sinking exercises (SINKEXs) are designed to train personnel and test weapons against a full-size ship. Each SINKEX uses an excess vessel hulk as a target that is eventually sunk during the course of the exercise. Any exercise that normally uses a surface target, such as an ASMEX, can be a part of the SINKEX. 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 approved 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 a P-3C 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. SINKEX vessels can number from one to six per Rim of the Pacific exercise.

These exercises are conducted at an approved site (minimum depth 1,800 meters [5,905 feet], at least 93-111 kilometers [50-60 nautical miles] northwest from shore) within a PMRF Warning Area. Future Rim of the Pacific exercises could involve from 1 to 6 SINKEX, each lasting from 3 to 8 hours.

Live Fire Exercise

Live fire exercises (LFXs) are designed to provide ground troops with live-fire training and combined arms live-fire exercises training, including aerial gunnery and artillery firing. This benefits ground personnel by receiving semi-realistic training. These exercises can include platoon troop movements through numerous target objectives with various weapons. Aerial gunnery exercises and artillery and mortar exercises are also conducted as part of combined and separate exercises. Live fire and blanks are used. Blanks are used outside of defined impact areas. Each exercise generally lasts 1 to 24 hours.

Humanitarian Assistance Operation/Non-Combatant Evacuation Operation

Humanitarian assistance operation/non-combatant evacuation operations *(*HAO/NEOs) are designed to provide training in implementing humanitarian assistance in an increasingly hostile setting, ultimately requiring evacuation of personnel and troops. These training exercises involve approximately 150 personnel and troops and specialists who initially provide assistance to civilians and then evacuate the civilians when necessary. This scenario could also be used to simulate a prisoner-of-war camp or place where people are interned. Direct action is also included in the exercise because it involves a similar number of troops. The direct action exercise is much quicker and involves about 50 personnel and 150 troops who gain access to an area by boat or helicopter, storm the location, recover the mission target, and return to their units.

Special Warfare Operations

Special warfare operations (SPECWAROPs) are designed to provide covert insertion and reconnaissance training for small Special Warfare units. These exercises are performed by the U.S. Navy and the U.S. Marines. Activities include special reconnaissance, Combat Search and Rescue, and Direct Action Tactical Recovery of Aircraft and Personnel. Special reconnaissance units consist of small special warfare unit and utilize helicopters, submarines, and CRRC to gain covert access to military assets, gather intelligence, stage raids, and return to their host units. Reconnaissance inserts and beach surveys are often conducted before large-scale amphibious landings and can involve several units gaining covert access using a boat.

Amphibious insertions would be conducted at PMRF, Niihau, and Kahuku Beach, Oahu and K-Pier, Hawaii. Insertions from helicopters would take place at Bradshaw Army Airfield, Makua Military Reservation, and Kahuku Military Training Area, Dillingham Military Reservation, and Wheeler Army Airfield. Port Allen, Kauai and Marine Corps Base Hawaii, Oahu are used to stage boat raids, and Makaha Ridge-PMRF, Niihau, Bradshaw Army Airfield and Dillingham Military Reservation would also be used for helicopter raids and downed pilot training. Similar activities are conducted at Pearl Harbor including Ford Island and various underwater ranges, Coast Guard Air

Station Barbers Point/Kalaeloa Airport, Oahu, Hickam Air Force Base, Marine Corps Training Area Bellows/Bellows Air Force Station, and Pohakuloa Training Area. Also activities occur within the Oahu and PMRF Warning Areas as well as in the open ocean. These exercises last from several hours to several days.

Underwater demolition exercises (DEMOs) are designed to provide training in identifying and destroying or neutralizing inert ground mines and floating/moored mines and possibly excess ship hulks. The DEMO exercises are mainly training in the detection and explosive attack of inert, underwater mines. Tactics against 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 typically detonated at the surface. In support of an amphibious assault, divers and U.S. Navy marine mammal assets deploy in very shallow water depths (3 to 12 meters [10 to 40 feet]) to locate mines and obstructions.

Divers are transported to the mines by boat or helicopter. Inert dummy mines can be used in the exercises. The total net explosive weight used against each mine ranges from less than 0.5 kilogram to 9 kilograms (less than 1 pound to 20 pounds). As part of Rim of the Pacific exercises, the U.S. Navy's Very Shallow Water Mine Countermeasures Detachment of Commander Mine Warfare Command will deploy trained Atlantic bottlenose dolphins (*Tursiops truncatus*) of their marine mammal mine-hunting systems in several missions. Each mission will include up to four motorized small craft, several crew members and a trained dolphin. Each trained animal is deployed under behavioral control.

These activities take place offshore in the Pu'uloa Underwater Range, Pearl Harbor; Iroquois Land/Underwater Range within Pearl Harbor; Barbers Point Underwater Range off-shore of Coast Guard Air Station Barbers Point/Kalaeloa Airport; and PMRF, Kauai (Majors Bay area); PMRF and Oahu Training Areas; and in open-ocean areas. Rim of the Pacific exercises may involve from 1 to 30 demo events, which each even lasting 1 to 4 hours.

Salvage operations, which are designed to provide a realistic training environment for fire at sea, de-beaching of ships, and harbor clearance operations training by U.S. Navy diving and salvage units. As part of these exercises, the U.S. Navy’s Mobile Diving and Salvage Unit One and divers from other countries would practice swift and mobile ship and barge salvage, towing, battle damage repair, deep ocean recovery, harbor clearance, removal of objects from navigable waters, and underwater ship repair capabilities.

Amphibious Exercise

Amphibious exercises (AMPHIBEXs) 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 operations and well decks for carrying landing craft and assault amphibian vehicles (AAVs). 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. Naval Surface Fire Support and CASEX are integrated into an amphibious assault. Typically, simulated gunnery is part of the PMRF AMPHIBEX, using small arms with blanks. 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 will normally be accomplished over a 2- to 3-day period.

The primary location for the amphibious landings is Majors Bay, PMRF, Kauai. Amphibious landings could also occur at the K-Pier boat ramp, Kawaihae, Hawaii, Marine Corps Base Hawaii (three beaches), Marine Corps Training Area Bellows portion of Bellows Air Force Station, Oahu, and at the K-Pier boat ramp, Kawaihae, Hawaii. These exercises typically occur over a 2- to 3-day period, with three separate exercises per Rim of the Pacific exercises, but could range from a 2 to 14 days, with one to four separate exercises.

Amphibious landings are restricted to specific areas of designated beaches. As described by the Navy, these exercises would be conducted in compliance with Executive Order 13089, Coral Reef Protection. Before each major amphibious landing exercise is conducted, a hydrographic survey is typically performed to map out the precise transit routes through sandy bottom areas. Within 1 hour of initiating landing activities, the landing routes and beach areas would be determined to be clear of marine mammals and sea turtles. If any are seen, the exercise would be delayed until the animals leave the area. During the landing the crews follow established procedures, such as having a designated lookout watching for other vessels, obstructions to navigation, marine mammals (whales or monk seals), or sea turtles. Other measures include publication of training overlays that identify the landing routes and any restricted areas. Sensitive cultural resource areas are identified and bounded by a keep-out buffer. Pre-exercise surveys for turtles are conducted in areas where turtles may be present so their feeding and nesting areas would be avoided. Vehicles are restricted to existing roads, trails, and other disturbed areas and would not traverse undisturbed, off-road areas where they might harm vegetation or stimulate erosion.

Submarine Operations

Submarine operations (SUBOPs) are designed to train Navy personnel in using active and passive sonar systems to find surface ships and submarines, responding to simulated attacks using evasive maneuvering and countermeasures in deep and shallow waters, and avoiding detection by submarine warfare weapon systems. Exercises include underway operations, Submarine Warfare Exercises (submarine versus submarine and submarine versus ship tracking), Range exercises (torpedo firing exercises), and a Torpedo Training and Certification program conducted at the PMRF ranges.

Submarine operations will occur throughout much of the Hawaii Operating Area. Weapon firing would mainly occur in the PMRF Shallow Water Training Range, Barking Sands Tactical Underwater Range and Barking Sands Underwater Range Expansion Ranges, and the training areas within the 100-fathom isobath contour between the islands of Maui, Lanai, and Molokai, including Penguin Bank. Submarine operations would occur continuously throughout Rim of the Pacific exercises although individual exercises typically last several hours to 7 days.

2.1.2 Undersea Warfare Exercises (USWEX)

The U.S. Navy plans to conduct up to ten USWEX Exercises in the Hawai'i Range Complex from January 2012 to January 2014. These exercises are advanced anti-submarine warfare exercises conducted by the U.S. Navy’s Carrier Strike Groups and Expeditionary Strike Groups while in transit from the west coast of the United States to the western Pacific Ocean.

As a combined force, submarines, surface ships, and aircraft will conduct anti-submarine warfare exercises against submarine targets representing an opposing force. Submarine targets would include real submarines, target drones that simulate the operations of an actual submarine, and virtual submarines interjected into the training events by exercise controllers. The primary event of each exercise involves one or more surface ships equipped with sonar, with one or more helicopters, and maritime patrol aircraft (P-3s, P-8s, or analogous aircraft) searching for one or more submarines.

Each of the training events is expected to last for about 72 to 96 hours. Over this time interval, expeditionary strike groups would engage in about 280 hours of active sonar training, while carrier strike groups would engage in about 444 hours of active sonar training over two years. All of the proposed Undersea Warfare Exercise activities would occur within the Hawaiʹi Range Complex which encompasses offshore, near shore, and onshore areas located on or around the major islands of the Hawaiian Island chain.

The following narratives discuss those aspects of the proposed USWEX that are necessary to understand their potential effects on threatened and endangered species under the jurisdiction of NMFS and critical habitat that has been designated for those species. For a complete description of all elements of the proposed exercises, readers should refer to the U.S. Navy’s Final EIS on the Hawaiʹi Range Complex.

Antisubmarine Warfare

The types of anti-submarine warfare training conducted during the proposed USWEX include the use of ships, submarines, aircraft, non-explosive exercise weapons, and other training related devices. Anti-submarine warfare events could occur throughout the Hawai'i Range Complex. Undersea Warfare Exercises typically employ tactical mid-frequency sonars that are designed to search for, detect, localize, classify, and track submarines. The types of active sound sources that might be used in Undersea Warfare Exercises include:

Sonar Systems Associated with Surface Ships. A variety of surface ships might participate in the proposed Undersea Warfare 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.

Sonar Systems Associated with Submarines. Submarines are equipped with a variety of active and passive sonar systems 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 a USWEX include sonobuoys and dipping sonar. Aircraft (P-3) 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.

Most sonobuoys are passive, but some can generate active acoustic signals, as well as listen passively. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets. During an Undersea Warfare Exercise, the active modes of these sonar systems are only used briefly to localize contacts and are not used in primary search capacity. Because active mode dipping sonar use is very brief (2-5 pulses of 3.5-700 msec), it is extremely unlikely its use would have any effect on marine mammals.

Torpedoes. Torpedoes 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. All torpedoes used for anti-submarine warfare during an Undersea Warfare Exercise are typically located in the range area managed by the Pacific Missile Range Facility and would be non-explosive and recovered after use.

Acoustic Device Countermeasures. These countermeasures act as decoys by making sounds that simulate submarines to prevent 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 (for example, 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).

2.1.3 Other Training Activities during Undersea Warfare Exercises

In addition to the anti-submarine warfare exercises, Undersea Warfare Exercises typically include the following activities:

Anti-submarine warfare exercises which are designed to provide crews of anti-submarine ships, aircraft (including airships), submarines, and helicopters experience in locating and pursuing underwater targets and dropping inert torpedo weapons. The exercise involves locating and pursuing underwater targets and dropping inert torpedoes and inert air-dropped mines from anti-submarine aircraft and helicopters. Weapon recovery boats and helicopters are used to locate and recover the targets, torpedoes, and mines.

Sonobuoys used during USWEX exercises are generally limited to areas greater than 183 meters (100 fathoms, or 600 feet) in depth. Before dropping sonobuoys, crews visually determine that an area is clear. Although the altitude varies at which buoys are dropped, the potential for drift during descent generally favors release at lower altitudes, where visual searches for marine mammals or sea turtles are more effective. When the sonobuoy is released, a small parachute (about 4 feet in diameter) retards its entry into the ocean. For operational reasons, the sonobuoy is designed to float on the surface and, after a controlled period of time (no longer than 8 hours), the complete package (with the parachute) will sink to the bottom.

Strike warfare exercises which are designed to train U.S. Air Force, U.S. Navy and U.S. Marine air groups in air-to-surface missile firing; conventional ordnance delivery including bombing (MK-80 series bombs, live and inert), gunnery, and rocket and precision guided munitions firing; and close air support techniques. An exercise typically involves a flight of two aircraft, but can involve up to 28 aircraft. At sea, excess ship hulks and a computer-generated island that is located within the Barking Sands Underwater Range Expansion are used as targets for aircraft missile firing and bomb drops. On land, terrain features, constructed props, or tank hulks are used as targets. The average range time for these exercises is 60 minutes.

Gunnery exercises which are designed to provide gunnery practice for surface vessel crews against both stationary and moving targets. Air-to-ground gunnery exercises typically involve about 400 rounds of 0.50-caliber or 7.62 mm ordnance and last for about 1 – 2 hours. Surface-to-surface gunnery exercises typically involve about 20 rounds of 5-inch or 76 mm ordnance and about 150 rounds of 0.5-caliber or 25 mm ordnance and last for 2 to 4 hours.

Amphibious exercise (AMPHIBEX), which are designed to provide a realistic environment for amphibious assault training, reconnaissance training, hydrographic surveying, surf condition observance, and communication. Amphibious forces could utilize the beaches at the Pacific Missile Range Facility or at Marine Corps Training Area Bellows to conduct amphibious landings. Embarked Marines would board landing craft and practice an amphibious landing. An AMPHIBEX involves the movement of Marine Corps combat and support forces from Navy ships at sea to an objective or an operations area ashore. AMPHIBEXs could involve an amphibious assault across a beach, or the insertion of Marines to an inland location called Ship-to-Objective Maneuver.

Amphibious landings are restricted to specific areas of designated beaches. As described by the Navy, these exercises would be conducted in compliance with Executive Order 13089, Coral Reef Protection. Before each major amphibious landing exercise is conducted, a hydrographic survey is typically performed to map out the precise transit routes through sandy bottom areas. Within 1 hour of initiating landing activities, the landing routes and beach areas would be determined to be clear of marine mammals and sea turtles. If any are seen, the exercise would be delayed until the animals leave the area. During the landing the crews follow established procedures, such as having a designated lookout watching for other vessels, obstructions to navigation, marine mammals (whales or monk seals), or sea turtles. Other measures include publication of training overlays that identify the landing routes and any restricted areas. Sensitive cultural resource areas are identified and bounded by a clearly-marked keep-out buffer. Pre-exercise surveys for turtles are conducted, where appropriate, so their feeding and nesting areas would be avoided. Vehicles are restricted to existing roads, trails, and other disturbed areas and would not traverse undisturbed, off-road areas where they might harm vegetation or stimulate erosion.

Air combat maneuvers include fighter maneuvers where aircraft engage in offensive and defensive maneuvering against each other. These maneuvers typically involve supersonic flight and expenditure of chaff and flares. No air-to-air ordnance is released during this exercise. Air combat maneuvers within the Hawai′i Range Complex are primarily conducted with W-189, W-190, W-192, W-193 and W-194 under Fleet Area Control and Surveillance Facility Pearl Harbor’s control. These operations typically involve from two to eight aircraft. Based on the training requirement, however, these exercises may involve over a dozen aircraft engaged in sorties that can last up to 2 hours.

Air to Surface Missile/Bomb Exercises that provide training for U.S. Navy and U.S. Marine Corps tactical aircrews in air-to surface missile firing include conventional ordnance delivery (such as bombing, gunnery and rocketry) and precision-guided munitions firing. Precision-guided munitions include optical, infrared seeking or laser-guided missiles fired at surface targets. These events take place at-sea against ships, boats, small craft, and other maritime targets. These exercises can last up to 2 hours.

2.1.4 Multiple Strike Group Exercise

Multiple Strike Group Exercises involve Navy assets engaging in a schedule of events battle scenario, with U.S. forces (blue forces) pitted against a notional opposition force (red force). Participants use and build upon training skill sets they have gained previously to maintain and improve the proficiency required of units that are ready for deployment. These exercises typically occur over 5- to 10-day periods at any time during the year.

These exercises are similar to Undersea Warfare Exercises in that they entail combined force, submarines, surface ships, and aircraft that conduct anti-submarine warfare maneuvers against opposition submarine targets. In addition to the use of hull-mounted sonar (AN/SQS-53 and AN/SQS -56), submarine sonar, helicopter dipping sonar, and sonobuoys, Multiple Strike Group Exercises include events that involve underwater detonations, including sinking exercises, air-to-surface missile exercises, mine neutralization exercises, and EER/IEER exercises. Exercises that entail underwater detonations do not overlap in space and time with sonar exercises. Mine neutralization training exercise would include the use of time-delay firing devices; the number of events (68 annually) would be the same as in previous years.

2.2 Unit- and Intermediate-Level Training Activities

From January 2012 to January 2014, the U.S. Navy plans to conduct the following unit-level or intermediate-level training events in the Hawai'i Range Complex annually.

2.2.1 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. No Air-to-Air ordnance is released during this exercise. Air Combat Maneuver operations within the range complex are primarily conducted within W-188, W-189, W-190, W-192, W-193, and W-194 under Fleet Area Control and Surveillance Facility Pearl Harbor’s control. 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.

The U.S. Navy plans to conduct about 814 of these maneuvers annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.2 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, 2 to 20 aircraft, 2 to 20 missiles, and a weapons recovery boat for target recovery, and are conducted within Pacific Missile Range Facility Warning Area W-188. Jet target drones are launched from an existing ground-based target launch site at Pacific Missile Range Facility Launch Complex, from a Mobile Aerial Target Support System located in the open ocean within the Pacific Missile Range Facility Warning Areas, or from an aircraft controlled by Pacific Missile Range Facility. The targets are engaged by aircraft equipped with air-to-air missiles. The 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 24 of these exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.3 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. The exercise involves 1 to 10 surface vessels, towed aerial targets, or jet aerial targets. Ship-deployed and air-deployed weapons systems are used, ranging from 20-mm to 5-inch caliber guns. Gunnery exercise activities are conducted within Pacific Missile Range Facility Warning Areas W-186 and W-188, Oahu Warning Areas W-187 (Kaula), W-194, and Restricted Airspace R-3107 (Kaula).

The U.S. Navy plans to conduct about 108 of these exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.4 Surface-to-Air Missile Exercise

A surface-to-air missile exercise (MISSILEX) involves surface combatants firing live missiles (RIM-7 Sea Sparrows, SM-1 or SM-2 Standard Missiles) at target drones. The surface ship must detect, track, and engage the target using its onboard weapon systems. The purpose of the exercise is to provide realistic training and evaluation of surface ships and their crews in defending against enemy aircraft and missiles.

Target drones representing enemy aircraft or missiles are flown or towed into the vicinity of the surface ship. The crew must identify the incoming object and respond with surface-to-air missiles as appropriate. 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 exercise consists of one or more surface ships, one or more target drones, and a helicopter and weapons recovery boat for target recovery. The surface-to-air missiles are launched from ships located within Pacific Missile Range Facility Warning Area W-188. Targets are launched from an existing ground-based target launch site at Pacific Missile Range Facility Launch Complex; from a Mobile Aerial Target Support System located in the open ocean within the Pacific Missile Range Facility Warning Areas; or released from an aircraft.

The U.S. Navy plans to conduct about 26 of these exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.5 Air-to-Surface Missile Exercise

Air-to-surface missile exercises consist of releasing a forward-fired, guided weapon at the designated towed target. The exercise involves locating the target, usually with a laser. Air-to-surface missile exercises that do not involve the release of a live weapon can take place if a captive air training missile, simulating the weapon involved in the training, is carried. An air to surface missile exercise that involves a captive air training missile is identical to a live-fire exercise in every aspect except that a weapon is not released. The operation requires a laser-safe range as the target is located just as in a live-fire exercise.

From one to 16 fixed wing aircraft or helicopters, carrying air training missiles or flying without ordnance (dry runs), are used during the exercise. Missiles include air-to-surface missiles and anti-radiation missiles (electromagnetic radiation source seeking missiles). At sea, SEPTARS, Improved Surface Towed Targets, and excess ship hulks are used as targets.

The U.S. Navy plans to conduct about 50 of these exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.6 Chaff Exercise

A chaff exercise trains aircraft and shipboard personnel in the use of chaff to counter anti-ship missile threats. During a chaff exercise, ships combine maneuvering with deployment of multiple rounds of mk-36 super rapid bloom off board chaff to confuse incoming missile threats, simulated by aircraft. In an integrated exercise scenario, helicopters deploy air-launched, rapid-bloom off board chaff in pre-established patterns designed to enhance anti-ship missile defense. Chaff exercises average about 4 hours in duration.

The U.S. Navy plans to conduct about 37 chaff exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.7 Naval Surface Fire Support Exercise

Navy surface combatants conduct fire support exercise operations at Pacific Missile Range Facility on a virtual range against “Fake Island”, located on Barking Sands Tactical Underwater Range. Fake Island is unique in that it is a virtual landmass simulated in three dimensions. Ships conducting fire support training against targets on the island are given the coordinates and elevation of targets. Pacific Missile Range Facility is capable of tracking fired rounds.

The U.S. Navy plans to conduct about 28 naval surface fire support exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.8 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 require a cooperative surface ship. The typical duration of these operations is approximately between 1 and 2 hours.

The U.S. Navy plans to conduct about 66 visit, board, search, and seizure training events annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.9 Surface-to-Surface Gunnery Exercise

Surface gunnery exercises take place in the open ocean to provide gunnery practice for Navy and Coast Guard ship crews. Surface-to-surface training operations conducted in the Offshore Operating Area involve stationary targets such as an MK-42 Floating At Sea Target or an MK-58 marker (smoke) buoy. Gunnery Exercises last about 1 to 2 hours, depending on target services and weather conditions. The gun systems employed against surface targets include the 5-inch, 76-millimeter (mm), 25 mm chain gun, 20-mm Close-In Weapon System, and .50-caliber machine gun. A single gunnery exercise will typically expend a minimum of 21 rounds of 5-inch or 76-mm ammunition, and about 150 rounds of 25-mm or .50-caliber ammunition. Both live and inert training rounds are used. After impacting the water, the rounds and fragments sink to the bottom of the ocean and those targets that are not destroyed are removed.

Five- inch gun ordnance the U.S. Navy intends to use in the Hawai'i Range Complex includes the following. A High Explosive Electronically Timed Projectile is a standard High Explosive round with an improved electronically timed fuse. A Kinetic Energy Projectile, commonly called the “bb” round, contains 9,000 tungsten pellets and is designed to be fired down a bearing at incoming boats. An EX-171 Extended Range Guided Munition projectile is a major component of the Navy’s littoral warfare concept. The 5-inch, rocket-assisted projectile is capable of carrying a 4-caliber submunition, and is typically fired from the new 5-inch, 62-caliber gun aboard the Arleigh Burke (DDG-51) class destroyers.

The U.S. Navy plans to conduct about 91 surface-to-surface gunnery exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.10 Surface-to-Surface Missile Exercises

A surface-to-surface missile exercise involves the attack of surface targets at sea by use of cruise missiles or other missile systems, usually by a single ship conducting training in the detection, classification, tracking and engagement of a surface target. Engagement is usually with surface-to-surface Harpoon missiles or Standard missiles. Targets include virtual targets or the seaborne powered target or ship deployed surface target.

A surface-to-surface missile exercise includes 4 to 20 surface-to-surface missiles, SEPTARs, a weapons recovery boat, and a helicopter for environmental and photo evaluation. All missiles are equipped with instrumentation packages or a warhead. Surface-to-air missiles can also be used in a surface-to-surface mode. The activities associated with surface-to-surface missile exercises are conducted within Pacific Missile Range Facility Warning Area W-188. These exercises typically last about 5 hours, but could last between 4 to 35 hours.

The U.S. Navy plans to conduct about 12 surface-to-surface missile exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.11 Air-to-Surface Gunnery Exercise

Air-to-Surface gunnery exercise operations are conducted by aircraft against stationary targets (fast and smoke buoy). Aircraft involved in this operation include a single SH-60 using either 7.62-mm or .50-caliber door-mounted machine guns. A typical Gunnery Exercise lasts about 1 hour and involves the expenditure of about 400 rounds of 20 mm, 0.50-caliber, or 7.62-mm ammunition.

The U.S. Navy plans to conduct about 152 air-to-surface gunnery exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.12 Anti-Submarine Warfare Tracking Exercise

Anti-submarine warfare tracking exercises train aircraft, ship, and submarine crews in the tactics, techniques, and procedures used to search for, detect, and track submarines. Anti-submarine warfare tracking exercises include ships, fixed wing aircraft, helicopters, torpedo targets, 1 to 10 submarines, and weapons recovery boats or helicopters. As a unit-level exercise, an aircraft, ship, or submarine is typically used versus one target submarine or simulated target. The target may be non-evading while operating on a specified track or it may be fully evasive, depending on the state of training of an anti-submarine warfare unit. No torpedoes are fired during these tracking exercises.

The duration of anti-submarine warfare tracking exercises depends on the tracking platform and its available on-station time. A maritime patrol aircraft can remain on station for 8 hours, and typically conducts tracking exercises that last 3 to 6 hours. An Anti-Submarine Warfare helicopter has a much shorter on-station time, and conducts a typical tracking exercise in 1 to 2 hours.

Surface ships and submarines, which measure their on-station time in days, conduct tracking exercises exceeding 8 hours and averaging up to 18 hours. Anti-submarine warfare tracking exercises are conducted on ranges within Pacific Missile Range Facility Warning Area W-188, the Hawai′i Offshore Areas or the open ocean. Whenever aircraft use the ranges for anti-submarine warfare training, range clearance procedures include a detailed visual range search for marine mammals and unauthorized boats and planes by the aircraft releasing the inert torpedoes, range safety boats/aircraft, and range controllers. Sensors used during ASW events include sonars, sonobuoys, non-acoustic sensors such as radars, and airborne early warning radars. The use of sonobuoys is generally limited to areas greater than 100 fathoms, or 600 feet, in depth. Before dropping sonobuoys, the crew visually determines that the area is clear. When the sonobuoy is released, a small parachute (about 4 feet in diameter) retards its entry into the ocean. The sonobuoy is designed to float on the surface and, after a controlled period of time (no longer than 8 hours), the complete package (with the parachute) sinks to the bottom.

The U.S. Navy plans to conduct about 372 anti-submarine warfare tracking exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.13 Bombing Exercise at Sea

Fixed-wing aircraft conduct operations against stationary targets (MK-42 fast or MK-58 smoke buoy) at sea. An aircraft clears the area, deploys a smoke buoy or other floating target, and then sets up a racetrack pattern, dropping on the target with each pass. At Pacific Missile Range Facility, a range boat might be used to deploy the target for an aircraft to attack.

The U.S. Navy plans to conduct about 38 bombing exercises annually in the Range Complex from January 2012 to January 2014.

2.2.14 Sinking Exercise

Sinking exercises provide training to ship and aircraft crews in delivering live ordnance on real targets. Each Sinking Exercise uses an excess vessel as a target that is eventually sunk during the course of the exercise. The target is an empty, cleaned, and environmentally remediated ship hull that is towed to a designated location where multiple types of weapons fire shots at the hulk. Sinking Exercise vessels can number from one to as many as six during a major range exercise. The duration of a Sinking Exercise is unpredictable since it ends when the target sinks, sometimes immediately after the first weapon impact and sometimes only after multiple impacts by a variety of weapons.

Weapons can include missiles, precision and non-precision bombs, gunfire, and torpedoes. 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 a P-3C 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, and Hellfire.

If none of the shots result in the hulk sinking, either a submarine shot or placed explosive charges are used to sink the ship. Charges ranging from 100 to 200 pounds, depending on the size of the ship, are 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 have been approved by the U.S. Environmental Protection Agency (Department of the Navy and U.S. Environmental Protection Agency, 1996). The EPA granted the Department of the Navy a general permit through the Marine Protection, Research, and Sanctuaries Act to transport vessels “for the purpose of sinking such vessels in ocean waters…” (40 CFR Part 229.2) Subparagraph (a)(3) of this regulation states “All such vessel sinkings shall be conducted in water at least 1,000 fathoms (6,000 feet) deep and at least 50 nautical miles from land.” In Hawai′i, SINKEX events take place within Pacific Missile Range Facility Warning Area W-188.

The U.S. Navy plans to conduct about 6 sinking exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.15 Anti-Surface Warfare Torpedo Exercise (Submarine-Surface)

Submarines conduct most of their torpedo firings at Pacific Missile Range Facility, and many of those are against surface targets. Surface targets will typically be Pacific Missile Range Facility range boats or targets, or U.S. Navy combatants. Anti-surface Warfare Torpedo Exercises culminate with the submarine firing mk-48 torpedoes against the surface target.

Twice a year, “Hollywood” operations are conducted on Pacific Missile Range Facility as part of the Submarine Commander’s Course, which trains prospective submarine Commanding Officers and Executive Officers. These are integrated operations involving complex scenarios that will include a coordinated surface, air, and submarine force challenging the submarine’s Commanding Officers and crew. During these events, submarines are typically engaged in torpedo firings during anti-surface warfare exercises, as well as anti-submarine warfare tracking exercises and anti-submarine torpedo exercises.

The U.S. Navy plans to conduct about 35 anti-surface warfare torpedo exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.16 Flare Exercise

A flare exercise is an aircraft defensive operation in which the aircrew uses an infrared or radar energy source to disrupt attempts to lock onto the aircraft. During infrared break-lock (flare) training, a shoulder-mounted infrared surface-to-air missile simulator is trained on the aircraft by an operator attempting to lock onto the aircraft’s infrared signature. The aircraft maneuvers while expending flares. The scenario is captured on videotape for replay and debrief. No actual missiles are fired during this training operation. Radar break-lock training is similar except that the energy source is an electronic warfare simulator, and the aircraft expels chaff during its defensive maneuvering. Chaff is a radar confusion reflector, consisting of thin, narrow metallic strips of various lengths and frequency responses, used to deceive radars.

The U.S. Navy plans to conduct about 7 flare exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.17 Anti-submarine Warfare Torpedo Exercises

Antisubmarine Warfare Torpedo Exercises (which the Navy abbreviates as ASW TORPEX) operations train crews in tracking and attack of submerged targets, firing one or two Exercise Torpedoes or Recoverable Exercise

Torpedoes. Targets used in Torpedo Exercises in the Offshore Areas include live submarines, MK-30 anti-submarine warfare training targets, and MK-39 Expendable Mobile anti-submarine warfare training targets. A target may be non-evading while operating on a specified track, or it may be fully evasive, depending on the training requirements of the operation. Submarines periodically conduct torpedo firing training exercises within the Hawai′i Offshore Operating Area. The typical duration of a submarine Torpedo Exercise is 22.7 hours, while air and surface anti-submarine warfare platform Torpedo Exercises are considerably shorter.

The U.S. Navy plans to conduct about 500 anti-submarine torpedo exercises annually in the Hawai′i Range Complex from January 2012 to January 2014.

2.2.18 Extended Echo Ranging/Improved Extended Echo Ranging Training Exercise

The Extended Echo Ranging and Improved Extended Echo Ranging (which the U.S. Navy abbreviates as EER/IEER) 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-110 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 a visual search of 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-110 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.

The AN/SSQ-101 ADAR Sonobuoy is an expendable passive sonobuoy. After water entry, the ADAR sonobuoy descends to a selected depth and deploys hydrophones. Once activated, the ADAR sonobuoy works in conjunction with the ssq-110 sonobuoy sound source, receiving active echoes reflecting off any target or reverberant present including submarine hulls, seamounts, bottom features, etc. Ordnance is used during these exercises. Sonobuoys are released from aircraft and active and passive sonar is used.

The AN/SSQ-125 Advanced Extended Echo Ranging (AEER) Sonobuoy is a third generation of multi-static active acoustic search systems to be developed under the Extended Echo Ranging family of the systems and is being developed as the replacement for the AN/SSQ-110A. The AN/SSQ-125 sonobuoy is composed of two sections, the control section and the active source section. The control section contains the electronics package while the lower section consists of the active sonar source. The echoes from pings of the sonar are then analyzed on the aircraft to determine a submarine’s position.

The U.S. Navy plans to conduct about four Echo Ranging exercises annually in the Hawai'i Range Complex from January 2012 to January 2014, using either a combination of AEER or EER/IEER systems.

2.2.19 Electronic Combat Operations

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 100 electronic combat exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.20 Mine Countermeasures Exercise

Mine Countermeasures exercises train forces to detect, identify, mark, or disable mines using a variety of methods. Organic Mine Countermeasures include systems deployed by air, ship, and submarine. Five Organic Airborne Mine Counter-measure systems are deployed by the MH-60S Seahawk Multi-Mission, including:

- Advanced Mine Hunting Sonar: The AN/AQS-20A Advanced Mine Hunting Sonar is a single-pass multi-sonar system designed to detect, locate, and identify mines on the sea floor and in the water.
- The AN/AES-1 Airborne Laser Mine Detection System (ALMDS): The AN/AES-1 ALMDS is a sensor designed to detect moored, near surface mines using light detection and ranging technology.
- The AN/ALQ-220 Organic Airborne and Surface Influence Sweep (OASIS): The AN/ALQ-220 OASIS System is a lightweight magnetic/acoustic system employed by the MH-60S.
- The AN/AWS-2 Rapid Airborne Mine Clearance System (RAMICS): The AN/AWS-2 RAMICS is being developed to destroy near-surface and floating mines using a 30-mm cannon hydro-ballistic projectile, and includes a target reacquisition pod on the MH-60S.
- The AN/ASQ-235 Airborne Mine Neutralization System (AMNS): The AN/ASQ-235 AMNS is a lightweight expendable system designed to rapidly neutralize bottom and moored mines

The U.S. Navy plans to conduct about 62 mine countermeasures exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.21 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. The Navy proposes to conduct mine neutralization activities using both positive control and time-delay firing devices (TDFDs). The number of mine neutralization events (68 events) would remain unchanged from the 2011 Request for Letter of Authorization.

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 divers 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 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. These animals are transported to and housed in the State of Hawai'i in accordance with applicable regulations of the Hawai'i State Department of Agriculture.

Mine neutralization operations take place offshore in the Puuloa Underwater Range (called Keahi Point in earlier documents), Pearl Harbor; Lima Landing; Barbers Point Underwater Range off-shore of Coast Guard Air Station Barbers Point/Kalaeloa Airport (formerly Naval Air Station [NAS] Barbers Point); Pacific Missile Range Facility, Kauai (Majors Bay area); Pacific Missile Range Facility and Oahu Training Areas; and in open-ocean areas.

All underwater demolition activities are 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 consist of tying 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 sandy areas that avoid or minimize potential impacts to coral are used for explosive charges.

The Navy uses both timed-delayed and positive control to initiate a particular underwater detonation depending on the training event objectives in question and in particular, the training objectives applicable to that underwater detonation. The time-delay firing is called the Timed Delay Firing Device (TDFD). The most common positive control firing is called a Remote Firing Device (RFD). For a surface mine neutralization training event involving a helicopter or a boat, the minimum time-delay that is reasonable for EOD divers to make their way outside of the detonation human safety buffer zone is approximately 10 minutes. For a mine neutralization training event at depth using small boats, the time-delay can be minimized to five minutes however this would require the instructors to handle initiation of the detonation and therefore would result in decreased training value for students.

A RFD, a type of positive control device, can be used to initiate an underwater detonation, but it is not normally preferred as the primary firing device due to HERO concerns with electric detonators, Operational Risk Management (i.e., safety) considerations, and established Navy tactical procedures. Current Navy RFD uses a radio signal to remotely detonate a charge.

Basic training involves neutralizing either a simulated mine on the surface or at depth. The ratio between surface detonations and bottom detonations (at depth) for EOD is about 50/50. This is dependent mainly on range availability and weather conditions. During neutralization of a surface mine, EOD divers are deployed and retrieved via helicopter. However, when helicopter assets are unavailable, a small boat is used as is done with neutralization of a mine at depth. During training exercises, regardless of whether a helicopter or small boat is used, a minimum of two small boats participate in the exercise.

For a surface mine neutralization training event involving a helicopter or a boat, the minimum reasonably safe time-delay for EOD divers to make their way outside of the detonation plume radius/human safety buffer zone (typically 1000 ft (334 yd)) is 10 min. For mine neutralization training events at depth using small boats, the time-delay can be minimized to 5 min. However, this would require the instructors to handle initiation of the detonation and therefore would result in decreased training value for students. The range area and associated support equipment are required for a 6 - 8 hour window. Training exercises are conducted during daylight hours for safety reasons. The U.S. Navy plans to conduct about 68 mine neutralization exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.22 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. Aerial mining lines are generally developed off the southwest coast of Kaua′i and the southeast coast of Ni′ihau, within Pacific Missile Range Facility Warning Areas W-186 and W-188. Submarine mining exercises are conducted within Pacific Missile Range Facility Warning Area W-188. Aircraft operations are conducted within R3101.

The U.S. Navy plans to conduct about 32 mine laying exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.23 Swimmer Insertion/Extraction

Naval Special Warfare personnel conduct underwater swimmer insertion and extraction training in the Hawai’i Offshore Areas using the Sea, Air, Land (SEAL) Delivery Vehicle or the Advanced SEAL Delivery System. Both submersibles are designed to deliver special operations forces for clandestine operations. The SEAL Delivery Vehicle is an older, open-design delivery vehicle. The Advanced SEAL Delivery System is a new dry compartment vehicle that keeps the seals warmer during transit. The battery-powered Advanced SEAL Delivery System is capable of operating independently or with submarines.

Two types of training occur with the Advanced SEAL Delivery System — unit and integrated. Unit training with the Advanced SEAL Delivery System consists of the SEAL Delivery Vehicle Team operating the Advanced SEAL Delivery System independently. Integrated training operations involve the Seal Delivery Vehicle submarine and the Advanced SEAL Delivery System. Underwater swimmer insertion and extraction training is focused on undersea operation of the Seal Delivery Vehicle or Advanced SEAL Delivery System, and does not typically involve seal personnel landing ashore or conducting shore operations. Although undersea range areas are usually reserved for a 24-hour period, the insertion/extraction operation itself lasts approximately 8 hours. Swimmer insertion and extraction operations can also include the use of helicopters to insert or extract naval special warfare personnel using a variety of techniques.

The U.S. Navy plans to conduct about 145 of these exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.24 Salvage Operations

The purpose of Salvage Operations is to provide a realistic training environment for battling fires at sea, de-beaching of stranded ships, and harbor clearance operations training by U.S. Navy diving and salvage units. The U.S. Navy's Mobile Diving and Salvage Unit One (MDSU-1) and divers from other countries practice swift and mobile ship and barge salvage, towing, battle damage repair, deep ocean recovery, harbor clearance, removal of objects from navigable waters, and underwater ship repair capabilities. Diving and salvage forces exercise include the following activities:

- SCUBA and surface supplied air and mixed gas (HeO_2) diving operations to depths of 300 feet of sea water
- Hyperbaric recompression chamber operations
- Underwater ship inspection, husbandry, and repair of coalition Naval ships and submarines
- Underwater search and recovery operations
- Underwater cutting employing hydraulic, pneumatic, and oxy-arc powered tools
- Underwater welding
- Removal of petroleum, oil, and lubricants exercising various techniques for offloading these classes of chemicals.
- Restoring Buoyancy (Survey, Patch, De-water) to a grounded or sunken vessel or object of value
- Harbor clearance for removal of derelict vessels or other obstructions from navigable waterways and berthing
- Off-Ship fire fighting to simulate rescue and assistance operations battling fires

These activities take place at Puuloa Underwater Range, Pearl Harbor, and Keehi Lagoon. Staging for these activities is from the MDSU-1 Facility located on Bishop Point, an annex of Pearl Harbor, on the southwestern side of Hickam Air Force Base, Oahu. To capitalize on real-world training opportunities and to provide mutual benefit for both the U.S. Naval and Coalition Salvage Force and for the State of Hawaii, salvage training and harbor clearance exercises take place in any of the shoal waters, harbors, ports, and in-land waterways throughout the Hawai'i Operating Area.

The ship fire exercise lasts no more than 1 day per event. De-beaching activities last no more than 1 to 2 days per event. Deep ocean recovery exercises last up to 2 weeks and could be longer depending on the availability of missions. The duration of salvage exercises varies considerably. For a fire at sea or ship retraction of a grounded vessel, the exercise lasts up to 4 days. For underwater cutting, welding, pumping, restoring buoyancy, and exercises that practice a single skill in a controlled environment, the event usually does not exceed 1 day. However, multiple iterations could extend throughout the duration of the exercise.

The U.S. Navy plans to conduct about 3 salvage exercises annually in the Hawai'i Range Complex from January 2012 to January 2014.

2.2.25 Humanitarian Assistance Operation/Non-combatant Evacuation Operation

The purpose of Humanitarian Assistance Operation/Non-combatant Evacuation Operation (HAO/NEO) is to train Navy personnel in providing humanitarian assistance in an increasingly hostile setting, which could require the evacuation of personnel and troops. Marine Corps Base Hawai'i is used for HAO/NEO and direct action training. Marine Corps Training Area Bellows, Kahuku Training Area, Majors Bay at Pacific Missile Range Facility, and Niihau are also be used for HAO/NEO.

The HAO/NEO training exercises, which occur about once a year, last about 4 days and involve about 150 personnel, troops, and specialists who initially provide assistance to civilians and then evacuate them when necessary. This scenario is also used to simulate a prisoner-of-war camp or place where people are interned. A direct action exercise (lasting several hours) is another scenario included in the HAO/NEO. It is much quicker and involves approximately 200 personnel who gain access to an area by boat or helicopter, storm the location, recover the mission target, and return to their units. The HAO/NEO exercises use trucks; helicopters; landing craft air cushion; landing craft, utility or Combat Rubber Raiding Craft to shuttle supplies. Evacuations may be made using helicopters, or landing craft air cushion vehicles. Direct actions may use Combat Rubber Raiding Craft, Rigid Hull, Inflatable Boats, trucks, or helicopters. Existing building and facilities are used to the extent practicable, but in some instances tents and other temporary structures may be used.

2.2.26 Humanitarian Assistance/Disaster Relief

The purpose of Humanitarian Assistance/Disaster Relief (HA/DR) is to provide training in responding to a United Nations request for complex emergency support. The HA/DR training exercises involve approximately 125 to 250 troops and 125 to 200 refugee actors. An amphibious landing craft off-loads approximately four transport trucks, three support vehicles, three water supply vehicles, water and food supply, and 125 troops. They travel along authorized highways to the HA/DR site. A safe haven camp is established in existing facilities or temporary facilities (tents, etc.).

Thus far, HA/DR exercises have occurred about once a year and have lasted for about ten days. Over the next year, HA/DR exercises could range from 2 to 18 days, with camps established in two days. Personnel are provided water, shelter, food, sanitation, and communications for 5 days. Takedown takes about two days. For each exercise, there are two sites: a refugee camp and a Civil–Military Operations Center area. There are roughly 30 five-person Red Cross tents within the refugee camp, with a few larger tents for various support functions including meals, showers, recreation, administration, and storage. The Civil – Military Operations Center section contains more storage, communication links, staff housing, experimentation (including information management and high-bandwidth informatics support, digital transcription facilities to interview refugees for war crimes documentation, and solar powered computer systems), and various public relations areas for visitors. Approximately 18 portable latrines are at the sites. Buses or trucks, and military helicopters as needed, are used to transport refugees. A safe haven refugee camp would be established within the Marine Corps Base Hawai’i, Marine Corps Training Area Bellows, or Kahuku Training Area. An amphibious landing craft or trucks would offload equipment, vehicles, troops, and refugees. Airstrips at these locations would be used to transport personnel.

Humanitarian assistance/disaster relief exercises take place near an existing training trail. The access road to the site would be graded before the exercise, if required. Grading would be within the existing roadway in accordance with standard procedures. Equipment and personnel would be transferred to the camp location via transport trucks and buses, respectively. Training map overlays that identify the transit route, camp location, and any nearby restricted areas or sensitive biological and cultural resource areas would be used by participants.

2.3 Research, Development, Test, and Evaluation Activities

In addition to conducting Major Exercises in the Hawai'i Range Complex, the U.S. Navy and other federal agencies (including the U.S. Department of Defense's Missile Defense Agency, U.S. Army and U.S. Army's Space and Missile Command, U.S. Air Force, U.S. Coast Guard, and National Oceanic and Atmospheric Administration) plan to conduct a suite of Research, Development, Test, and Evaluation (RDT&E) activities in the Hawai'i Range Complex. The RDT&E operations would occur primarily at either the Pacific Missile Range Facility or the NUWC Detachment Pacific ranges. The following narratives summarize those activities (Table 1).

Table 1. Research, development, test and evaluation activities (R,D,T&E) and the areas in which they are proposed.

RDT&E Exercise	Area	Open Ocean	Offshore	Onshore	No. Per Year
Current RDT&E Activities					
Anti-air Warfare RDT&E	Hawai'i Operating Area (OPAREA), Pacific Missile Range Facility (PMRF) (Main Base)	X	X	X	44
Anti-Submarine Warfare	Hawai'i OPAREA, PMRF (Main Base)	X	X		23
Combat System Ship Qualification Trial	Hawai'i OPAREA	X			9
Electronic Combat/Electronic Warfare (EC/EW)	Hawai'i OPAREA, PMRF (Main Base), Niihau	X	X	X	80
High Frequency	Hawai'i OPAREA, PMRF (Main Base)	X	X	X	11
Missile Defense	Temporary Operating Area (TOA), Hawai'i OPAREA, PMRF (Main Base)	X	X	X	50
Joint Task Force Wide Area Relay Network	PMRF (Main Base)			X	4
Shipboard Electronic Systems Evaluation Facility (SESEF) Quick Look Tests	SESEF Range		X		4,225
SESEF System Performance Tests	SESEF Range		X		74
Fleet Operational Readiness Accuracy Check Site (FORACS) Tests	FORACS Range		X		6
Planned RDT&E Activities					
Additional Chemical Simulant	TOA, Hawai'i OPAREA, PMRF (Main Base)	X	X	X	Upgrade
Intercept Targets launched into PMRF Controlled Area	TOA, Hawai'i OPAREA	X			3
Launched SM-6 from Sea-Based Platform (AEGIS)	TOA, Hawai'i OPAREA, PMRF (Main Base)	X	X		Upgrade

RDT&E Exercise	Area	Open Ocean	Offshore	Onshore	No. Per Year
Micro-Satellites Launch	TOA, Hawai'i OPAREA, PMRF (Main Base)	X	X	X	Upgrade
Test Unmanned Surface Vehicles	TOA, Hawai'i OPAREA	X	X		Upgrade
Test Unmanned Aerial Vehicles	TOA, Hawai'i OPAREA, PMRF (Main Base)	X	X	X	Upgrade
Test Hypersonic Vehicles	TOA, Hawai'i OPAREA, PMRF (Main Base)	X	X	X	Upgrade
Planned Enhancements					
Portable Undersea Tracking Range	Hawai'i OPAREA (various islands)	X	X		Upgrade
Large Area Tracking Range Upgrade	Hawai'i OPAREA; locations on Kauai, Oahu, Maui, Hawai'i	X	X	X	Upgrade
Enhanced Electronic Warfare Training	Hawai'i OPAREA; locations on Kauai, Maui, Hawai'i, Niihau	X	X	X	Upgrade, Construction
Expanded Training Capability for Transient Air Wings	Hawai'i OPAREA, locations on Kauai, Maui, Hawai'i	X	X	X	Upgrade, Construction
MK-84/MK-72 Pinger Acoustic Test Facility	Pearl Harbor (Ford Island)		X		Upgrade Training Area
Mobile Diving and Salvage Unit Training Area	Puuloa Underwater Range, Naval Defensive Sea Area		X		Upgrade
Kingfisher Underwater Training Area	Offshore Niihau, PMRF (Main Base)		X		Upgrade, Construction
FORCEnet Antenna	PMRF (Makaha Ridge or Kokee)			X	Upgrade, Construction
Enhanced Auto Identification System and Force Protection Capability	PMRF (Makaha Ridge)			X	Construction
Construct Range Operations Control Building	PMRF (Main Base)			X	Construction
Improve Fiber Optics Infrastructure	PMRF (Main Base, Kokee)			X	Construction
Future RDT&E Activities					
Directed Energy	Hawai'i OPAREA, PMRF (Main Base)	X	X	X	Range Upgrade
Advanced Hypersonic Weapon	Hawai'i OPAREA, PMRF (Main Base)	X	X	X	1

2.3.1 Anti-Air Warfare RDT&E

Anti-air Warfare RDT&E operations involve testing and training on Aegis-capable ships after refurbishment or overhaul. Aegis Ballistic Missile Defense operations involve testing and evaluating the ship's missile system gunnery missile ordnance, active sonar, and associated hardware in support of the ship's missile defense mission. An additional operation for Aegis ships is the waterfront integration test, which provides pier side testing, simulating events that take place during the on range Aegis ballistic missile defense operations. Waterfront integration tests ensure that all shipboard systems are operable.

2.3.2 Antisubmarine Warfare Test and Evaluation

Anti-submarine Warfare Test and Evaluation operations at Pacific Missile Range Facility include sensor, fire control, and weapon testing. The use of Pacific Missile Range Facility's Submarine Tracking Systems involves using this system to evaluate MK-30 system upgrades. The MK-30 target is a self-propelled underwater vehicle capable of simulating the dynamic, acoustic, and magnetic characteristics of a submarine. The Navy uses in-water submarine simulators such as the MK-30 ASW target. The MK-30 target fulfills the need for a convenient, cost-effective means for operational training of Fleet units. Submarine system evaluation operations conducted in submarine training areas near Maui are also part of ASW training and testing operations.

2.3.3 Combat System Ship Qualification Trial

Combat System Ship Qualification Trials (which the Navy abbreviates as CSSQT) are performed at Pacific Missile Range Facility and are categorized as training and testing operations. Combat system ship qualification trials are conducted for new ships and for ships that have undergone modification or overhaul of their combat systems. Although combat system ship qualification trials can vary from ship to ship as requirements dictate, the primary goals are to ensure that the ship's equipment and combat systems are in top operational condition, and that the ship's crew is proficient at operating these systems. Therefore, combat system ship qualification trials can include operating any or all of a ship's combat systems and might include firing missiles and conducting gunnery exercises.

2.3.4 Electronic Combat/Electronic Warfare

Electronic Combat/Electronic Warfare (EC/EW) operations include tests designed to assess how well EC/EW training exercises are performed. The EC/EW operations, which occur typically in W-188, are monitored at Pacific Missile Range Facility shore sites. No ordnance is used during these activities.

2.3.5 High Frequency

High frequency testing and evaluation operations include the use of high frequency radio signals and the evaluation of their effectiveness. High frequency in the radio spectrum refers to frequencies between 3 megahertz (MHz) and 30 MHz. This frequency range is commonly used for maritime and amateur short-wave radio transmissions. These operations can take place both at Pacific Missile Range Facility shore sites and within W-188.

2.3.6 Missile Defense

Aerial targets are launched from Pacific Missile Range Facility, mobile sea-based platforms, or military cargo aircraft. During Navy Aegis missile defense RDT&E operations, a ballistic missile target vehicle is launched from Pacific Missile Range Facility and intercepted by a ship-launched missile. The test operations can involve:

- Aegis ships
- Use of the Mobile Range Safety System
- On-load and off-load of aircraft
- Long-Range and Short-Range Air Launch Target
- Smart Test Vehicle
- Light Detection and Ranging
- Mobile At-Sea Sensor System
- Use of the Battle Management Interoperability Center
- Transportation of liquid propellants to Pacific Missile Range Facility
- Flight Termination System preparations for an operation
- Dress rehearsals and dry runs for specific missile defense operations

The Army’s Terminal High Altitude Area Defense (THAAD) is part of the Department of Defense Ballistic Missile Defense System. It is the antimissile system designed to intercept and destroy missiles in the final phase of their trajectories. The THAAD Pacific Missile Range Facility training operations include midcourse tracking of ballistic missiles using the Coherent Signal Processing radar, telemetry, C-Band precision radars, and Mobile Aerial Target Support System. This system differs from other missile defense testing in that THAAD scenarios involve the target vehicle being launched outside of Pacific Missile Range Facility, with the THAAD interceptor launched from an existing launch pad at Pacific Missile Range Facility. The intercept occurs in the Temporary Operating Area.

Other missile defense operations associated with the Navy proposed Research, Development, Test & Evaluation activities include preparing security, range instrumentation and communications checks, radar calibrations, and range surveillance and clearance. As part of the required clearance before an exercise, the target area must be inspected visually and determined to be clear. Range Control is charged with hazard area surveillance and clearance and the control of all range operational areas.

2.3.7 Joint Task Force Wide Area Relay Network

Joint Task Force Wide Area Relay Network (JTF WARNET) is a demonstration of advanced Command, Control and Communications technologies in a highly mobile, wireless, wide area relay network in support of tactical forces. The objective of a network of this type is to link tactical forces, providing a common operating picture. Although similar in function to a common internet setting, JTF WARNET demonstrates this capability in a very austere battlefield environment, without the luxury of existing communication systems. In addition, the network must be capable of transmitting classified information. The JTF WARNET testing evaluates joint and allied command, control and communications decision making, planning and execution, and tactical capability. These tests are monitored from shore facilities at Pacific Missile Range Facility. They do not use ordnance.

2.3.8 Shipboard Electronic Systems Evaluation Facility Quick Look Tests

The Shipboard Electronic Systems Evaluation Facilities (SESEF) range, located off Barbers Point on Oahu, provides state-of-the-art test and evaluation of combat systems that radiate or receive electromagnetic energy. The SESEF range includes land based test facilities established to provide electromagnetic system test and evaluation services to afloat and shore commands. SESEF services can be used for the development of new and upgraded systems, and provide a real-time evaluation of a system in an operational environment. The Fleet Operational Readiness Accuracy Check Site range control is located near Nanakuli, Oahu. The electronic equipment at this site checks range and bearing accuracy for Navy and Coast Guard ships to ensure equipment function and calibration. Specific frequencies and power settings are dependent on the type of test being conducted. The test equipment operated by SESEF allows for a performance evaluation of the ship, shore, or aircraft system. Neither SESEF test uses ordnance or sonar.

Tests conducted by SESEF fall into one of two broad categories:

Quick Look

Quick Look tests are generally conducted during transit to and from port, or while pier side at Pearl Harbor. These tests provide the ship a quick operational evaluation of the system(s) being tested with a simple “SAT or UNSAT” grade along with any detected system anomalies or problems. An example is a radio check that confirms that a ship's radio can both transmit and receive voice communications. Quick Look tests have the following characteristics:

- Generally short in duration
- Require little or no advance scheduling
- Require little or no shipboard maneuvering
- May be accomplished pier side (Communications, link -4A and link-11 only)
- Require minimal internal shipboard coordination

System Performance Tests

System performance testing provides the ship with a more detailed analysis and evaluation of the system(s) under test. The testing requirements and the desired measurement precision dictate a higher degree of control on the ship and coordination of its personnel. System performance tests are characterized as tests which:

- Generally require longer periods of dedicated testing
- Require advance scheduling and coordination with SESEF
- Require the ship to maneuver in pre-defined geometries within a certain geographic area; and
- Require internal shipboard coordination

2.3.9 Fleet Operational Readiness Accuracy Check Site Tests

The purpose of the fleet operational readiness accuracy check site tests are to provide accuracy checks of ship and submarine sonar, both in active and passive modes, and to evaluate the accuracy of a ship's radar. The ship will conduct a series of "runs" on the range, each taking between 1 and 2 hours. Both active and passive sonar can be checked on a single run. During a run, the ship will approach the target, a stationary underwater acoustic transducer located near shore, making a slow turn to eventually track outbound from the target, establishing a bearing to the target in use. This information is compared with the known bearing by range technicians stationed onboard the ship. During active sonar testing, range-to-target information is also evaluated.

Examples of specific Feet Operational Readiness Accuracy Check Site Tests are:

- Surface Weapons System Accuracy Trial - both an acoustic and an RF accuracy evaluation for a surface ship's radar.
- At-Sea Bearing Accuracy Test - a test of a ship's radar alone.
- Submarine Warfare System Assessment - an assessment of a submarine's radar and sonar. This kind of assessment is similar to Surface Weapons System Accuracy Trial, but is only for submarines.
- Undersea Warfare Readiness Evaluation Facility - a test of a ship's radar and sonar. This kind of test is similar to, but less involved than, the previous two tests.

2.3.10 Additional Chemical Simulant

The purpose of using a chemical simulant in target launch vehicles is to assess the effectiveness of defensive missiles against threat missiles carrying chemical agents as payloads. To adequately emulate this threat in testing, it is necessary to use materials that are similar to the physical characteristics of actual chemical agents, but without the toxic effects. Use of actual chemical agents in testing would present the potential for unacceptable hazards, thus the need for a simulant.

Target launches from Pacific Missile Range Facility typically incorporate additional chemical simulants to include larger quantities of tributyl phosphate (TBP) and various glycols. The list of potential glycols typically includes glyceryl tributyrate, propylene glycol, diethyl phthalate, polyethylene glycol, triethylene glycol, diethyl decanedioate, dibenzyl ether, dibutyl phthalate, di (2-ethylhexyl) phthalate, diethylene glycol, and polypropylene glycol 425. The top three preferred simulants are typically TBP, glyceryl tributyrate, and propylene glycol.

About 120 gallons of simulant are typically used in target vehicles launched from Pacific Missile Range Facility. The simulant is typically transported from the continental United States to the Pacific Missile Range Facility with the target vehicle and would be loaded into the target vehicle payload as part of the payload processing activities.

Intercept Targets Launched Into PMRF Controlled Area. Launches from Wake Island, the Reagan Test Site at U.S. Army Kwajalein Atoll, and Vandenberg Air Force Base would be intercepted in the Broad Ocean Area and Temporary Operating Area of the Pacific Missile Range Facility Range. Launches from those sites would be from existing launch facilities, and no new boosters from these sites are proposed. Targets would also continue to be launched from sea-based and air-based platforms as analyzed in previous environmental documents.

Launch SM-6 from Sea-Based Platform. Pacific Missile Range Facility also plans to develop the capability to launch the Extended Range Active Missile, tentatively designated SM-6, from a sea-based platform. This testing should be similar to ongoing launches of the current version of the Standard Missile from Aegis ships. For testing purposes the SM-6 could also be launched from the Mobile Aerial Target Support System or other mobile launch platform. The SM-6 typically consists of the SM-2 Block IV booster system and an active Advanced Medium Range Air-to-Air Missile seeker to provide enhanced capabilities. Testing typically occurs in the Temporary Operating Area.

2.3.11 Test Unmanned Surface Vehicles

Future testing of Unmanned Surface Vehicles (USVs) is proposed to occur within the Hawai'i Range Complex. These remote-controlled boats could be equipped with modular packages to potentially support surveillance and reconnaissance activities, mine warfare, anti-terrorism/force protection, port protection, Special Forces training operations, and possibly anti-submarine warfare. An USV is generally a small boat up to approximately 40 feet (ft) in length, with either rigid hulls or inflatable pontoons. Inboard or outboard diesel or gasoline engines up to several hundred horsepower would likely be used for propulsion. Test packages carried on the USVs may include radars; sonar; multi-functional camera suites; autonomous equipment packages; and required communications, testing, and support equipment. Onboard electrical power for equipment operations and engine starting would come from a series of batteries (lead-acid, lithium, etc.), and possibly an electrical generator run off the main engine.

For testing just off the coast of Pacific Missile Range Facility, the USV is typically launched from either Port Allen or the Kikiaola Small Boat Harbor. For safety purposes, the USV is typically towed by a manned vessel out of the harbor and up the coast to Pacific Missile Range Facility before operating remotely under its own power.

Testing typically occurs only in areas cleared of vessels that are not essential to the mission. Using computers, personnel would remotely operate the USV from a transportable command post in a trailer or located within an existing building at Pacific Missile Range Facility. The types of tests may include low-speed surveillance activities using cameras, radar, or sonar; maneuvering through obstacles; and high-speed runs in excess of 40 knots. Individual test operations could occur day or night and last for up to 24 hours, depending on test requirements. Following each test, the USV is typically towed back to harbor. Depending on test schedules, the USV might be temporarily docked, or taken out of the water on a trailer for storage at the harbor or at Pacific Missile Range Facility. No new storage or docking facilities would be required.

The testing of USVs could also occur in open waters within the Temporary Operating Area. In that case, the USV is typically towed out to sea or launched directly from a surface ship.

2.3.12 Test Unmanned Aerial Vehicles

A variety of Unmanned Aerial Vehicles (UAVs) may also be tested at Pacific Missile Range Facility. UAVS are remotely piloted or self-piloted aircraft that include fixed-wing, rotary-wing, and other vertical takeoff vehicles. They can carry cameras, sensors, communications equipment, weapons, or other payloads. At Pacific Missile Range Facility, UAV testing could support one or more of the following mission areas: intelligence, surveillance, and reconnaissance; suppression of enemy air defenses; electronic attack; anti-surface ship and anti-submarine warfare; mine warfare; communications relay; and derivations of these themes.

A UAV can vary in size up to approximately 45 ft in length, with gross vehicle weights ranging from several hundred pounds to about 45,000 pounds. Forms of propulsion for UAVs can range from traditional turbofans, turboprops, and piston engine-driven propellers; to electric motor-driven propellers powered by rechargeable batteries (lead-acid, nickel-cadmium, and lithium ion), photovoltaic cells, or hydrogen fuel cells.

Before they are tested at Pacific Missile Range Facility, each UAV is typically ground checked at existing facilities to ensure proper system operations. Depending on engine propulsion, the vehicle would be fueled most likely with gasoline or diesel fuel (approximately 50 to 700 lb); or jet fuel (approximately 50 to 17,000 pounds of JP-5 or JP-8). Takeoff procedures would vary by UAV system, using a traditional runway takeoff, small solid rocket-assisted takeoff, or a portable catapult launcher. Personnel use computers to remotely operate the UAV from a transportable command post in a trailer or located within an existing building at Pacific Missile Range Facility.

Depending on the UAV system being tested, individual flights could extend just a few nautical miles off the Pacific Missile Range Facility coast, or well over 100 nm into the Temporary Operating Area. Maximum altitudes for flights could range from a few thousand feet for the smallest UAVs to over 30,000 ft for the largest jet-powered vehicles. Maximum velocities attained would range from approximately 100 to 500 knots. Testing would only occur in areas cleared of non-mission essential aircraft and away from populated areas. The types of tests conducted could include demonstration of aircraft flight worthiness and endurance, surveillance activities using onboard cameras and other sensors, and over-the-horizon targeting. Individual test flights could last from a few hours to more than a day. At the completion of each flight test, vehicle landing would occur via traditional runway landing or using retrieval nets for smaller UAVs. The storage and ground support for UAVs would occur within existing facilities at Pacific Missile Range Facility. No new facilities are planned. In some cases, UAV flight tests, including takeoff and landing procedures, may be conducted from surface ships in the Temporary Operating Area. Remote control of the UAV would occur from a command center on a vessel. Again, testing would only occur in areas cleared of non-mission essential aircraft.

2.3.13 Test Hypersonic Vehicles

The Navy and the Department of Defense are developing air-breathing hypersonic vehicles that are capable of maximum sustainable cruising speeds in excess of Mach 4. As potential ordnance delivery systems, such vehicles could significantly decrease the launch to target engagement timeline.

Hypersonic vehicles, such as those being developed under the Hypersonic Flight Demonstration program, could be flight tested at Pacific Missile Range Facility from within and beyond the Temporary Operating Area. The missile-like test vehicle would be fueled at Pacific Missile Range Facility using JP-10 (exo-tetrahydrocyclopentadiene) or a similar turbine liquid fuel. On-board fuel weights are currently undetermined, but are expected to not exceed 500 lb. Because the hypersonic vehicles use a scramjet technology, engine operation requires a high-speed boost on a rocket or from a jet aircraft. Rocket launching a hypersonic test vehicle could occur from the Vandal launch site at Pacific Missile Range Facility and follow a similar flight trajectory as other missiles launched from Pacific Missile Range Facility. For example, a two-stage Terrier-Orion sounding rocket could be used to boost the hypersonic vehicle. Following a launch and booster motor separation, the spent motor casings would impact in the open ocean.

Upon reaching hypersonic velocities at altitudes in excess of 50,000 ft, the test vehicle would continue on a pre-designated flight trajectory under its own scramjet power, before making a controlled splashdown into the open ocean. For flight insertion using a jet aircraft, such as an F-15, the test vehicle would be attached under the aircraft at Pacific Missile Range Facility. Following takeoff, and upon reaching an appropriate altitude and velocity over the Temporary Operating Area, the test vehicle would be released from the aircraft. With engine ignition, the hypersonic test vehicle would climb to an appropriate cruising altitude before making a controlled splashdown into the open ocean.

The hypersonic vehicle flight tests would serve to demonstrate flight performance and flight worthiness. Testing would only occur in areas cleared of non-mission essential aircraft and vessels, and away from populated areas. In support of test operations at Pacific Missile Range Facility, no new facilities would be needed.

2.4 Navy Proposed Mitigation

As required to satisfy the requirements of the Marine Mammal Protection Act of 1972, as amended, the U.S. Navy 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 Permit Division’s regulations and Letter of Authorization:

2.4.1 Measures Applicable to Hull-Mounted Surface and Submarine Active Sonar

Personnel Training

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

All Commanding Officers, Executive Officers, and officers standing watch on the Bridge will have reviewed the MSAT material prior to a training event employing the use of MFAS.

Navy lookouts will undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (NAVEDTRA 12968-D) (Navy 2007b).

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.

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.

Lookout and Watchstander Responsibilities

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

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

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

On surface vessels equipped with MFAS, pedestal mounted “Big Eye” (20x110) binoculars will be present and in good working order to assist in the detection of marine mammals in the vicinity of the vessel.

Personnel on lookout will employ visual search procedures employing a scanning methodology in accordance with the Lookout Training Handbook (NAVEDTRA 12968-D) (Navy 2007b).

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

Personnel on lookout will be responsible for reporting all objects or anomalies sighted in the water (regardless of the distance from the vessel) to the Officer of the Deck, since any object or disturbance (e.g., trash, periscope, surface disturbance, discoloration) in the water may be indicative of a threat to the vessel and its crew or indicative of a marine species that may need to be avoided as warranted.

Operating Procedures

A Letter of Instruction, Mitigation Measures Message or Environmental Annex to the Operational Order will be issued prior to the exercise to further disseminate the personnel training requirement and general marine mammal protective measures.

Commanding Officers will make use of marine species detection cues and information to limit interaction with marine species to the maximum extent possible consistent with safety of the ship.

All personnel engaged in passive acoustic sonar 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.

During MFAS operations, personnel will utilize all available sensor and optical systems (such as night vision goggles) to aid in the detection of marine mammals.

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

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

Marine mammal detections will be immediately reported to assigned Aircraft Control Unit for further dissemination to ships in the vicinity of the marine species as appropriate where it is reasonable to conclude that the course of the ship will likely result in a closing of the distance to the detected marine mammal.

Safety Zones—When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically), the Navy will ensure that MFA transmission levels are limited to at least 6 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).
>
> Prior to start up or restart of MFA sonar, operators will check that the Safety Zone radius around the sound source is clear of marine mammals.

MFA sonar levels (generally)—the ship or submarine will operate MFA sonar at the lowest practicable level, not to exceed 235 dB, except as required to meet tactical training objectives.

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

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

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

Increased vigilance during major ASW training with tactical MFA sonar when critical conditions are present.

Based on lessons learned from strandings in the Bahamas (2000), Madeira (2000), the Canaries (2002), and Spain (2006), beaked whales are of particular concern since they have been associated with MFA sonar operations. 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) are 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).

MFA/HFA Sonar Use associated with training events in the Humpback Whale Cautionary Area

Humpback whales migrate to the Hawaiian Islands each winter to rear their calves and mate. Data indicate that, historically, humpback whales have clearly concentrated in high densities in certain areas around the Hawaiian Islands. NMFS has reviewed the Navy’s data on MFA sonar training in these dense humpback whale areas since June 2006 and found it to be rare and infrequent. While past data is no guarantee of future activity, it documents a history of low level MFA sonar activity in dense humpback areas. In order to be successful at operational missions and against the threat of quiet, diesel-electric submarines, the Navy has, for more than 40 years, routinely conducted ASW training in Major Exercises in the waters off the Hawaiian Islands, including the Humpback Whale National Marine Sanctuary. During this period, no reported cases of harmful effects to humpback whales attributed to MFA sonar use have occurred. Coincident with this use of MFA sonar, abundance estimates reflect an annual increase in the humpback whale stock (Mobley 2001; Mobley 2004).

NMFS and the Navy explored ways of affecting the least practicable impact (which includes a consideration of practicality of implementation and impacts to training fidelity) to humpback whales from exposure to MFA sonar. Proficiency in ASW requires that Sailors gain and maintain expert skills and experience in operating MFA sonar in myriad marine environments. Exclusion zones or restricted areas are impracticable and adversely impact MFA sonar training fidelity. The Hawaiian Islands, including areas in which humpback whales concentrate, contain unique bathymetric features the Navy needs to ensure Sailors gain critical skills and experience by training in littoral waters. Sound propagates differently in shallow water. No two shallow water areas are the same. Each shallow water area provides a unique training experience that could be critical to address specific future training requirements. Given the finite littoral areas in the Hawaiian Islands area, maintaining the possibility of using all shallow water training areas is required to ensure Sailors receive the necessary training to develop and maintain critical MFA sonar skills. In real world events, crew members will be working in these types of areas and these are the types of areas where the adversary’s quiet diesel-electric submarines will be operating. Without the critical ASW training in a variety of different near-shore environments, crews will not have the skills and varied experience needed to successfully operate MFA sonar in these types of waters, negatively affecting vital military readiness.

The Navy recognizes the significance of the Hawaiian Islands for humpback whales. The Navy has designated a humpback whale cautionary area (described below), which consists of a 5-km buffer zone that has been identified as having one of the highest concentrations of humpback whales during the critical winter months. The Navy has agreed that training exercises in the humpback whale cautionary area will require a much higher level of clearance than is normal practice in planning and conducting MFA sonar training. Should national security needs require MFA sonar training and testing in the cautionary area between 15 December and 15 April, it shall be personally authorized by the Commander, U.S. Pacific Fleet (CPF). The CPF shall base such authorization on the unique characteristics of the area from a military readiness perspective, taking into account the importance of the area for humpback whales and the need to minimize adverse impacts on humpback whales from MFA sonar whenever practicable. Approval at this level for this type of activity is extraordinary. The CPF is a four-star Admiral and the highest ranking officer in the U.S. Pacific Fleet. This case-by-case authorization cannot be delegated and represents the Navy’s commitment to fully consider and balance mission requirements with environmental stewardship. Further, CPF will provide specific direction on required mitigation prior to operational units transiting to and training in the cautionary area. This process will ensure the decisions to train in this area are made at the highest level in the Pacific Fleet, heighten awareness of humpback whale activities in the cautionary area, and serve to reemphasize that mitigation measures are to be scrupulously followed. The Navy will provide NMFS with advance notification of any such activities.

Humpback Whale Cautionary Area

The U.S. Navy and Permits Division define the Humpback Whale Cautionary Area as follows: “starting at 21-06-03N 157-04-14W (a point approximately five kilometers west of Kaunakakai on the south coast of Molokai); proceed SSW across Kalohi Channel to a point in open water at 20-54-10N 157-06-25W (approximately five kilometers west of Lanai); then to a point in open water at 20-41-45N 157-00-00W (approximately five kilometers WSW of Palaoa Point on the SW coast of Lanai); proceed ESE across Kealaikahiki Channel to a point at 20-34-27N 156-37-46W on the NW coast of Kahoolawe; then clockwise along the coast to the point 20-32-20N 156-33-12W in Kanapou Bay; then across Alalakeiki Channel to the Hanamanio lighthouse on the SW tip of Maui at 20-34-58.4N 156-24-45.2W; then clockwise along the coast to Lipoa Point on the NW tip of Maui at 21-01-29.8N 156-38-22.0W; then across Pailolo Channel to Cape Halawa on the western tip of Molokai at 21-09-29.5N 156-42-37.2W; then clockwise along the coast to the starting point described above." This cautionary area excludes the existing submarine operating area located within its boundaries.

Should national security needs require MFA sonar training and testing in the cautionary area between 15 December and 15 April, it must be personally authorized by the Commander, U.S. Pacific Fleet based on his determination that training and testing in that specific area is required for national security purposes. This authorization shall be documented by the CPF in advance of transiting and training in the cautionary area. Further, CPF will provide specific direction on required mitigation measures prior to operational units transiting to and training in the cautionary area. The Navy will provide advance notification to NMFS of any such activities. The Navy will include in its periodic reports for compliance with the MMPA whether or not activities occurred in the area above and any observed effects on humpback whales due to the conduct of these activities.

2.5 Measures Applicable to Underwater Detonations

To ensure protection of marine mammals and sea turtles during underwater detonation training and Mining Operations, the surveillance area must be determined to be clear of marine mammals and sea turtles prior to detonation. Implementation of the following mitigation measures continues to ensure that marine mammals would not be exposed to temporary threshold shift (TTS) of hearing or permanent threshold shift (PTS) of hearing. The Navy has modified the mitigation measures for activities to occur in 2012 through 2014 related to demolition and mine countermeasure activities associated with time-delay firing devices.

Demolition and Ship Mine Countermeasures Operations (up to 20 pounds)

Exclusion Zones - All Mine Warfare and Mine Countermeasures Operations involving the use of explosive charges must include exclusion zones for marine mammals and sea turtles to prevent physical or acoustic effects on those species. These exclusion zones shall extend in a 700-yard arc radius around the detonation site.

For activities involving time-delay firing devises, the revised buffer zones are specific to the size of the charge and the potential time-delay used and may be smaller than the original 700 yd buffer zone when using a short time-delay (see Table 2).

Pre-Exercise Surveillance - For Demolition and Ship Mine Countermeasures Operations, pre-exercise surveillance shall be conducted within 30 minutes prior to the commencement of the scheduled explosive event. The surveillance may be conducted from the surface, by divers, and/or from the air, and personnel shall be alert to the presence of any marine mammal or sea turtle. Should such an animal be present within the surveillance area, the exercise shall be paused until the animal voluntarily leaves the area.

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

Reporting - Any evidence of a marine mammal or sea turtle that may have been injured or killed by the action shall be reported immediately to Commander, Pacific Fleet and Commander, Navy Region Hawai'i, Environmental Director.

Sinking Exercise, Gunnery Exercise, Missile Exercise and Bombing 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 CFR §229.2), and the identification of areas with a low likelihood of encountering ESA listed species. To meet operational suitability criteria, locations must be within a reasonable distance of the target vessels' originating location. The locations should also be close to active military bases to allow participating assets access to shore facilities. For safety purposes, these locations should also be in areas that are not generally used by non-military air or watercraft. The MPRSA permit requires vessels to be sunk in waters which are at least 1,000 fathoms (6,000 ft or 1,828 m) deep and at least 50 nm from land.

In general, most listed species prefer areas with strong bathymetric gradients and oceanographic fronts for significant biological activity such as feeding and reproduction.

Although the siting of the location for the exercise is not regulated by a permit, the range clearance procedures used for Gunnery Exercise, Missile Exercise, and Bombing Exercise are the same as those described below for a SINKEX.

Underwater Detonations Mitigation Procedures

The Navy has developed range clearance procedures to maximize the probability of sighting any ships or protected species in the vicinity of an exercise, which are: All weapons firing would be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.

Extensive range clearance operations would be conducted in the hours prior to commencement of the exercise, ensuring that no shipping is located within the hazard range of the longest-range weapon being fired for that event.

An exclusion zone with a radius of 1.0 nm would be established around each target. This exclusion zone is based on calculations using a 990-pound (lb) H6 net explosive weight high explosive source detonated 5 feet (ft) below the surface of the water, which yields a distance of 0.85 nm (cold season) and 0.89 nm (warm season) beyond which the received level is below the 182 decibels (dB) re: 1 micropascal squared-seconds (μPa^2-s) threshold established for the Winston S. Churchill (ddg-81) shock trials (U.S. Department of the Navy, 2001b). An additional buffer of 0.5 nm would be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which extends from the exclusion zone at 1.0 nm out an additional 0.5 nm, would be surveyed. Together, the zones extend out 2 nm from the target.

A series of surveillance over-flights would be conducted within the exclusion and the safety zones, prior to and during the exercise, when feasible. Survey protocol would be as follows:

a. Overflights within the exclusion zone would be conducted in a manner that optimizes the surface area of the water observed. This may be accomplished through the use of the Navy's Search and Rescue Tactical Aid, which provides the best search altitude, ground speed, and track spacing for the discovery of small, possibly dark objects in the water based on the environmental conditions of the day. These environmental conditions include the angle of sun inclination, amount of daylight, cloud cover, visibility, and sea state.

b. All visual surveillance activities would be conducted by Navy personnel trained in visual surveillance. At least one member of the mitigation team would have completed the Navy’s marine mammal training program for lookouts.

c. In addition to the overflights, the exclusion zone would be monitored by passive acoustic means, when assets are available. This passive acoustic monitoring would be maintained throughout the exercise. Potential assets include sonobuoys, which can be utilized to detect vocalizing marine mammals (particularly sperm whales) in the vicinity of the exercise. The sonobuoys would be re-seeded as necessary throughout the exercise. Additionally, passive sonar onboard submarines may be utilized to detect any vocalizing marine mammals in the area. The Officer Conducting the Exercise (OCE) would be informed of any aural detection of marine mammals and would include this information in the determination of when it is safe to commence the exercise.

d. On each day of the exercise, aerial surveillance of the exclusion and safety zones would commence 2 hours prior to the first firing.

e. The results of all visual, aerial, and acoustic searches would be reported immediately to the OCE. No weapons launches or firing would commence until the OCE declares the safety and exclusion zones free of marine mammals and threatened and endangered species.

f. If a protected species observed within the exclusion zone is diving, firing would be delayed until the animal is re-sighted outside the exclusion zone, or 30 minutes have elapsed. After 30 minutes, if the animal has not been re-sighted it would be assumed to have left the exclusion zone. This is based on a typical dive time of 30 minutes for traveling listed species of concern. The OCE would determine if the listed species is in danger of being adversely affected by commencement of the exercise.

g. During breaks in the exercise of 30 minutes or more, the exclusion zone would again be surveyed for any protected species. If protected species are sighted within the exclusion zone, the OCE would be notified, and the procedure described above would be followed.

h. Upon sinking of the vessel, a final surveillance of the exclusion zone would be monitored for 2 hours, or until sunset, to verify that no listed species were harmed.

Aerial surveillance would be conducted using helicopters or other aircraft based on necessity and availability. The Navy has several types of aircraft capable of performing this task; however, not all types are available for every exercise. For each exercise, the available asset best suited for identifying objects on and near the surface of the ocean would be used. These aircraft would be capable of flying at the slow safe speeds necessary to enable viewing of marine vertebrates with unobstructed, or minimally obstructed, downward and outward visibility. The exclusion and safety zone surveys may be cancelled in the event that a mechanical problem, emergency search and rescue, or other similar and unexpected event preempts the use of one of the aircraft onsite for the exercise. The exercise would not be conducted unless the exclusion zone could be adequately monitored visually.

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

2.5.1 Mitigation measures associated with events using EER/IEER Sonobuoys

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 operations, 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 co-locate 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.

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.

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 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 a 1000 yd safety zone, visually clear of marine mammals, is maintained around each post as is done during ASW training using active sound sources.

(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.

2.5.2 Measures Applicable to Sea Turtles and Hawaiian Monk Seals on Beaches

Amphibious landings at MCTAB and Pacific Missile Range Facility shall adhere to all guidance regarding protection of sea turtles and Hawaiian monk seals on the beach relative to those areas. Mitigation measures shall be instituted to assure minimal impacts to these species. Specifically, prior to conducting a landing exercise, an inspection and survey protocol will include:

- Within one hour prior to the commencement of an amphibious landing exercise, observer(s) shall survey affected beaches for sea turtles, sea turtle nesting sites, and Hawaiian monk seals. Sea turtle nesting sites shall be marked and no trespassing by persons or vehicles within 50 ft (15 m) of the nest shall be allowed.
- Should sea turtles or Hawaiian monk seals be found on the beach, the landing shall be delayed until the animal(s) have voluntarily left the area or moved to another location free of such animals.
- Landing craft and AAV crews shall be made aware of the potential presence of these endangered and threatened species.

2.6 Scope of MMPA Letter of Authorization

The Commander, U.S. Pacific Fleet (CPF), 250 Makalapa Drive, Pearl Harbor, HI 96860-7000, and persons operating under his authority (i.e., Navy), are authorized to take marine mammals incidental to Navy exercises conducted in the Hawaii Range Complex (HRC) in accordance with 50 CFR Part 216, Subpart P – Taking Marine Mammals Incidental to U.S. Navy Training in the Hawaii Range Complex (HRC) subject to the provisions of the Marine Mammal Protection Act (16 U.S.C. 1361 et seq.; MMPA) and the following conditions:[2]

1. This Authorization is valid for the period January 15, 2012, through January 5, 2014.

2. This Authorization is valid only for the unintentional taking of the species of marine mammals and methods of take identified in 50 CFR § 216.172(c) and Condition (5) of this Authorization incidental to the activities specified in 50 CFR § 216.170(c) and Condition (4)(a) of this Authorization and occurring within the Hawaii Operating Area, which extends from 16 to 43° N. lat. and from 150 to 179° W. long.

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[2] *Numbering of this section follows the outline in the proposed LOA.*

3. This Authorization is valid only if the Holder of the Authorization or any person(s) operating under his authority implements the mitigation, monitoring, and reporting required pursuant to 50 CFR §§ 216.174 and 216.175 and implements the Terms and Conditions of this Authorization.

4. (a) This Authorization is valid for the activities and designated amounts of use listed below:

(1) The use of the following mid-frequency active sonar (MFAS) and high-frequency active sonar (HFAS) sources, or similar sources, for U.S. Navy anti-submarine warfare (ASW) training, maintenance, and research, development, testing, and evaluation (RDT&E) in the amounts indicated below:

(i) AN/SQS-53 (hull-mounted sonar) – 2,568 hours (an average of 1,284 hours annually)

(ii) AN/SQS-56 (hull-mounted sonar) – 766 hours (an average of 383 hours annually)

(iii) AN/AQS-22 or AN/AQS-13 (helicopter dipping sonar) – 2,020 dips (an average of 1,010 dips annually)

(iv) SSQ-62 (sonobuoys) – 4,846 sonobuoys (an average of 2,423 sonobuoys annually)

(v) MK-48, MK-46, or MK-54 (torpedoes) – 626 torpedoes (an average of 313 torpedoes annually)

(vi) AN/BQQ-10 or AN/BQQ-5 (submarine mounted sonar) – 400 hours (an average of 200 hours annually)

(vii) AN/SSQ-110A (IEER)/SSQ-125 (AEER) – up to eight events (an average of 1,920 buoys annually) combined of either AEER or EER/IEER

(2) The detonation of the underwater explosives indicated in (2)(i) conducted as part of the training exercises indicated in (2)(ii):

(i) Underwater Explosives:

(A) 5" Naval Gunfire – 19 lbs (an average of 9.5 lbs annually)
(B) 76 mm rounds – 3.2 lbs (an average of 1.6 lbs annually)
(C) Maverick – 157 lbs (an average of 78.5 lbs annually)
(D) Harpoon – 896 lbs (an average of 448 lbs annually)
(E) MK-82 – 476 lbs (an average of 238 lbs annually)
(F) MK-83 – 1,148 lbs (an average of 574 lbs annually)
(G) MK-84 – 1,890 lbs (an average of 945 lbs annually)
(H) MK-48 – 1,702 lbs (an average of 851 lbs annually)
(I) Demolition Charges – 40 lbs (an average of 20 lbs annually)
(J) EER/IEER – 10 lbs (an average of 5 lbs annually)

(ii) Training Events:

(A) Mine Neutralization – 136 exercises (an average of 68 exercises annually)

(B) Air-to-Surface MISSILEX – 100 exercises (an average of 50 exercises annually)

(C) Surface-to-Surface MISSILEX – 24 exercises (an average of 12 exercises annually)

(D) BOMBEX – 76 exercises (an average of 38 exercises annually)

(E) SINKEX – 12 exercises (an average of 6 exercises annually)

(F) Surface-to-Surface GUNEX – 182 exercises (an average of 91 exercises annually)

(G) Naval Surface Fire Support – 56 exercises (an average of 28 exercises annually)

(H) EER/IEER – up to eight events (an average of 1,920 buoys annually) combined of either AEER or EER/IEER

(b) If the number of sonar hours, dips, and sonobuoys, and exercises indicated in Condition 4(a)(1) are exceeded by more than 10 percent, subsequent LOAs issued under the HRC final rule will ensure that the total activities over five years do not result in exceeding the amount of authorized marine mammal takes indicated in 50 CFR 216.172(c).

(c) The sonar hours conducted as described in Condition (4)(a)(1) will be seasonally and spatially distributed such that no additional exposures of humpback whales to MFAS/HFAS would occur beyond those used to estimate take in the years with a RIMPAC.

5. This authorization is valid only for the incidental take of the following marine mammal species, and only by the indicated method and amount of take. The authorized take numbers include the total take occurring during the period from January 15, 2012 through January 5, 2014:

(a) Level B Harassment:

(i) Mysticetes:

(A) Humpback whale (*Megaptera novaeangliae*) – 2,992

(B) Minke whale (*Balaenoptera acutorostrata*) – 140

(C) Sei whale (*Balaenoptera borealis*) – 2

(D) Fin whale (*Balaenoptera physalus*) – 44

(E) Bryde's whale (*Balaenoptera edeni*) – 128

(ii) Odontocetes:

(A) Sperm whales (*Physeter macrocephalus*) – 1,600

(B) Pygmy sperm whales (*Kogia breviceps*) – 1,904

(C) Dwarf sperm whale (*Kogia sima*) – 4,668

(D) Cuvier's beaked whale (*Ziphius cavirostris*) – 2,530

(E) Blainville's beaked whale (*Mesoplodon densirostris*) – 786

(F) Longman's beaked whale (*Indopacetus pacificus*) – 232

(G) Rough-toothed dolphin (*Steno bredanensis*) – 2,370

(H) Bottlenose dolphin (*Tursiops truncatus*) – 1,614

(I) Pan-tropical dolphins (*Stenella attenuata*) – 4,838

(J) Spinner dolphins (*Stenella longirostris*) – 926

(K) Striped dolphins (*Stenella coeruleoalba*) – 7,060

(L) Risso’s dolphin (*Grampus griseus*) – 1,094

(M) Melon-headed whale (*Peponocephala electra*) – 1,314

(N) Fraser’s dolphin (*Lagenodelphis hosei*) – 2,744

(O) Pygmy killer whale (*Feresa attenuata*) – 432

(P) False killer whale (*Pseudorca crassidens*) – 102

(Q) Killer whale (*Orcinus orca*) – 102

(R) Short-finned pilot whale (*Globicephala macrorynchus*) – 3,956

(ii) Pinnipeds: Hawaiian monk seal (*Monachus schauinslandi*) – 242

(b) Level A Harassment and/or mortality of 10 individuals of each of the species listed below over the course of the 5-year regulations: Bottlenose dolphin (*Tursiops truncatus*), Pygmy and Dwarf sperm whales (*Kogia breviceps* and *sima*), Melon-headed whale (*Peponocephala electra*), Pantropical spotted dolphin (*Stenella attenuata*), Pygmy killer whale (*Feresa attenuata*), Short-finned pilot whale (*Globicephala macrorynchus*), Striped dolphin (*Stenella coeruleoalba*), Cuvier’s beaked whale (*Ziphius cavirostris*), Blainville’s beaked whale (*Mesoplodon densirostris*), and Longman’s beaked whale (*Indopacetus pacificus*).

(c) If any of the take in Condition (5)(b) occurs, it will be deducted from the take to be authorized in subsequent LOAs under 50 CFR Subpart P so as to ensure that the total taking over 5 years does not exceed the amounts indicated in Condition 5(b) and 50 CFR § 216.172(c).

2.7 Mitigation Requirements of the MMPA Letter of Authorization

The Permits Division is proposing to issue a LOA pursuant to 50 CFR 216.170(a) to the U.S. Navy to take marine mammals incidental to mid-frequency active sonar and high-frequency active sonar sources for anti-submarine warfare training, maintenance, and RDT&E activities conducted in the Hawai’i Range Complex. These activities are subject to (but not limited to) the following conditions:[3]

Mitigation - The Holder of this Authorization, and any individuals operating under his authority, must implement the following mitigation measures when conducting activities identified in 50 CFR § 216.170(c) and Condition 4(a) of this Authorization:

(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.

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[3] *Numbering of this section follows the outline in the proposed LOA.*

(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 this Authorization and NMFS’ Biological Opinion 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 (183 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 1,000 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 1,000-yard safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards (1,829 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 500-yard safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards (1,829 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 (183 m) of the sonar dome. MFAS transmissions will not resume until the marine mammal has been seen to leave the 200-yard safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yards (1,829 m) 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) Humpback Whale Cautionary Area – this area is defined as the area extending 5 km (2.7 nm) from a line drawn from Kaunakakai on the island of Molokai to Kaena Point on the Island of Lanai; and an area extending 5 km (2.7 nm) from a line drawn from Kaunolu on the Island of Lanai to the most Northeastern point on the Island of Kahoolawe; and within a line drawn from Kanapou Bay on the Island of Kahoolawe to Kanahena Point on the Island of Maui and a line drawn from Cape Halawa on the Island of Molokai to Lipoa Point on the Island of Maui, excluding the existing submarine operating area. Following are the required measures related to this area:

> (A) Should national security needs require MFAS training and testing in the cautionary area between 15 December and 15 April, it must be personally authorized by the CPF based on his determination that training and testing in that specific area is required for national security purposes. This authorization shall be documented by the CPF in advance of transiting and training in the cautionary area, and the determination shall be based on the unique characteristics of the area from a military readiness perspective, taking into account the importance of the area for humpback whales and the need to minimize adverse impacts on humpback whales from MFAS whenever practicable. Further, the CPF will provide specific direction on required mitigation measures prior to operational units transiting to and training in the cautionary area.
>
> (B) The Navy shall provide advance notification to NMFS of any such activities (listed in xxvii(A), above).
>
> (C) The Navy shall include in its periodic reports for compliance with the MMPA whether or not activities occurred in the Humpback Whale Cautionary Area described above and any observed effects on humpback whales due to the conduct of these activities.

(xxviii) The Navy shall abide by the letter of the final “Stranding Response Plan for Major Navy Training Exercises in the HRC” (Attachment A) to include the following measures:

> (A) Shutdown Procedures – When an Uncommon Stranding Event (USE – as defined in 50 C.F.R. § 216.171(b) and Attachment A) occurs during a Major Training Exercise (MTE, including RIMPAC, USWEX, or Multi-Strike Group Exercise) in the HRC, the Navy shall implement the procedures described below.
>
> > (1) The Navy shall implement a shutdown (as defined in 50 C.F.R. § 216.171(b) and Attachment A) when advised by a NMFS Office of Protected Resources Headquarters Senior Official designated in the HRC Stranding Communication Protocol of the need to implement shutdown procedures because a USE involving live animals has been identified and that at least one live animal is located in the water. NMFS and the 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 the notification of the USE the Navy will inform NMFS where and when they were conducting training (within 80 nm and 72 hours of the event) and whether or not they were operating sonar or detonating explosives. Within 7 days of the completion of any exercises that were being conducted within 80 nm or 72 hours prior to the event, the Navy will further provide information to NMFS (per the HRC Stranding Communication Protocol), as available, regarding the number and types of acoustic/explosive sources, direction and speed of units using MFAS, and marine mammal sightings information associated with those training activities. Information not initially available regarding the 80 nm, 72 hours, 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 (or classified information to qualified NMFS staff), if available.

(xxix) While in transit, Navy vessels shall be alert at all times, use extreme caution, and proceed at a "safe speed" so that the vessel can take proper and effective action to avoid a collision with any marine animal and can be stopped within a distance appropriate to the prevailing circumstances and conditions.

(xxx) When marine mammals have been sighted in the area, Navy vessels shall increase vigilance and take reasonable and practicable actions to avoid collisions and activities that might result in close interaction of naval assets and marine mammals. Actions may include changing speed and/or direction and are dictated by environmental and other conditions (e.g., safety, weather).

(2) Mitigation for IEER (SSQ-11) and AEER (SSQ-125)

(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 intended sonobuoy 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 (i.e., not the source) 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, the source sonobuoy (AN/SSQ-110A/SSQ-125) will be co-located with the receiver.

(iv) When able, crews will conduct continuous visual and aural monitoring of marine mammal activity. This shall include monitoring of aircraft sensors from the time of the first sensor placement until the aircraft have left the area and are out of RF range of these sensors.

(v) Aural Detection: If the presence of marine mammals is detected aurally, the aircrew will 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 source sonobuoy (AN/SSQ-110A/SSQ-125) intended for use, then that payload shall not be detonated (AN-SSQ-110 only) or activated (AN/SSQ-125). 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 (applies to SSQ-110 sonobuoys only; SSQ-125 sonobuoys do not contain an explosive charge). 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 ASW training using active sound sources.

(viii) Aircrews shall only leave posts with unexploded charges in the event of a sonobuoy malfunction (applies to SSQ-110 sonobuoy only), 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-110) 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 countermeasures (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 1.5 nm (2.41 km) shall be established around each target. This 1.5 nm (2.41 km) zone includes a buffer of 0.5 nm (0.93 km) to account for errors, target drift, and animal movement. In addition to the 1.5 nm (2.41 km) exclusion zone, a further safety zone, which extends from the exclusion zone at 1.5 nm 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.

(v) 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.

(vi) 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.

(vii) The exercise shall not be conducted unless the exclusion zone can be adequately monitored visually.

(viii) In the unlikely event that any marine mammals are harmed during the exercise, a detailed description of the animal shall be documented, the location noted, and if possible, photos taken. This information shall be provided to NMFS as soon as practicable.

(4) Mitigation for Underwater Detonations Using Positive Control during MINEX.

(i) Underwater detonations using positive control devices shall only be conducted during daylight hours.

(ii) A mitigation zone of 700 yd shall be established around each underwater detonation point.

(iii) A minimum of two boats shall be deployed; one boat will act as an observer platform, while the other boat will provide diver support.

(iv) Two observers will survey the detonation area and the mitigation zone for marine mammals beginning at least 30 min prior to the scheduled explosive event and lasting until at least 30 min following detonation.

(A) If a marine mammal is sighted within the 700-yd mitigation zone or moving towards it, underwater detonation events shall be suspended until the marine mammal has voluntarily left the area and the area is clear of marine mammals for at least 30 min.

(5) Mitigation for Underwater Detonations Using Time-delay firing devices (TDFDs).

(i) Underwater detonations using TDFDs shall only be conducted during daylight hours.

(ii) Time-delays longer than 10 min shall not be used.

(iii) Initiation of the firing device shall not start until the mitigation zone is clear for a full 30 min prior to initiation of the timer.

(iv) A monitoring and mitigation zone shall be established around each underwater detonation location, as indicated in (5)(iv)(A), based on charge weight and length of time-delay used.

(A)

Table 2. Monitoring and mitigation zone for underwater detonations based on charge weight and length of time-delay.

Charge Weight (lb)	Timed-Delay					
	5 min	6 min	7 min	8 min	9 min	10 min
5	1,000 yd	1,000 yd	1,000 yd	1,000 yd	1,400 yd	1,400 yd
10	1,000 yd	1,000 yd	1,000 yd	1,400 yd	1,400 yd	1,400 yd
15-29	1,000 yd	1,000 yd	1,400 yd	1,400 yd	1,500 yd	1,500 yd

(B) When conducting surveys, boats shall position themselves near the mid-point of the mitigation zone radius (but always outside the detonation plume/human safety zone) and travel in a circular pattern around the detonation location, surveying both the inner and outer areas.

(C) To the best extent practical, boats shall maintain a 10-knot search speed to ensure adequate coverage of the mitigation zone.

(v) Shallow water TDFD detonations with a mitigation zone of <1,400 yds:

(A) A minimum of two boats shall be used to survey for marine mammals.

(B) Each boat shall be positioned on opposite sides of the detonation location, separated by 180 degrees.

(vi) Shallow water TDFD detonations with a mitigation zone of ≥1,400 yds:

(A) A minimum of three boats or two boats and one helicopter shall be used to survey for marine mammals.

(B) When using at least three boats, each boat would be positioned equidistant from one another (120 degrees separation for three boats, 90 degrees separation for four boats, etc.)

(C) A helicopter, if available, can be used in lieu of one of the required boats.

(vii) Two dedicated observers in each boat would conduct continuous visual surveys of the monitoring zone for the duration of the training event.

(viii) Monitoring zones would be surveyed beginning 30 min prior to detonation and for 30 min after detonation.

(A) Divers placing the charges on mines shall observe the immediate underwater area around a detonation site for marine mammals and report sightings to surface observers.

(B) If a marine mammal is sighted within an established mitigation zone or moving towards it, underwater detonation events would be suspended until the marine mammal voluntarily leaves the area and the area is clear of marine mammals for at least 30 min.

2.8 Monitoring and Reporting

When conducting operations identified in 50 CFR § 216.170(c) and Condition 4(a), the Holder of the Authorization and any person(s) operating under his authority must implement the following monitoring and reporting measures. All reports should be submitted to the Director, Office of Protected Resources, National Marine Fisheries Service, 1315 East-West Highway, Silver Spring MD 20910 and a copy provided to the Assistant Regional Administrator for Protected Resources, Pacific Islands Regional Office, National Marine Fisheries Service, 1601 Kapiolani Boulevard, Suite 1110, Honolulu, HI 96814.

(a) The Navy must notify NMFS immediately (or as soon as clearance procedures allow) if the specified activity identified in Condition (4)(a) is thought to have resulted in the mortality or injury of any marine mammals, or in any take of marine mammals not identified in 50 C.F.R. § 216.172(c) and Condition 5.

(b) The Navy shall implement the 2012 Update to the HRC Monitoring Plan.

(c) The Navy shall comply with the Integrated Comprehensive Monitoring Program Plan and continue to improve the program, as appropriate, in consultation with NMFS.

(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 final HRC Stranding Response Plan (attachment A) to obtain more specific reporting requirements for specific circumstances.

(e) Annual HRC Monitoring Plan Report – The Navy shall submit a report on October 1, 2012 describing the implementation and results (through August 1, 2012) of the HRC Monitoring Plan, described above. The report will also include any analysis conducted or conclusions reached based on the previous year’s data that were not completed in time for the previous year’s monitoring report. 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 HRC Monitoring Plan shall, at a minimum, provide the same marine mammal observation data required in condition (7)(F). The HRC 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 HRC Exercise Report – The Navy shall submit an Annual HRC Exercise Report on October 1, 2012 (covering data gathered through August 1, 2012). This report shall contain the information identified below.

(1) MFAS/HFAS Major Training Exercises – This section shall contain the following information for Major Training Exercises (MTEs, which include RIMPAC, USWEX, and Multi Strike Group) conducted in the HRC:

(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, 500-1,000yd, 1,000-2,000yd, or >2,000yd from sonar source in (J) 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. 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) Total hours (from December through April) of hull-mounted active sonar operation occurring in the dense humpback areas generally shown on the Mobley map (73 FR 35510, 35520) plus a 5-km buffer, but not including the Pacific Missile Range Facility. The Navy shall work with NMFS to develop the exact boundaries of this area.

(iii) Total estimated annual hours of hull-mounted active sonar operation conducted in Humpback Whale Cautionary area between December 15 and April 15.

(iv) 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 RIMPAC, USWEX, or Multi-Strike Group 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 HRC. The Navy shall either include (in the HRC annual report) the Cumulative Impact Report, as described above, or provide a brief annual progress update on the status of development of the Cumulative Report.

(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 HRC); 2) the required exclusion zone (1 nm for SINKEX in HRC); (3) the required observation distance (if different than the exclusion zone (2 nm for SINKEX in HRC); 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/AEER Summary – This section shall include an annual summary of the following IEER information:

(i) Total number of IEER/AEER events conducted in the HRC

(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 identified in 50 C.F.R. § 216.170 and in Condition 4(a)(2) that are conducted in the HRC

(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 (list of email addresses and phone numbers attached) either an electronic (preferably) or verbal report within 15 calendar days after the completion of any major exercise (RIMPAC, USWEX, or Multi Strike Group) indicating:

(1) Location of the exercise

(2) Beginning and end dates of the exercise

(3) Type of exercise (e.g., RIMPAC, USWEX, or Multi Strike Group)

(h) HRC 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 HRC Exercise Reports and HRC 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 HRC, the Atlantic Fleet Active Sonar Training, the Southern California (SOCAL) Range Complex, the Mariana Islands Range Complex, the Northwest Training Range, and the Gulf of Alaska.

(j) The Navy shall respond to NMFS' comments and requests for additional information or clarification on the HRC Comprehensive Report, the draft National ASW report, the Annual HRC Exercise Report, or the Annual HRC 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 three 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.

3 APPROACH TO THE ASSESSMENT

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 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 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.

3.1 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 Hawai'i Range Complex 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 or from the use of the Extended Echo Ranging (EER/IEER/AEER) Systems;
4. Aircraft operations that occur during an exercise,
5. Amphibious landings; and
7. 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 NMFS jurisdiction) 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.

3.1.1 Exposure Analysis

Our 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. They 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 Hawai'i 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 the Hawaiian Islands (Baird et al. 2003; Baird et al. 2006; Mobley 2001; Mobley 2003; Mobley 2004; Mobley 2005; Mobley 2006; Norris et al. 2005; Smultea et al. 2008). 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, the number of 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 the Hawaiian Islands and reports from whale-watch vessels in the Hawaiian Islands, there is almost no empirical information on the distribution and abundance of marine mammals relative to active sonar associated with Navy training exercises. 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. 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 Hawai'i 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 Hawai'i Range Complex. The incidental “take” the Permits Division proposes to authorize in their proposed Letter of Authorization reflect these “take” estimates; and

2. An exposure model NMFS ESA IC 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 Hawai'i 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 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 respond given an exposure. As a result, the estimates produced by those approaches are 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 our exposure models are similar, they represent 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").

U.S. Navy Exposure Estimates

The following is a brief summary of the Navy's approach to estimating the number of marine mammals that might be exposed to activities to be conducted in the Hawai'i Range Complex over the next year (for more details, refer to Appendix K of the U.S. Navy's Hawai'i Range Complex Final Environmental Impact Statement (Navy 2008a).

The U.S. Navy's 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) (Navy 2008a), 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; Finneran et al. 2003; Finneran et al. 2005; Finneran and Schlundt. 2004; Schlundt et al. 2000b), (2) data from a reconstruction of an incident in which killer whales were probably exposed to mid-frequency active sonar (Fromme 2004), 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 would be 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 tend to overestimate the number of marine mammals that might be exposed, because the model assumes that marine mammals would not move away from sound stimuli, when in fact, 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.

NMFS Exposure Estimates

We used components of an ecological predator-prey model. The models the U.S. Navy used provided 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, $N = D \times A$ (Buckland 2001; Buckland and Borchers 1993), 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 Hawai'i, then we applied 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 of 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), and the time the predator spends searching for prey (Ts; 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:

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

The first component of this equation ($s \times 2r \times T_s$) 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 2001; Buckland and Borchers 1993). 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.

We adapted this component of the Holling’s disc equation by treating Navy vessels as the “predators” in the model, whose sensory field (2r, 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 one of the islands (for example, humpback whales that occur in the Maui basin), or the amount of time a pinniped spent in the water (in this case, for Hawaiian monk seals). This left us with the equation

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

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. For example, we distinguished between humpback whale densities in coastal and pelagic waters of Hawai'i.

We developed and simulated three separate scenarios with this model:

1. A scenario that assumed that marine mammal densities never changed and that individual animal did not move during the course of an exercise (this is the closest approximation of the U.S. Navy’s models).

2 A scenario that assumed that marine mammals would, in fact, 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). This scenario assumed that marine mammals would avoid being exposed to higher received levels of active sonar (received levels greater than 195 dB) at a faster rate than they would avoid lower received levels; we simulated avoidance by reducing marine mammal densities exponentially over time.

3. A scenario focused on humpback whales and assumed that humpback whale densities varied over the winter season in Hawai'i. Specifically, this scenario assumed that humpback whale densities during the winter months would be described by a standard normal distribution with densities increasing from zero starting in October, reaching a maximum between late-February through March, then declining to zero again through the spring.

Every scenario 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) for every scenario 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 Hawai'i Range Complex, adjusted to eliminate overlap (Navy 2008a). Finally, every scenario was 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.

Response Analysis

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 Hawai'i 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 2: 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 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 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 trade-offs (Beale and Monaghan 2004a; 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 2: Physical Damage, Mask Signal Reception, and Impair Call/Song Transmission).

Figure 2 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 this section; the specific studies, papers, and data that support our response analyses are presented in the Response Analyses section of this Opinion.

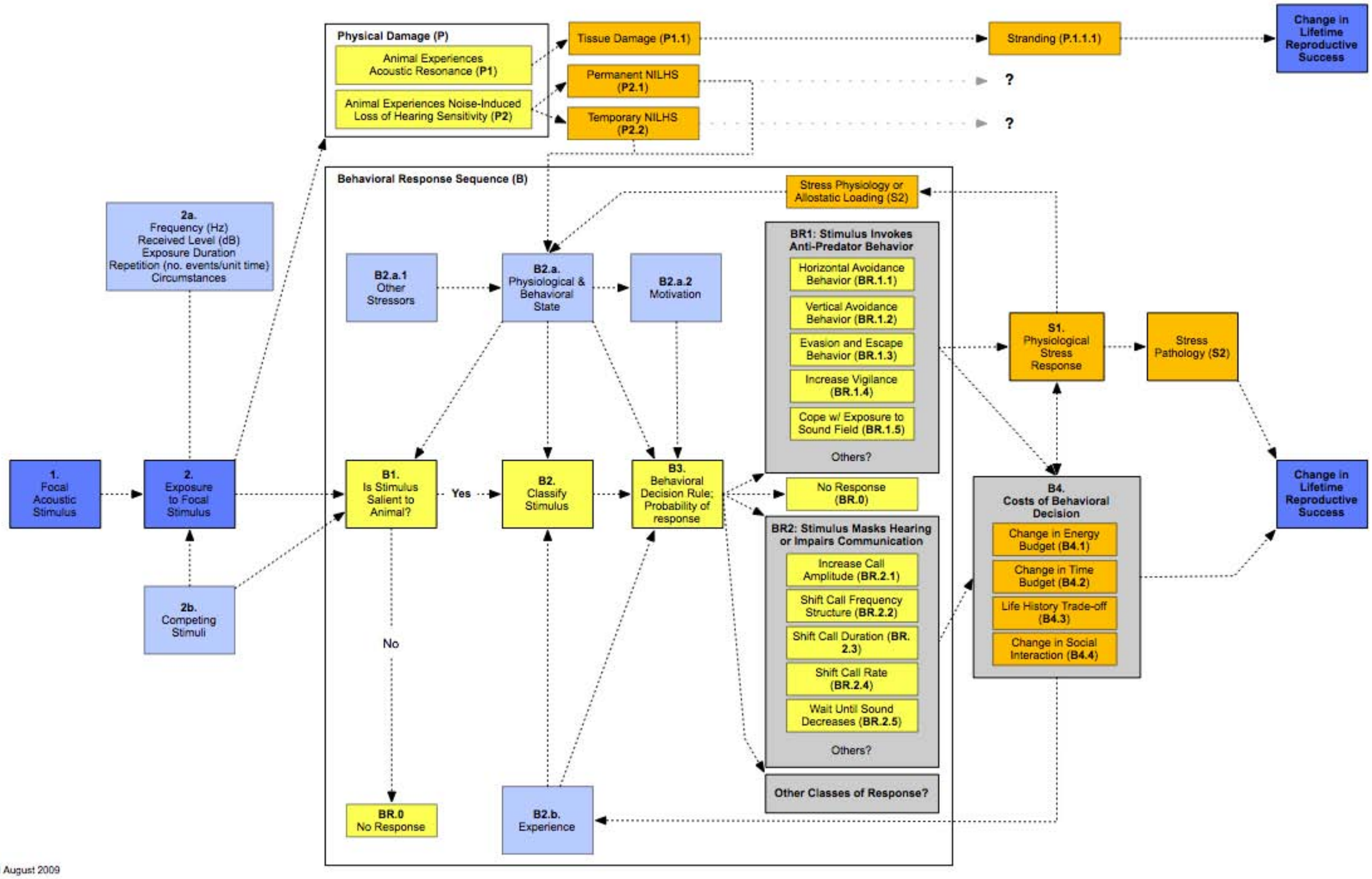

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Figure 2. Conceptual model of the potential responses of endangered and threatened species to being exposed to active sonar and the pathways by which those responses might affect the fitness of individual animals that have been exposed.

We used empirical 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

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

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, we formed the set of potential responses using the "proximate responses" identified in Figure 2 (see Table 3). 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 and 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.

To estimate 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). If we assumed, for the purposes of illustration, that 100 fin whales might be exposed to active sonar and further assumed that their probability of not 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.

We use the same response variables and analytical process for underwater detonations. Our analyses of the potential responses of endangered and threatened marine animals to vessel and aircraft traffic rely on different response variables: no response, attraction, avoidance, evasion, disturbance behavior, other adverse behavioral responses, and other positive behavioral responses. Otherwise, we use the same approach to estimate the probability of particular responses to vessel and aircraft traffic.

To estimate the number of animals that might be "taken" in this Opinion, we would classify the suite of responses (discussed in the preceding two paragraphs) 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."

Table 3. Grouping of proximate responses (identified in Figure 1) 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	Signal 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

3.1.2 Risk Analysis

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.

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 individual 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.

3.2 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 sound 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 (Bowles 1994; Croll et al. 2001a; Croll et al. 1999; Frankel and Clark 1998a; Gisiner 1998; Norris 1994; Southall et al. 2007; Tyack 2007; Tyack and Clark 2000; Wright et al. 2007).

More recently, the U.S. Navy conducted aerial and vessel surveys during Submarine Commander’s Courses conducted in 2009, 2010 and 2011, and during major training exercises (for example, the 2010 RIMPAC, 2010 and 2011 Koa Kai) and the surveys specifically looked for marine mammal behavioral reactions before and after those training events.

Thus far, none of this information reveals effects that we did not consider in either of our previous biological opinions or that would require us to reinitiate formal consultation on the activities or the Permits Division’s MMPA actions.

Despite the information that has become available since our earlier opinions, this assessment continued to involve 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 those unknowns)

3.3 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. 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 on 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.

3.4 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.

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 frequencies below 1000 Hz; however, is quite poor. On the other hand, the hearing sensitivity of most sea turtles appears 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 low frequency noise than would dolphins.

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 will be at given range along a particular transmission path).

Sound tends to follow many paths through the ocean, so that a listener may hear multiple, delayed copies of transmitted signals. 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. 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 do not follow a straight path.

Sound speed in seawater is generally 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.

As sound travels through the ocean, the intensity associated with the wave front diminishes, or attenuates. 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. 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 simple 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).

3.5 Action Area

The action area for this biological opinion encompasses the main Hawaiian Islands — Hawai'i, Kahoolawe, Kauai, Lanai, Maui, Molokai, Niihau, and Oahu — at the easternmost edge of the Hawaiian Archipelago (see Figure 1). With the exception of beach areas that might be occupied by Hawaiian monk seals, this action area is limited to those marine, coastal, and estuarine waters that are seaward of the mean higher high water line within this geographic area. With the exception of monk seals, 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.

4 STATUS OF LISTED RESOURCES

NMFS has determined that thirteen listed species or species proposed for listing under the ESA may occur within this action area for the proposed military readiness activities in the Hawai'i Range Complex (Table 4).

Table 4. Species listed under the Federal Endangered Species Act (ESA) under NMFS jurisdiction that may occur in the Action Area for the proposed military readiness activities in the Hawai'i Range Complex.

Species	ESA Status	Critical Habitat	Recovery Plan
Marine Mammals			
Blue Whale (*Balaenoptera musculus*)	E – 35 FR 18319	-- --	07/1998
Fin Whale (*Balaenoptera physalus*)	E – 35 FR 18319	-- --	71 FR 38385
Humpback Whale (*Megaptera novaeangliae*)	E -– 35 FR 18319	-- --	55 FR 29646
North Pacific Right Whale (*Eubalaena japonica*)	E – 73 FR 12024	73 FR 19000	-- --
Sei Whale (*Balaenoptera borealis*)	E – 35 FR 18319	-- --	12/2011
Sperm Whale (*Physeter macrocephalus*)	E – 35 FR 18619	-- --	75 FR 81584
Hawaiian Monk Seal (*Monachus schauinslandi*)	E – 41 FR 51611	53 FR 18988	72 FR 46966
Sea Turtles			
Green Turtle (*Chelonia mydas*)	E – 43 FR 32800	63 FR 46693	63 FR 28359
Hawksbill Turtle (*Eretmochelys imbricata*)	E – 35 FR 8491	63 FR 46693	57 FR 38818
Leatherback Turtle (*Dermochelys coriacea*)	E – 61 FR 17	44 FR 17710	63 FR 28359
Loggerhead Turtle (*Caretta caretta*)	E – 76 FR 58868	-- --	63 FR 28359
Olive Ridley Turtle (*Lepidochelys olivacea*)	E – 43 FR 32800	-- --	63 FR 28359

4.1 Species Not Considered Further in this Opinion

As described in the Approach to the Assessment, we use 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 Hawai'i Range Complex. The first criterion was exposure or some reasonable expectation of a co-occurrence between 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 listed species or 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.

4.1.1 North Pacific Right Whales

Historically, the endangered North Pacific right whale occurred in waters north of the Hawaiian archipelago (Clapham et al. 2004; Scarff 1986). However, the extremely low population numbers of this species and the rarity of reports from Hawaiian waters (despite intensive whale surveys in Hawai'i, the only sighting in recent years was in the late 1970s as reported by Herman et al. (1980) suggests that these right whales have a very low probability of being exposed to ship and aircraft traffic, sonar transmissions, underwater detonations, amphibious landings, and gunfire and missile exercises associated with the activities considered in this Opinion.

In the event right whales are exposed to mid-frequency sonar, the information available on right whale vocalizations suggests that right whales produce moans less than 400 Hz in frequency (Spero 1981; Thompson et al. 1979; Watkins and Schevill 1972). 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. Therefore, this species will not be considered in greater detail in the remainder of this Opinion.

4.2 Critical Habitat

In addition to these species, critical habitat that has been designated for Hawaiian monk seals also occurs in the action area. In May 1988, NMFS designated critical habitat for the Hawaiian monk seal out from shore to 20 fathoms in 10 areas of the northwestern Hawaiian Islands. Critical habitat for these species includes all beach areas, sand spits and islets, including all beach crest vegetation to its deepest extent inland, lagoon waters, inner reef waters, and ocean waters out to a depth of 20 fathoms around the following: Kure Atoll, Midway Islands, except Sand Island and its harbor, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, French Frigate Shoals, Necker Island, and Nihoa Island (50 CFR §226.201).

None of the proposed exercises are scheduled to occur in currently designated critical habitat of the Hawaiian monk seal (i.e., ocean waters out to 20 fathoms depth). In addition, the proposed naval exercises are not likely to adversely affect prey species of the Hawaiian monk seals. As a result, the proposed exercises are not likely to adversely affect the conservation value of the critical habitat that has been designated for Hawaiian monk seals.

NMFS proposed an expansion of critical habitat for Hawaiian monk seals in 2011 (76 FR 32026) to include near shore areas of the main Hawaiian Islands but excluded Navy training areas near Puuloa Training Range and the Naval Defensive Sea Area. However, other areas proposed for critical habitat designation may be impacted by Navy activities (76 FR 32026). If critical habitat is designated as proposed, then reinitiation of consultation under the ESA may be necessary.

Critical habitat was designated in 1998 for green turtles and hawksbill sea turtles in coastal waters around Culebra Island, Puerto Rico. In 1979, NMFS designated critical habitat for leatherback turtles to include the coastal waters adjacent to Sandy Point, St. Croix, U.S. Virgin Islands. Because these areas of sea turtle critical habitat are far removed from the Hawai'i Range Complex, the proposed actions would not impact these areas. As a result, the proposed exercises are not likely to adversely affect the conservation value of the critical habitat that has been designated for sea turtles.

4.3 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. The threats posed by the direct and indirect effects of global climate change are, 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 5).

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 2001; IPCC 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 5. 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 percent 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 sea 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 a 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 temperatures 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. 1990; Payne 1986); 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 which influences the abundance of marine mammal prey such as zooplankton and fish. In the 1970s and 1980s, the North Atlantic Oscillation Index has been positive and sea surface temperatures increased. These increases 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. 2003a). In the late 1980s and 1990s, the North Atlantic Oscillation 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 (Drinkwater et al. 2003; Pershing et al. 2010). 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. 2003b).

Although the North Atlantic Oscillation 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. 2003b) 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 turtle 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 ocean currents, the future climates that are forecast place sea turtles at substantially greater risk of extinction than they already face.

As of the date this Opinion was drafted, we do not know whether the computer models on which these projections are based are accurate or, if so, how far into the future these effects might become manifest because these are long-term projections. Nevertheless, based on the best scientific and commercial data available, none of these effects are likely to affect the status or trend of the endangered or threatened species we considered in our 2008 programmatic biological opinion on military readiness activities on the Hawai'i Range Complex or the activities that would occur during the twelve month interval of the proposed Letters of Authorization.

4.4 Species Considered Further in this Opinion

The rest of this section 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 Hawai'i Range Complex from January 2012 to January 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 how the different species are likely to respond to sounds produced by detonations.

More detailed background information on the status of these species can be found in a number of published documents including status reviews, recovery plans for the blue whale (NMFS 1998b), fin whales (NMFS 2010a), fin and sei whale (NMFS 1998a),(NMFS 2011a), humpback whale (NMFS 1991), sperm whale (NMFS 2010b), a status report on large whales prepared by Perry et al. (1999a) and recovery plans for sea turtles (NMFS and USFWS 1998a; NMFS and USFWS 1998c; NMFS and USFWS 1998d; NMFS and USFWS 2008; NMFS et al. 2010). Richardson et al. (1995a) and Tyack (2000b) provide detailed analyses of the functional aspects of cetacean communication and their responses to active sonar. Finally, Croll et al. (1999), NRC (2000a; 2003a; 2005), and Richardson and Wursig (1995) provide information on the potential and probable effects of active sonar on the marine animals considered in this Opinion.

4.4.1 Blue Whale

The blue whale, *Balaenoptera musculus* (Linnæus 1758), is a cosmopolitan species of baleen whale. Blue whales are the largest species of whale. Blue whales in the Northern Hemisphere are generally smaller than those in the Southern Ocean. Maximum body length in the North Atlantic was about 88.5 feet (27 m) and the largest blue whale reported from the North Pacific was about 88 feet (26.8 m). Adults in the Antarctic can reach a maximum body length of about 108 feet (33 m) and can weigh more than 330,000 pounds (150,000 kg).

As is true of other baleen whale species, female blue whales are somewhat larger than males. Blue whales are identified by the following characteristics: a long-body and comparatively slender shape; a broad, flat "rostrum" when viewed from above; a proportionately smaller dorsal fin than other baleen whales; and a mottled gray color pattern that appears light blue when seen through the water.

Distribution

Blue whales are found along the coastal shelves of North America and South America (Clarke 1980; Donovan 1984; Rice 1989) 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.

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; Gagnon and Clark 1993; Wenzel et al. 1988; Yochem and Leatherwood 1985). 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 1987a). In the eastern North Atlantic Ocean, blue whales have been observed off the Azores Islands, although Reiner et al. (1996) 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 Underwater 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).

There have only been a few reliable reports of blue whales from the Gulf of Mexico and these have been of animals that had stranded in 1924 and 1940 (Würsig et al. 2000). They are assumed to be extralimital in the Gulf of Mexico.

In the North Pacific Ocean, blue whales have been recorded off the island of Oahu in the main Hawaiian Islands and off Midway Island in the western edge of the Hawaiian Archipelago (Barlow 1994; Northrop et al. 1971; Thompson and Friedl 1982), although blue whales are rarely sighted in Hawaiian waters and have not been reported to strand in the Hawaiian Islands. Nishiwaki (1966) reported that blue whales occur in the Aleutian Islands and in the Gulf of Alaska. Fifteen blue whale sightings off British Columbia and in the Gulf of Alaska have been made since 1997

(Calambokidis et al. 2009). Three of these photographically verified sightings were in the northern Gulf of Alaska within 71 nm of each other and were less than 100 nm offshore (Calambokidis et al. 2009).

In the eastern tropical Pacific Ocean, the Costa Rica Dome appears to be important for blue whales based on the high density of prey (euphausiids) available in the Dome and the number of blue whales that appear to reside there (Reilly and Thayer 1990). Blue whales have been sighted in the Dome area in every season of the year, although their numbers appear to be highest from June through November.

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 distinct (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 the edge of Antarctic ice (south of 58° S) with concentrations between 60°-80° E and 66°-70° S (Kasamatsu 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 Futuymda (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 there may be more than one blue whale population in the Pacific Ocean Gilpatrick et al. (1997), Barlow et al.

(1995), Mizroch et al. (1984), Ohsumi and Wada (1972). 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 (Barlow 1997; Calambokidis et al. 1990; Sears 1987b).

A population or “stock” of endangered blue whales occurs in waters surrounding the Hawaiian archipelago (from the main Hawaiian Islands west to at least Midway Island), although blue whales are rarely reported from Hawaiian 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 1998b). However, acoustic monitoring has recorded blue whales off Oahu and the Midway Islands much more recently (McDonald and Fox 1999b; 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 (McDonald and Fox 1999b; Thompson and Friedl 1982). Twelve aerial surveys were flown within 25 nm^2 of the main Hawaiian 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 whale strandings in Hawaiian 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 include predation and disease (not necessarily in their order of importance). Blue whales are known to become infected with the nematode *Crassicauda boopis* (Baylis 1928), which are believed to have caused fin whales to die as a result of renal failure (Lambertsen 1986a); 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. 1999a).

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 (Cherfas 1992; Tonnessen and Johnsen 1982). 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 2005).

From 1889 to 1965, whalers killed about 5,761 blue whales in the North Pacific Ocean (NMFS 1998b). From 1915 to 1965, the number of blue whales captured declined continuously (Mizroch et al. 1984). Evidence of a population decline was seen 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. 1984).

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 Jr. 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 were implicated in the deaths of blue whales off California (Barlow 1997). More recently, Berman-Kowalewski et al. (2010) reported that between 1988 and 2007, 21 blue whale deaths were reported along the California coast, typically one or two cases annually. 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 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).

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 (IUCN 2010). 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 populations 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 there were 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). 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 approximately 1,400 to 1,900. Barlow (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 1974b) to 1,000 to 2,000 individuals (Sigurjónsson 1995). Gambell (1976) estimated there were between 1,100 and 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 (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, and Allee effects, among others, that cause their population size to become a threat in and of itself) or if blue whales 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

Blue whales spend more than 94 percent of their time underwater (Lagerquist et al. 2000). Generally, blue whales dive 5-20 times at 12-20 sec intervals before a deep dive of 3-30 min (Mackintosh 1965) (Croll et al. 1999; Leatherwood et al. 1976; Maser et al. 1981; Yochem and Leatherwood 1985). Average foraging dives are 140 m deep and last for 7.8 min (Croll et al. 2001b). Non-foraging dives are shallower and shorter, averaging 68 m and 4.9 min (Croll et al. 2001b). However, dives of up to 300 m are known (Calambokidis et al. 2003). Nighttime dives are generally shallower (50 m).

Blue whales occur singly or in groups of two or three (Aguayo 1974; Mackintosh 1965; Nemoto 1964; Pike and Macaskie. 1969; Ruud 1956; Slijper 1962). However, larger foraging aggregations, even with other species such as fin whales, are regularly reported (Fiedler et al. 1998; Schoenherr 1991). 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; Cummings and Thompson 1977; Edds-Walton 1997; Thompson and Friedl 1982). Blue whales produce a variety of low frequency sounds in the 10-100 Hz band (Clark and Fristrup. 1997; Cummings and Thompson 1971; McDonald et al. 2001; Thompson and Friedl 1982). 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; Cummings and Thompson 1977; Cummings and Thompson 1994).

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; maintenance of inter-individual distance, species and individual recognition, contextual information transmission, maintenance of social organization, location of topographic features, and location of prey. Responses to conspecific sounds have been demonstrated in a number of mysticetes, and there is no reason to believe that blue 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 (Edds-Walton 1997; Payne and Webb. 1971). The long-range sounds may also be used for echolocation in orientation or navigation (Tyack 1999b).

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 1999b). 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.

4.4.2 Fin Whale

Fin whales are the second-largest species of whale, with a maximum length of about 75 ft (22 m) in the Northern Hemisphere, and 85 ft (26 m) in the Southern Hemisphere. Fin whales show mild sexual dimorphism, with females measuring longer than males by 5-10 percent. Adults can weigh between 80,000-160,000 lbs (40-80 tons).

Fin whales have a sleek, streamlined body with a V-shaped head. They have a tall, falcate dorsal fin, located about two-thirds of the way back on the body, that rises at a shallow angle from the animal's back. The species has a distinctive coloration pattern: the back and sides of the body are black or dark brownish-gray, and the ventral surface is white. The unique, asymmetrical head color is dark on the left side of the lower jaw, and white on the right side. Many individuals have several light-gray, V-shaped "chevrons" behind their head, and the underside of the tail flukes is white with a gray border.

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 1985a).

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 1985a).

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 1985a).

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 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. Fin whales in the eastern North Atlantic have been found in highest densities in the Irminger Sea between Iceland and Greenland (Víkingsson et al. 2009). In the Atlantic Ocean, a general migration in the fall from the Labrador and Newfoundland region, south past Bermuda, and into the West Indies has been theorized (Clark 1995). Historically, fin whales were by far the most common large whale found off Portugal (Brito et al. 2009).

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.

Fin whales have been reported more frequently than blue whales in the Gulf of Mexico, although many of these reports are probably of Bryde’s whales, which are more common in the Gulf. Like blue whales, fin whales are assumed to occur only extralimitally in the Gulf of Mexico (Jefferson and Schiro 1997; Würsig et al. 2000).

Population Structure

Fin whales have two recognized subspecies: *Balaoptera physalus physalus* 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" are 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 demonstrated that individual fin whales migrate between management units (Mitchell 1974a; Sigurjonsson et al. 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 has lower genetic diversity, which suggests that these fin whales might represent an isolated population.

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. 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). Killer whale or shark attacks may injure or kill very young or sick whales (Perry et al. 1999a).

Anthropogenic Threats. Fin whales have undergone significant exploitation, but are currently protected under the IWC's global moratorium on whaling. Fin whales are still hunted in subsistence fisheries off West Greenland. In 2004, five males and six females were killed, and two other fin whales were struck and lost. In 2003, two males and four females were landed and two others 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. However, the scientific recommendation was to limit the number killed to four individuals until accurate populations could be produced (IWC 2005). 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 planned to kill 50 whales per year starting in the 2007-2008 season and continuing for the next 12 years (IWC 2006; Nishiwaki et al. 2006).

Fin whales experience significant injury and mortality from fishing gear and ship strikes (Carretta et al. 2007; Douglas et al. 2008; Lien 1994; Perkins and Beamish 1979; Waring et al. 2007). Between 1969 and 1990, 14 fin whales were captured in coastal fisheries off Newfoundland and Labrador; of these seven are known to have died because of capture (Lien 1994; Perkins and Beamish 1979). In 1999, one fin whale was reported killed in the Gulf of Alaska pollock trawl fishery and one was killed the same year in the offshore drift gillnet fishery (Angliss and Outlaw 2005; Carretta and Chivers. 2004). According to Waring et al. (2007), four fin whales in the western North Atlantic died or were seriously injured in fishing gear, while another five were killed or injured as a result of ship strikes between January 2000 and December 2004. Jensen and Silber (2004) review of the NMFS' ship strike database revealed fin whales as the most frequently confirmed victims of ship strikes (26 percent of the recorded ship strikes [n = 75/292 records]), with most collisions occurring off the east coast, followed by the west coast of the U.S. and Alaska/Hawaii. Between 1999-2005, there were 15 reports of fin whales strikes by vessels along the U.S. and Canadian Atlantic coasts (Cole et al. 2005; Nelson et al. 2007). Of these, 13 were confirmed, resulting in the deaths of 11 individuals. Five of seven fin whales stranded along Washington State and Oregon showed evidence of ship strike with incidence increasing since 2002 (Douglas et al. 2008). Similarly, 2.4 percent of living fin whales from the Mediterranean show ship strike injury and 16 percent of stranded individuals were killed by vessel collision (Panigada et al. 2006b). There are also numerous reports of ship strikes off the Atlantic coasts of France and England (Jensen and Silber 2004).

Management measures aimed at reducing the risk of ships hitting right whales should also reduce the risk of collisions with fin whales. In the Bay of Fundy, recommendations for slower vessel speeds to avoid right whale ship strike appear to be largely ignored (Vanderlaan et al. 2008). However, new rules for seasonal (June through December) slowing of vessel traffic to 10 knots and changing shipping lanes by less than one nautical mile to avoid the greatest concentrations of right whales are predicted to be capable of reducing ship strike mortality by 27 percent in the Bay of Fundy region.

The organochlorines DDE, DDT, and PCBs have been identified from fin whale blubber, but levels are lower than in toothed whales due to the lower level in the food chain that fin whales feed at (Aguilar and Borrell 1988; Borrell 1993; Borrell and Aguilar 1987; Henry and Best 1983; Marsili and Focardi 1996). Females contained lower burdens than males, likely due to mobilization of contaminants during pregnancy and lactation (Aguilar and Borrell 1988; Gauthier et al. 1997). Contaminant levels increase steadily with age until sexual maturity, at which time levels begin to drop in females and continue to increase in males (Aguilar and Borrell 1988).

Climate change also presents a potential threat to fin whales, particularly in the Mediterranean Sea, where fin whales appear to rely exclusively upon northern krill as a prey source. These krill occupy the southern extent of their range and increases in water temperature could result in their decline and that of fin whales in the Mediterranean Sea (Gambaiani et al. 2009).

Status

Fin whales were listed as endangered under the ESA in 1970. In 1976, the IWC protected fin whales from commercial whaling. Fin whales are listed as endangered on the IUCN Red List of Threatened Animals (IUCN 2010). 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 populations prior to whaling and (2) estimates of the current size of the different fin whale populations vary widely (NMFS 2006). We may never know the size of the fin whale populations 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 percent 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 2006); however, the recovery plan also states that this estimate, which is based 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 2010a). 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 percent since the early 1980s. The 2010 U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment Report indicates the best abundance estimate for the western North Atlantic fin whale stock is 3,985 (cv=0.24) based on 2006 Gulf of Maine surveys and 2007 northern Labrador to Scotian Shelf surveys (Waring et al. 2011).

The East Greenland-Iceland fin whale population was estimated at 10,000 animals (95 percent 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 percent 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 percent 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, and 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 dives lasting 13-20 seconds followed by a deep dive lasting between 1.5 and 15 minutes (Gambell 1985a). 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 et al. 1981).

In waters off the Atlantic Coast of the U.S. individual fin whales or pairs represented about 75 percent 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 percent 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 (Edds 1988b; Thompson et al. 1992; Watkins et al. 1981; Watkins et al. 1987). 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; Thompson et al. 1992; Watkins et al. 1987). 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 (Clarke and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald et al. 1995b). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999b).

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 1999b). The seasonality and stereotype of the bouts of patterned sounds suggest that these sounds are male reproductive displays (Watkins et al. 1987), while the individual counter-calling data of McDonald et al. (1995b) suggest that the more variable calls are contact calls. Some authors feel there are 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: 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 (Edds-Walton 1997; Payne and Webb. 1971). 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 1999b).

A general description of the anatomy of the ear for cetaceans is provided in the description of the blue whale above; that description is also applicable to fin whales.

4.4.3 Humpback Whale

Humpback whales are well known for their long "pectoral" fins, which can be up to 15 feet (4.6 m) in length. Their scientific name, *Megaptera novaeangliae*, means "big-winged New Englander" as the New England population was the one best known to Europeans. These long fins give them increased maneuverability; they can be used to slow down or even go backwards.

Similar to all baleen whales, adult females are larger than adult males, reaching lengths of up to 60 feet (18 m). Their body coloration is primarily dark grey, but individuals have a variable amount of white on their pectoral fins and belly. This variation is so distinctive that the pigmentation pattern on the undersides of their "flukes" is used to identify individual whales, similar to a humans fingerprint.

Humpback whales are the favorite of whale watchers, as they frequently perform aerial displays, such as breaching (jumping out of the water), or slap the surface with their pectoral fins, tails, or heads.

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 (Johnson and Wolman 1984; Nemoto 1957; Tomilin 1967). These whales migrate to Hawai'i, southern Japan, the Mariana Islands, and Mexico during the winter.

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 the coast of Norway in the Barents Sea. These humpback whales migrate to the western coast of Africa and the Caribbean Sea during the winter (Boye et al. 2010; Katona and Beard 1990; Smith et al. 1999b).

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; Rasmussen et al. 2007).

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 Hawaiian 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 Hawaiian 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.

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.

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. 1999a). The principal breeding range for these whales lies from the Antilles and northern Venezuela to Cuba (Balcomb III and Nichols Jr. 1982; Whitehead 1982; Winn et al. 1975). 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; Smith et al. 1999a) (Clapham 1993; Mattila et al. 1994; Palsbøll et al. 1997; Stevick et al. 2003). 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 (Levenson and Leapley 1978; Swartz et al. 2003; Winn et al. 1975). Winter aggregations also occur at the Cape Verde Islands in the Eastern North Atlantic (Reiner et al. 1996) (Reeves and Smith. 2002). 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 (Florezgonzalez et al. 1994; 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. 1999a). 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 Hawaiian 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 Hawaiian waters; 16 of these reports were from 2005 and 2006.

Many of the entangled humpback whales observed in Hawaiian 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 Hawaiian Islands have been confirmed to have been entangled in gear from Alaska. Nevertheless, humpback whales are also entangled in fishing gear in the Hawaiian 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 2003a). 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 percent) 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 a 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, and South Africa.

Status

Humpback whales were listed as endangered under the ESA in 1973. Humpback whales are listed as a species of least concern on the IUCN Red List of Threatened Animals (IUCN 2010). 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 percent 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 1985b; Baker and Herman. 1987; Calambokidis et al. 1997; Darling and Morowitz 1986). 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. 2001).

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 Hawaiian 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 percent 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, and 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 Hawaiian 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). 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). 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 and Mayo (1987) 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; Clapham 1996), and calving areas. 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). Inter-male 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 to 4 kHz with estimated source levels from 144 to 174 dB, which are mostly produced by males on breeding areas (Richardson et al. 1995a; Winn et al. 1970); (2) social sounds in breeding areas that extend from 50 Hz to more than 10 kHz with most energy below 3 kHz (Richardson et al. 1995a; Tyack 1983); 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 (Richardson et al. 1995a; Thompson et al. 1986). 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 (Silber 1986; Tyack and Whitehead. 1983). 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 blue 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 III 2000; Richardson et al. 1995a; Winn et al. 1970);

2. Social sounds in the breeding areas that extend from 50Hz – more than 10 kHz with most energy below 3 kHz (Richardson et al. 1995a; Tyack 1983); 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 (Richardson et al. 1995a; Thompson et al. 1986).

Helweg et al. (2000) produced a mathematical model of a humpback whales 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 0.7 kHz to 10 kHz, with a maximum sensitivity between 2 and 6 kHz.

4.4.4 Sei Whale

Sei whales (pronounced "say" or "sigh") are members of the baleen whale family and are considered one of the "great whales" or rorquals. Two subspecies of sei whales are recognized, *B. b. borealis* in the Northern Hemisphere and *B. B. schlegellii* in the Southern Hemisphere.

These large animals can reach lengths of about 40-60 ft (12-18 m) and weigh 100,000 lbs (45,000 kg). Females may be slightly longer than males. Sei whales have a long, sleek body that is dark bluish-gray to black in color and pale underneath. The body is often covered in oval-shaped scars (probably caused from cookie-cutter shark and lamprey bites) and sometimes has subtle "mottling". This species has an erect "falcate", "dorsal" fin located far down (about two-thirds) the animals back. They often look similar in appearance to Bryde's whales, but can be distinguished by the presence of a single ridge located on the animal's "rostrum". Bryde's whales, unlike other rorquals, have three distinct prominent longitudinal ridges on their rostrum. Sei whales have 219-410 baleen plates that are dark in color with gray/white fine inner fringes in their enormous mouths. They also have 30-65 relatively short ventral pleats that extend from below the mouth to the naval area. The number of throat grooves and baleen plates may differ depending on geographic population.

When at the water's surface, sei whales can be sighted by a columnar or bushy blow that is about 10-13 feet (3-4 m) in height. The dorsal fin usually appears at the same time as the blowhole, when the animal surfaces to breathe. This species usually does not arch its back or raise its flukes when diving.

Sei whales are usually observed singly or in small groups of 2-5 animals, but are occasionally found in larger (30-50) loose aggregations. Sei whales are capable of diving 5-20 minutes to opportunistically feed on plankton (e.g., copepods and krill), small schooling fish, and cephalopods (e.g., squid) by both gulping and skimming. They prefer to feed at dawn and may exhibit unpredictable behavior while foraging and feeding on prey. Sometimes seabirds are associated with the feeding frenzies of these and other large whales.

Sei whales become sexually mature at 6-12 years of age when they reach about 45 ft (13 m) in length, and generally mate and give birth during the winter in lower latitudes. Females breed every 2-3 years, with a gestation period of 11-13 months. Females give birth to a single calf that is about 15 ft (4.6 m) long and weighs about 1,500 lbs (680 kg). Calves are usually nursed for 6-9 months before being weaned on the preferred feeding grounds. Sei whales have an estimated lifespan of 50-70 years.

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. 1999a). 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. 2011; Waring et al. 2004).

In the western Atlantic Ocean, sei whales occur from Labrador and Nova Scotia, in the summer months and migrate south to Florida, and the northern Caribbean (Gambell 1985b; 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 1977) (Gambell 1985a). Sei whales have been reported with about the same frequency as fin whales in the Gulf of Mexico, although there are still only five reliable records of sei whales from the Gulf. Like blue and fin whales, sei whales are assumed to occur only extralimitally in the Gulf of Mexico.

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). Historically, sei whales had been observed north of 20̣°̃23°N Masaki (1977), Gambell (1985a) in the winter, however, a recent survey in the Mariana Islands observed sei whales as far south as 11°N (Fulling et al. 2011);. Harwood (1987) reported that 75 – 85 percent 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 1975b).

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 (Perry et al. 1999a). 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 scarcer. 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 three sei whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, two 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 sei whales were given full protection in 1976. 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 (IUCN 2010; Reilly et al. 2008). 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 Masaki (Ohsumi and Masaki 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 (Mitchell and Chapman 1977).

About 50 sei whales are estimated to occur in the North Pacific “stock” with another 77 sei whales in the Hawaiian “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 (Mitchell 1975b) 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, and Allee effects, among others, that cause their population size to become a threat in and of itself) or if sei whales 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.

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 et al. 1999; Fagan et al. 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 1985a). 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 1985a).

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 a 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. 1995a).

During visual and acoustic surveys conducted in the Hawaiian 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 vocalizations 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 Hawaiian 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 2007b). 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. 2008).

A general description of the anatomy of the ear for mysticetes is provided in the preceding description of the blue whale.

4.4.5 Sperm Whale

Sperm whales (*Physeter macrocephalus*) are the largest of the odontocetes (toothed whales) and the most sexually dimorphic cetaceans, with males considerably larger than females. Adult females may grow to lengths of 36 feet (11 m) and weigh 15 tons (13607 kg). Adult males, however, reach about 52 feet (16 m) and may weigh as much as 45 tons (40823 kg).

The sperm whale is distinguished by its extremely large head, which takes up to 25 to 35 percent of its total body length. It is the only living cetacean that has a single blowhole asymmetrically situated on the left side of the head near the tip. Sperm whales have the largest brain of any animal (on average 17 pounds (7.8 kg) in mature males); however, compared to their large body size, the brain is not exceptional in size.

There are between 20-26 large conical teeth in each side of the lower jaw. The teeth in the upper jaw rarely erupt and are often considered to be vestigial. It appears that teeth may not be necessary for feeding, since they do not break through the gums until puberty, if at all, and healthy sperm whales have been caught that have no teeth.

Sperm whales are mostly dark gray, but oftentimes the interior of the mouth is bright white, and some whales have white patches on the belly. Their flippers are paddle-shaped and small compared to the size of the body, and their flukes are very triangular in shape. They have small dorsal fins that are low, thick, and usually rounded.

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 (Christensen et al. 1992; Gunnlaugsson and Sigurjonsson 1990; Oien 1990).

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 Gordon 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.

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 Scott and Sadove (135-180 ft; 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

There is no clear understanding of the global population structure of sperm whales (Dufault et al. 1999). Recent ocean-wide genetic studies indicate low, but statistically significant, genetic diversity and no clear geographic structure, but strong differentiation between social groups (Lyrholm and Gyllensten 1998; Lyrholm et al. 1996; Lyrholm et al. 1999). The IWC currently recognizes four sperm whale stocks: North Atlantic, North Pacific, northern Indian Ocean, and Southern Hemisphere (Dufault et al. 1999; Reeves and Whitehead 1997). The NMFS recognizes six stocks under the MMPA- three in the Atlantic/Gulf of Mexico and three in the Pacific (Alaska, California-Oregon-Washington, and Hawaii; (Perry et al. 1999a; Waring et al. 2004). Genetic studies indicate that movements of both sexes through expanses of ocean basins are common, and that males, but not females, often breed in different ocean basins than the ones in which they were born (Whitehead and Mesnick 2003). Sperm whale populations appear to be structured socially, at the level of the clan, rather than geographically (Whitehead 2003; Whitehead 2008).

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 (Fritts et al. 1983; Hansen et al. 1995; Schmidly 1981), although the International Whaling Commission does not recognize these sperm whales as a separate population or "stock."

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 (1975a) reported one sperm whale that was tagged on the Scotian Shelf and killed about 7 years later off Spain. Donovan (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).

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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. 1999b).

Pacific Ocean: Several authors have proposed population structures that recognize at least three sperm whales populations in the North Pacific for management purposes (Bannister and Mitchell 1980; Kasuya 1991). 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 Hawaiian Islands throughout the year and are the most abundance large whale in waters off Hawai'i during the summer and fall (Lee 1993; Mobley et al. 2000; Shallenberger et al. 1981). Sperm whale clicks recorded from hydrophones off Oahu confirm the presence of sperm whales near the Hawaiian 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 Hawaiian 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. 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 Hawaiian 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 Hawaiian 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 (Dufault and Whitehead 1995; Wade and Gerrodette 1993).

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; Weller et al. 1996). Sperm whales have been observed with bleeding wounds their heads and tail flukes after attacks by these species (Arnbom et al. 1987; Palacios and Mate. 1996; Weller et al. 1996). 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 (Lambertsen 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 (Lambertsen et al. 1987; Smith and Latham 1978). 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. (1999a) 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 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 (IWC) 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.

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.

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 1997). Interactions between longline fisheries and sperm whales in the Gulf of Alaska have been reported over the past decade (Hill et al. 1999; Rice 1989). 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 et al. 1999). 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 as a vulnerable species (IUCN 2010) 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. 1999b), 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. 1999b). 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 is about 20 percent 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.

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 percent 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.

A mark recapture analysis using photo-identification images in the Gulf of Mexico resulted in a population estimate of 281 with 95 percent confidence intervals of 202-434 (Jochens et al. 2008). This is in general agreement with, though a little lower than, the population sizes indicated by visual surveys.

The information available on the status and trend of sperm whales do not allow us to make a 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 females 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 and Mesnick 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).

A draft Recovery Plan written in 2006 was finalized in December 2010 (NMFS 2010b).

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 (Goold and Jones 1995; Weilgart et al. 1993; Weilgart and Whitehead. 1997). 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 (but see Clarke 1979; Cranford 1992; Norris and Harvey. 1972). 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 (Goold and Jones 1995; Weilgart and Whitehead. 1993; Weilgart and Whitehead. 1997). 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 et al. 1993; Watkins and Schevill 1975). 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. 1995b). 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.

4.4.6 Hawaiian Monk Seal

The Hawaiian monk seal has a silvery-grey colored back with lighter creamy coloration on the underside; newborns are black. Additional light patches and red and green tinged coloration from attached algae are common. The back of the animals may become darker with age, especially in males. Adults generally range in size from 375 lbs-450 lbs (170-205 kg); females are slightly larger than males; pups are 35 lbs (16 kg) at birth. Monk seals grow to 7.0-7.5 feet (2.1-2.3 m) in length with females being slightly larger than males; pups are 3 feet (1 m) at birth. The lifespan is estimated at 25-30 years.

Distribution

The Hawaiian monk seal is found primarily on the Northwest Hawaiian Islands, especially Nihoa, Necker, French Frigate Shoals, Pearl and Hermes Reef, Kure Atoll, Laysan, and Lisianski. Sightings on the main Hawaiian Islands have become more common in the past 15 years and monk seals have been born on the Islands of Kauai, Molokai, Niihau, and Oahu (Carretta et al. 2005; Johanos and Baker. 2004; Kenyon 1981). Midway was an important breeding rookery, but is now used by a small number of monk seals (Reeves et al. 1992). Hawaiian monk seals breed primarily at Laysan Island, Lisianski Island, and Pearl and Hermes Reefs (Tomich 1986). Monk seals have been reported on at least three occasions at Johnston Island over the past 30 years (not counting nine adult males that were translocated there from Laysan Island in 1984).

The distribution, destinations, routes, food sources, and causes of monk seal movements when they are not traveling between islands are not well known (Johnson and Johnson 1979), but recent tagging studies have shown individuals sometimes travel between the breeding populations in the Northwest Hawaiian Islands. Tagging studies in the main Hawaiian Islands results show that monk seals tended to stay within the 600 m depth contour surrounding the main Hawaii Islands and neighboring banks, and most dove to depths less than 100 m. Their foraging trips typically lasted less than one day, but some seals were observed to take trips lasting 1-3 weeks in duration.

Population Structure

Hawaiian monk seal appear to exist as a single population that occurs in the Northwest Hawaiian Islands and Main Hawaiian Islands. However, groups of individuals that occupy specific islands or atolls in the Hawaiian Archipelago are treated as sub-populations for the purposes of research and management activity.

Pearl and Hermes Reef, the Midway Islands, and Kure Atoll form the three westernmost sub-populations of Hawaiian monk seals. There is a higher degree of migration among these sub-populations than among the sub-populations that occupy Laysan, Lisianski and French Frigate Shoals, which are more isolated. As a result, population growth in the westernmost sub-populations can be influenced more by immigration than by intrinsic growth. Several recent cohorts (groups of individuals born in the same year) at all three sites indicate that survival of juveniles has declined.

Threats to the Species

Natural Threats. Monk seals are threatened by natural predation, disease outbreaks, biotoxins, and agonistic behavior by male monk seals. Monk seals, particularly pups, are also subjected to extensive predation by sharks, which appear to be a particular problem for the monk seals occupying French Frigate Shoals in the Northwest Hawaiian Islands. Monk seal remains have been found in the stomachs of both tiger and Galapagos sharks. Sharks predation has increased significantly in the Northwest Hawaiian Islands, particularly French Frigate Shoals.

Hawaiian monk seals appear to be threatened by the spread of infectious diseases, including leptospirosis, toxoplasmosis, and West Nile virus, although domestic animals and humans may be vectors for these diseases (which would make them anthropogenic rather than natural threats). The absence of antibodies to these diseases in monk seals would make them extremely vulnerable to potential infection. Biotoxins such as ciguatera can cause mortality in phocids, but its role in mortality of monk seals was implicated and not confirmed, remaining unclear due to the lack of assays for testing tissues and the lack of epidemiological data on the distribution of toxin in monk seal prey.

The primary cause of adult female mortality affecting the recovery potential in the monk seal population during the 1980s and early 1990s was injury and death of female monk seals caused by “mobbing” attacks initiated by male monk seals. Although NMFS has developed and implemented measures to mitigate the effects of mobbing attacks, they are still considered a serious threat to Hawaiian monk seals. In recent years, low juvenile survival, in part due to food limitation, has been evident at all subpopulations of Hawaiian monk seals in the Northwest Hawaiian Islands. Nevertheless, the death of adult and immature females that resulted from this behavior would reduce the total number of breeding females and the recruitment of immature females into the adult, breeding population. Fewer breeding adults would produce fewer pups which, by itself, would increase the population’s rate of decline; when coupled with reductions in the survival probability of pups, it would create a feedback loop that would tend to cause the population to decline.

Anthropogenic Threats. Several human activities are known to threaten Hawaiian monk seals: commercial and subsistence hunting, intentional harassment, competition with commercial fisheries, entanglement in fishing gear, habitat destruction on breeding beaches, pollution, and unintentional human disturbance (Kenyon 1981; Reeves et al. 1992; Riedman 1990). The revised recovery plan for Hawaiian monk seals identifies food limitation, entanglements, and shark predation as crucial threats to the continued existence of this species (NMFS 2007a).

One of the most substantial threats to Hawaiian monk seals results from dramatic declines in the survival of juveniles and appears to be related to significantly reduced body sizes in pup and juvenile seals. These declines in body size appear to be evidence of chronic or episodic limitations in available prey. In recent years, low juvenile survival, in part due to food limitation, has been evident at all subpopulations of monk seals in the Northwest Hawaiian Islands. The mean age-specific birth rates of adult female Hawaiian monk seals, which are low relative to other phocid seals, could also be evidence of food limitation (NMFS 2007a).

Entangled monk seals were first observed in 1974 (Henderson 1984). Historically, monk seals have become entangled in net, line (including monofilament nylon line), net and line combinations, straps, rings (including hagfish or eel traps), and other random items such as discarded lifejackets, buckets (portion of rims), bicycle tires, rubber hoses, etc. (Henderson 1990a). Monk seal pups (including newly weaned pups) are entangled at higher rates than other age classes (Henderson 1985; Henderson 1990a; Henderson 2001). Between 1982 and 1988, pups comprised 11 percent of the population, but represent about 42 percent of observed entanglements (for comparison, adults represented about 49 percent of the population but only 16 percent of entanglements)(Henderson 1990a). Collectively immature monk seals were involved in almost 80 percent of all observed entanglements, even though they represented only 46 percent of the population (Henderson 2001).

Between 1982 and 2006, a total of 268 entanglements of monk seals were documented, including 118 in fishing gear. There were 57 serious injuries (including 32 from fishing gear) and 8 mortalities (including 7 from fishery items). From 1982 – 2000, there was an estimated minimum rate of 2.3 serious injuries or deaths per year attributable to fishery related marine debris (NMFS 2007a).

Recovery Actions. Over the past decade, there have been several attempts to combat or mitigate the effects of shark predation on Hawaiian monk seals. From 2000 through 2003, sharks were removed (through hazing or targeted fishing) at Trig Island, which was followed by declines in the number of monk seal pups killed at the island. These effects were only successful temporarily and, in 2002 and 2003, hazing was discontinued because it made the sharks wary and difficult to catch.

There have been several attempts to balance sex ratios at Laysan Island by removing problem males. In 1984, a group of ten adult males that had been observed attacking females, or whose behavior profile was similar to those that attacked females, were captured on Laysan and transported to Johnston Atoll. One of the ten died prior to release, and of the remaining nine, most were not seen after a few months. The last male was not observed until after a period of 16 months. Another group of five problem males was removed from Laysan and entered into captivity in 1987 for studies identified in the plan. Males in the 1987 group were used to define the testosterone cycle in males and to evaluate a drug to suppress testosterone for possible field application to reduce aggressive behavior. The captive trials proved effective at suppressing testosterone levels in the male seals (Atkinson et al. 1993) and a pilot field trial was performed (Atkinson et al. 1998). However, severe limitations in this approach (each male had to be captured and injected a number of times over the course of the breeding season; these repeated captures would have resulted in extensive disturbance to most seals on the island during the breeding season) caused it to be terminated.

In June 2006, the Papahanaumokuakea Marine National Monument (71 FR 51134, August 29, 2006) was established in the Northwest Hawaiian Islands. The boundary of the Monument includes about 140,000 square miles of emergent and submerged lands and waters of the northwest Hawaiian Islands and regulating activities such as fishing that pose potential risks to the marine habitat of Hawaiian monk seals.

Status

Hawaiian monk seals were listed as endangered under the Endangered Species Act of 1973 on November 23, 1976 (41 FR 51611). A 5-year status review completed in 2007 recommended retaining monk seals as an endangered species (72 FR 46966, August 22, 2007). Critical habitat was originally designated for Hawaiian monk seals on April 30, 1986 (51 FR 16047), and was extended on May 26, 1988 (53 FR 18988; CFR 226.201). NMFS proposed an expansion of critical habitat for Hawaiian monk seals in 2011 (76 FR 32026) to include near shore areas of the main Hawaiian Islands but excluded Navy training areas near Puuloa Training Range and the Naval Defensive Sea Area.

Monk seals are considered one of the most endangered groups of pinnipeds on the planet because all of their populations are either extinct (for example, the Caribbean monk seal) or exist at numbers that are precariously close to extinction (Mediterranean and Hawaiian monk seals). Two periods of decline have been reported for Hawaiian monk seals. The first decline occurred in the 1800s when sealers, crews of wrecked vessels, and guano and feather hunters nearly hunted the population to extinction (Dill and Bryan 1912; Kenyon and Rice 1959). Following the collapse of this population, expeditions to the Northwest Hawaiian Islands reported increasing numbers of seals (Bailey 1952). A survey in 1958 suggested that the population had partially recovered from its initial collapse.

Consistent declines in the monk seal population trends have been recorded since range-wide surveys began in the late 1950s (survey results that were reported by Kenyon and Rice (1959) and Rice (1960). Rice (1960) conducted additional counts at Midway Islands in 1956-1958 and Wirtz (1968) conducted counts at Kure Atoll in 1963-1965. Between the late 1950s and 1980s, counts at the atolls, islands, and reefs in the Northwest Hawaiian Islands suggested a 50 percent decline in this population (Johnson et al. 1982). 1982). The total population for the five major breeding locations plus Necker Island for 1987 was estimated to be 1,718 seals including 202 pups of the year (Gilmartin 1988). This compares with 1,488 animals estimated for 1983 (Gerrodette 1985). In 1992 the Hawaiian monk seal population was estimated to be 1580 (standard error = 147) (Ragen 1993). The best estimate of total abundance for 1993 was 1,406 (standard error = 131, assuming a constant coefficient of variation).

Beach counts of juveniles, sub-adults, and adults declined by about 5 percent per year from 1985 – 1993, and then became relatively stable until the current decline began in 2001 (NMFS 2007a). Between 1958 and 1993, mean beach counts declined by 60 percent and included declines in the number of monk seals at French Frigate Shoals, which once accounted for more than 50 percent of the total non-pup beach counts among the six primary Northwest Hawaiian Island sub-populations. Between the years 1958 and 2006, beach counts of juveniles, sub-adults and adults declined by 66 percent; the total abundance of monk seals at the six primary subpopulations in the Northwest Hawaiian Islands is declining at an annual rate of 3.9 percent (95 percent CI = -4.8 to - 3.0 percent)(NMFS 2007a). In 2006, the monk seal population was estimated to number about 1,200 animals.

Based on the evidence available, Hawaiian monk seals exist as a population that is subject to the dynamics of “small” populations. That is, they experience phenomena such as demographic stochasticity, inbreeding depression, and Allee effects, among others, that cause their population size to become a threat in and of itself. For example, Hawaiian monk seals have very low juvenile and sub-adult survival rates (due to starvation which is believed to be caused by limitations in the food base), low juvenile survival has led to low juvenile recruitment into the adult population, and the adult population increasingly consists of ageing females whose reproductive success is expected to decline (if it has not already declined) in the foreseeable future. A positive feedback loop between reduced reproductive success of adult females and reduced recruitment into the adult population (which reduces the number of adult females) is the kind of demographic pattern that is likely to increase the monk seal’s decline toward extinction. As a result, we assume that Hawaiian monk seals have elevated extinction probabilities because of exogenous threats caused by anthropogenic activities (primarily reductions in prey base due to competition with commercial and subsistence hunting, entanglement in fishing gear, and habitat destruction), natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate), and endogenous threats caused by the small size of their population.

Diving and Social Behavior

Several recent studies of the foraging patterns of Hawaiian monk seals near rookeries in the northwestern Hawaiian Islands provide insight into their diving behavior. Dive depths appear to differ slightly between rookeries as well as between age classes and genders. At Pearl and Hermes Reef, most dives were from 8-40 m with a second much smaller node at 100- 120 m (Stewart 2004). At Kure Atoll, most dives were shallower than 40 m, with males tending to dive deeper than females (Stewart and Yochem. 2004). At Laysan Island, a similar dive pattern was recorded with most dives shallower than 40 m, but at that location females tended to dive deeper than males (250-350 m) (Stewart and Yochem 2004). Parrish et al. (2002) noted a tendency towards night diving at French Frigate Shoals, with dives to ~80-90 m. Based on these data, the following are rough order estimates of time at depth: 90 percent at 0-40 m; 9 percent at 40-120 m; 1 percent at >120 m.

Vocalizations and Hearing

The information on the hearing capabilities of endangered Hawaiian monk seals is somewhat limited, but they appear to have their most sensitive hearing at 12 to 28 kHz. Below 8 kHz, their hearing is less sensitive than that of other pinnipeds. Their sensitivity to high frequency sound drops off sharply above 30 kHz (Richardson et al. 1995a; Richardson et al. 1995b; Thomas et al. 1990). An underwater audiogram for Hawaiian monk seal, based on a single animal whose hearing may have been affected by disease or age, was best at 12 to 28 kHz and 60 to 70 kHz (Thomas et al. 1990). The hearing showed relatively poor hearing sensitivity, as well as a narrow range of best sensitivity and a relatively low upper frequency limit (Thomas et al. 1990).

4.4.7 Green Sea Turtle

Green turtles are the largest of all the hard-shelled sea turtles, but have a comparatively small head. While hatchlings are just 2 inches (50 mm) long, adults can grow to more than 3 feet (0.91 m) long and weigh 300-350 pounds (136-159 kg).

Adult green turtles are unique among sea turtles in that they are herbivorous, feeding primarily on sea grasses and algae. This diet is thought to give them greenish colored fat, from which they take their name. A green turtle's carapace (top shell) is smooth and can be shades of black, gray, green, brown, and yellow. Their plastron (bottom shell) is yellowish white.

Scientists estimate green turtles reach sexual maturity anywhere between 20 and 50 years, at which time females begin returning to their natal beaches (i.e., the same beaches where they were born) every 2-4 years to lay eggs.

The nesting season varies depending on location. In the southeastern U.S., females generally nest between June and September, while peak nesting occurs in June and July. During the nesting season, females nest at approximately two week intervals, laying an average of five clutches. In Florida, green turtle nests contain an average of 135 eggs, which will incubate for approximately 2 months before hatching.

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°Celsius 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. 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 1998b). 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 and USFWS 1998b).

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; NMFS and USFWS 1998c; Seminoff et al. 2002).

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.

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 et al. 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 including 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 Hawaiian 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). Preliminary evidence suggests an association between the distribution of fibropapillomatosis in the Hawaiian Islands and the distribution of toxic benthic dinoflagellates (*Prorocentrum* spp.) known to produce a tumor promoter, okadaic acid (Landsberg et al. 1999).

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 populations of green sea turtles still lose a 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 (Brautigam and Eckert 2006); the turtle fishery along the Caribbean coast of Nicaragua, by itself, has captured more than 11,000 green sea turtles each year (Brautigam 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 1998c).

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. 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.

Oil spills are a risk for all sea turtles. Several aspects of sea turtles life histories put them at risk, including the lack of avoidance behavior of oiled waters and indiscriminate feeding in convergence zones. Sea turtles are air breathers and all must come to the surface frequently to take a breath of air. In a large oil spill, these animals may be exposed to volatile chemicals during inhalation (NMFS 2010c).

Additionally, sea turtles may experience oiling impacts on nesting beaches when they come ashore to lay their eggs, and their eggs may be exposed during incubation potentially resulting in increased egg mortality and/or possibly developmental defects in hatchlings. Hatchlings emerging from their nests may encounter oil on the beach and in the water as they begin their lives at sea (NMFS 2010c).

External Effects: Oil and other chemicals on skin and body may result in skin and eye irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (NMFS 2010c).

Internal Effects: Inhalation of volatile organics from oil or dispersants may result in respiratory irritation, tissue injury, and pneumonia. Ingestion of oil or dispersants may result in gastrointestinal inflammation, ulcers, bleeding, diarrhea, and maldigestion. Absorption of inhaled and ingested chemicals may damage organs such as the liver or kidney, result in anemia and immune suppression, or lead to reproductive failure or death (NMFS 2010c).

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 percent to 58 percent over the last three generations (approximately 150 years); although actual declines may be closer to 70 percent to 80 percent. 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 percent 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 percent and 88 percent since the late 1970s. Population trend variations also appear in the Indian Ocean. Declines greater than 50 percent 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 2004).

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 2004). 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 a 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, and Allee effects, among others, that cause their population size to become a threat in and of itself) or if green sea turtles 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 Hawaiian 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.

A recovery plan for the U.S Population of Atlantic Green Turtles was written in 1991 (NMFS and USFWS 1991a). A recovery plan for the U.S. Pacific Populations of the Green Turtle was written in 1998 (NMFS and USFWS 1998c). Critical habitat was designated in 1998 for green turtles in coastal waters around Culebra Island, Puerto Rico.

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 1998c).). The maximum recorded dive depth for an adult green turtle was 110 meters (Berkson 1967; 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. 1999b).

In a study of the auditory brainstem responses of subadult green sea turtles, Bartol and Ketten (2005) 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 frequencies 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). Wood turtles are reported to have sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Patterson 1966).

4.4.8 Hawksbill Sea Turtle

The hawksbill turtle is a small to medium-sized sea turtle; adults typically range between 65 and 90 cm (26 to 35 in) in carapace length and weigh around 80 kg (176 lb) (Witzell 1983). Hawksbills are distinguished from other sea turtles by their hawk-like beaks, posteriorly overlapping carapace scutes, and two pairs of claws on their flippers (NMFS and USFWS 1993). The carapace of this species is often brown or amber with irregularly radiating streaks of yellow, orange, black, and reddish-brown.

Distribution

Hawksbill sea turtles occur in tropical and subtropical seas of the Atlantic, Pacific and Indian Oceans. The species is widely distributed in the Caribbean Sea and western Atlantic Ocean, with individuals from several life history stages occurring regularly along southern Florida and the northern Gulf of Mexico (especially Texas); in the Greater and Lesser Antilles; and along the Central American mainland south to Brazil. Within the United States, hawksbills are most common in Puerto Rico and its associated islands, and in the U.S. Virgin Islands.

In the continental U.S., hawksbill sea turtles have been reported in every state on the coast of the Gulf of Mexico and along the coast of the Atlantic Ocean from Florida to Massachusetts, except for Connecticut; however, sightings of hawksbill sea turtles north of Florida are rare. The only states where hawksbill sea turtles occur with any regularity are Florida (particularly in the Florida Keys and the reefs off Palm Beach County on Florida's Atlantic coast, where the warm waters of the Gulf Stream pass close to shore) and Texas. In both of these states, most sightings are of post-hatchlings and juveniles that are believed to have originated from nesting beaches in Mexico. Hawksbill sea turtles have stranded along the almost the entire Atlantic coast of the United States, although most stranding records occur south of Cape Canaveral, Florida, particularly in Palm Beach, Broward and Miami-Dade counties (Florida Sea Turtle Stranding and Salvage database). Hawksbill sea turtles are very rare north of Florida, although they have been recorded as far north as Massachusetts. During their pelagic-stage, hawksbills disperse from the Gulf of Mexico and southern Florida in the Gulfstream Current, which would carry them offshore of Georgia and the Carolinas. As evidence of this, a pelagic-stage hawksbill was captured 37 nautical miles east of Sapelo Island, Georgia in May 1994 (Parker 2005). There are also records of hawksbill sea turtles stranding on the coast of Georgia (Odell et al. 2008), being captured in pound nets off Savannah, and being captured in summer flounder trawls (Epperly et al. 1995) , gillnets (Epperly et al. 1995), and power plants off Georgia and the Carolinas.

Within United States territories and U.S. dependencies in the Caribbean Region, hawksbill sea turtles nest principally in Puerto Rico and the U.S. Virgin Islands, particularly on Mona Island and Buck Island. They also nest on other beaches on St. Croix, Culebra Island, Vieques Island, mainland Puerto Rico, St. John, and St. Thomas. Within the continental United States, hawksbill sea turtles nest only on beaches along the southeast coast of Florida and in the Florida Keys.

Hawksbill sea turtles occupy different habitats depending on their life history stage. After entering the sea, hawksbill sea turtles occupy pelagic waters and occupy weed-lines that accumulate at convergence points. When they growth to about 20-25 cm carapace length, hawksbill sea turtles re-enter coastal waters where they inhabit and forage in coral reefs as juveniles, sub-adults and adults. Hawksbill sea turtles also occur around rocky outcrops and high energy shoals, where sponges grow and provide forage, and they are known to inhabit mangrove-fringed bays and estuaries, particularly along the eastern shore of continents where coral reefs are absent.

Population Structure

Hawksbill 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 hawksbill turtles are usually based on the distribution of their nesting aggregations.

Threats to the Species

Natural Threats. The various habitat types hawksbill sea turtles occupy throughout their lives exposes these sea turtles to a wide variety of natural threats. The beaches on which hawksbill 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 hawksbill sea turtles are also killed by sharks and other large, marine predators.

Anthropogenic Threats. Three human activities are known to threaten hawksbill 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 hawksbill sea turtle populations was overharvests by humans for subsistence and commercial purposes. In the Atlantic, hawksbill sea turtles are still captured and killed in turtle fisheries in Colombia, Grenada, the Lesser Antilles, Nicaragua, St. Vincent and the Grenadines (Brautigam and Eckert 2006).

For centuries, hawksbill sea turtles have been captured for their shells, which have commercial value, rather than food (the meat of hawksbill sea turtles is considered to have a bad taste and can be toxic to humans) (NMFS and USFWS 1998d). Until recently, tens of thousands of hawksbills were captured and killed each year to meet demand for jewellery, ornamentation, and whole stuffed turtles (Eckert 1993; Milliken and Tokunaga 1987). In 1988, Japan's imports from Jamaica, Haiti and Cuba represented some 13,383 hawksbills: it is extremely unlikely that this volume could have originated solely from local waters (Greenpeace 1989 cited in Eckert 1993). Although Japan banned the importation of turtle shell in 1994, domestic harvests of eggs and turtles continue in the United States, its territories, and dependencies, particularly in the Caribbean and Pacific Island territories. Large numbers of nesting and foraging hawksbill sea turtles are captured and killed for trade in Micronesia, the Mexican Pacific coast, southeast Asia and Indonesia (NMFS and USFWS 1998d). In addition to the demand for the hawksbill's shell, there is a demand for other products including leather, oil, perfume, and cosmetics. Before the U.S. certified Japan under the Pelly Amendment, Japan had been importing about 20 metric tons of hawksbill shell per year, representing approximately 19,000 turtles.

The second most important threat to hawksbill sea turtles is the loss of nesting habitat caused by the expansion of resident human populations in coastal areas of the world and increased destruction or modification of coastal ecosystems to support tourism. Hawksbill sea turtles are also captured and killed in commercial fisheries. Along the Atlantic coast of the U.S., NMFS estimated that about 650 hawksbill sea turtles are captured in shrimp trawl fisheries each year in the Gulf of Mexico, with most of those sea turtles dying as a result of their capture. Each year, about 35 hawksbill sea turtles are captured in Atlantic pelagic longline fisheries. Although most of these turtles are released alive, these fisheries are expected to kill about 50 hawksbill sea turtles each year; the health effects of being captured on the sea turtles that survive remain unknown. Like green sea turtles, hawksbill 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

Hawksbill sea turtles were listed as endangered under the ESA in 1970. Critical habitat for hawksbill turtles was designated in 1998 to include the coastal waters surrounding Mona and Monito Islands, Puerto Rico. Under the Convention on International Trade in Endangered Species of Wild Fauna and Flora, hawksbill sea turtles are identified as "critically endangered" (IUCN 2010).

Hawksbill sea turtles are solitary nesters, which makes it difficult to estimate the size of their populations. There are no global estimates of the number of hawksbill sea turtles, but a minimum of 15,000 to 25,000 females are thought to nest annually in more than 60 geopolitical entities (Groombridge and Luxmoore 1989). Moderate populations appear to persist around the Solomon Islands, northern Australia, Palau, Persian Gule islands, Oman, and parts of the Seychelles. In a more recent review, Groombridge and Luxmoore (1989) list Papua New Guinea, Queensland, and Western Australia as likely to host 500-1,000 nesting females per year, while Indonesia and the Seychelles may support >1,000 nesting females. The largest known nesting colony in the world is located on Milman Island, Queensland, Australia where Loop (1995) tagged 365 hawksbills nesting within an 11 week period.

Of the 65 geopolitical units on which hawksbill sea turtles nest and where hawksbill nesting densities can be estimated, 38 geopolitical units have hawksbill populations that are suspected or known to be declining. Another 18 geopolitical units have experienced well-substantiated declines (NMFS and USFWS 1995). The largest remaining nesting concentrations occur on remote oceanic islands off Australia (Torres Strait) and the Indian Ocean (Seychelles).

Hawksbill sea turtles, like green sea turtles, are thought to be declining globally as a direct consequence of a historical combination of overexploitation and habitat loss. However, like several of the species we have already discussed, the information available on the status and trend of hawksbill sea turtles do not allow us to make definitive statements about the global extinction risks facing these sea turtles or the risks facing particular populations (nesting aggregations) of these turtles. However, the limited data available suggests that several hawksbill sea turtles populations 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) while others are large enough to avoid these problems. Exogenous threats such as overharvests and entanglement in fishing gear only increase their probabilities of becoming extinct in the foreseeable future.

Diving and Social Behavior

The duration of foraging dives in hawksbill sea turtles commonly depends on the size of the turtle: larger turtles diving deeper and longer. At a study site also in the northern Caribbean, foraging dives were made only during the day and dive durations ranged from 19-26 minutes in duration at depths of 8-10 m. At night, resting dives ranged from 35-47 minutes in duration (vanDam and Diez 1997).

Vocalizations and Hearing

There is no information on hawksbill 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. 1999b).

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). Wood turtles are reported to have sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Patterson 1966).

4.4.9 Leatherback Sea Turtle

The leatherback is the largest turtle and the largest living reptile in the world. Mature males and females can be as long as six and a half feet (2 m) and weigh almost 2000 lbs. (900 kg). The leatherback is the only sea turtle that lacks a hard, bony shell. A leatherback's carapace is approximately 1.5 inches (4 cm) thick and consists of leathery, oil saturated connective tissue overlaying loosely interlocking dermal bones. The carapace has seven longitudinal ridges and tapers to a blunt point. Adult leatherbacks are primarily black with a pinkish white mottled ventral surface and pale white and pink spotting on the top of the head. The front flippers lack claws and scales and are proportionally longer than in other sea turtles; back flippers are paddle-shaped. The ridged carapace and large flippers are characteristics that make the leatherback uniquely equipped for long distance foraging migrations.

Female leatherbacks lay clutches of approximately 100 eggs on sandy, tropical beaches. Females nest several times during a nesting season, typically at 8-12 day intervals. After 60-65 days, leatherback hatchlings with white striping along the ridges of their backs and on the margins of the flippers emerge from the nest. Leatherback hatchlings are approximately 50-77 cm (2-3 inches) in length, with fore flippers as long as their bodies, and weigh approximately 40-50 grams (1.4-1.8 ounces).

Leatherbacks lack the crushing chewing plates characteristic of sea turtles that feed on hard-bodied prey (Pritchard 1971) Instead, they have pointed tooth-like cusps and sharp edged jaws that are perfectly adapted for a diet of soft-bodied pelagic (open ocean) prey, such as jellyfish and salps. A leatherback's mouth and throat also have backward-pointing spines that help retain such gelatinous prey.

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 and KwaZulu Natal, South Africa.

Leatherback sea turtles are highly migratory, exploiting convergence zones and upwelling areas in the open ocean, along continental margins, and in archipelagic waters (Eckert and Eckert 1988; Eckert 1999; Morreale et al. 1994). 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 1998a). 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 1998a). 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, the Andaman and Nicobar Islands, and KwaZulu Natal, South Africa.

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 (Caut et al. 2009). 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 (Pitman and Dutton 2004).

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 1998e).

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 percent mortality rate (or 33 percent 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 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 (Tomás et al. 2000). 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 1998). Observers on shrimp trawlers operating in the northeastern region of Venezuela documented the capture of six leatherbacks from 13,600 trawls (Marcano and Alió-M 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 percent (Eckert et al. 2007). 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. 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 percent of the eggs laid have been harvested. Spotila et al. (1996) and Eckert et al. (2007) note that adult mortality has also increased significantly, particularly as a result of driftnet and longline fisheries. Like green and hawksbill 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.

Oil spills are a risk for all sea turtles. Several aspects of sea turtles life histories put them at risk, including the lack of avoidance behavior of oiled waters and indiscriminate feeding in convergence zones. Sea turtles are air breathers and all must come to the surface frequently to take a breath of air. In a large oil spill, these animals may be exposed to volatile chemicals during inhalation (NMFS 2010c).

Additionally, sea turtles may experience oiling impacts on nesting beaches when they come ashore to lay their eggs, and their eggs may be exposed during incubation potentially resulting in increased egg mortality and/or possibly developmental defects in hatchlings. Hatchlings emerging from their nests may encounter oil on the beach and in the water as they begin their lives at sea (NMFS 2010c).

External Effects: Oil and other chemicals on skin and body may result in skin and eye irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (NMFS 2010c).

Internal Effects: Inhalation of volatile organics from oil or dispersants may result in respiratory irritation, tissue injury, and pneumonia. Ingestion of oil or dispersants may result in gastrointestinal inflammation, ulcers, bleeding, diarrhea, and maldigestion. Absorption of inhaled and ingested chemicals may damage organs such as the liver or kidney, result in anemia and immune suppression, or lead to reproductive failure or death (NMFS 2010c).

Status

The leatherback turtles are listed as endangered under the ESA throughout the species' 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 percent increase), although it is important 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 et al. 1999). 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 et al. 1996), but is now estimated to number less than 3,000 total adult and subadult animals (Spotila et al. 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 percent 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 et al. 2000). In the western Pacific, the decline is equally severe. Current nestings at Terengganu, Malaysia represent 1 percent 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 percent 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 (NMFS and USFWS 1998a; Spotila et al. 1996; 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 (Eckert and Sarti 1997; Sarti et al. 1996).

Based on recent modeling efforts, some authors concluded that leatherback turtle populations cannot withstand more than a 1 percent 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 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 status of leatherback sea turtles in the Atlantic Ocean remains uncertain.

In 1979, NMFS designated critical habitat for leatherback turtles to include the coastal waters adjacent to Sandy Point, St. Croix, U.S. Virgin Islands.

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 inter-nesting intervals and during the 1995 through 1998 nesting seasons. The turtles dived continuously for the majority of their time at sea, spending 57 - 68 percent 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 percent 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. 1999b).

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). Wood turtles are reported to have sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Patterson 1966).

4.4.10 Loggerhead Sea Turtle

Loggerheads were named for their relatively large heads, which support powerful jaws and enable them to feed on hard-shelled prey, such as whelks and conch. The carapace (top shell) is slightly heart-shaped and reddish-brown in adults and sub-adults, while the plastron (bottom shell) is generally a pale yellowish color. The neck and flippers are usually dull brown to reddish brown on top and medium to pale yellow on the sides and bottom. Mean straight carapace length of adults in the southeastern U.S. is approximately 36 in (92 cm); corresponding weight is about 250 lbs (113 kg).

Loggerheads reach sexual maturity at around 35 years of age. In the southeastern U.S., mating occurs in late March to early June and females lay eggs between late April and early September. Females lay three to five nests, and sometimes more, during a single nesting season. The eggs incubate approximately two months before hatching sometime between late June and mid-November.

Hatchlings vary from light to dark brown to dark gray dorsally and lack the reddish-brown coloration of adults and juveniles. Flippers are dark gray to brown above with white to white-gray margins. The coloration of the plastron is generally yellowish to tan. At emergence, hatchlings average 1.8 in (45 mm) in length and weigh approximately 0.04 lbs (20 g).

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 (NMFS and USFWS 1998e). The majority of loggerhead nesting is at the western rims of the Atlantic and Indian Oceans. Nesting aggregations occur in the eastern Atlantic at Cape Verde, Greece, Libya, Turkey and along the West African Coast. The western Atlantic and Caribbean hosts nesting aggregations along the U.S. east coast from Virginia through the Florida peninsula, the Dry Tortugas and Northern Gulf of Mexico, the Bahamas, the Yucatan Peninsula, Central America and the Caribbean and into South America. Within the Indian Ocean, nesting aggregations occur at Oman, Yemen, Sri Lanka and Madagascar and South Africa. Pacific Ocean nesting sites include western and eastern Australia and Japan.

Adult loggerheads are known to make considerable migrations from nesting beaches to foraging grounds (TEWG 2009); and evidence indicates turtles entering the benthic environment undertake routine migrations along the coast that are limited by seasonal water temperatures. Small juveniles are found in pelagic waters (e.g., of the North Atlantic and the Mediterranean Sea); and the transition from oceanic to neritic juvenile stages can involve trans-oceanic migrations (Bowen et al. 2004). Loggerhead nesting is confined to lower latitudes, concentrated in temperate zones and subtropics; the species generally does not nest in tropical areas (NMFS and USFWS 1991b; NRC 1990; Witherington et al. 2006). Loggerhead turtles travel to northern waters during spring and summer as water temperatures warm, and southward and offshore toward warmer waters in fall and winter; loggerheads are noted to occur year round in offshore waters of sufficient temperature.

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 is usually based on the distribution of their nesting aggregations. 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 percent of the loggerhead nests in the western North Atlantic, comprise between 25 and 59 percent of the loggerhead sea turtles captured in foraging areas from Georgia to waters of the northeastern United States (Bass et al. 1998; Rankin-Baransky et al. 1998; Sears et al. 1995). About 10 percent 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 percent of the loggerhead sea turtles captured) and the Mediterranean Sea (where they represent about 45-47 percent 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.

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 increase of 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 represent 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 and USFWS 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 combined to capture about 2,000 loggerhead 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. 2002). 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

Loggerhead sea turtles are currently listed as nine Distinct Population Segments (DPSs); four listed as threatened and five listed as Endangered under the ESA (Table 6).

Table 6. Loggerhead sea turtle distinct population segments (76 FR 58868).

Population Segment	Population Boundaries	Proposed Status
Mediterranean Sea	Mediterranean Sea east of 5°36’ W. Long.	Endangered
North Indian Ocean	North Indian Ocean north of the equator and south of 30° N. Lat.	Endangered
North Pacific Ocean	North Pacific north of the equator and south of 60° N. Lat.	Endangered
Northeast Atlantic Ocean	Northeast Atlantic Ocean north of the equator, south of 60° N. Lat, east of 40° W. Long, and west of 5°36’ W. Long	Endangered
Northwest Atlantic Ocean	Northwest Atlantic Ocean north of the equator, south of 60° N. Lat, and west of 40° W. Long	Threatened
South Atlantic Ocean	South Atlantic Ocean south of the equator, north of 60° S. Lat, west of 20° E. Long, and east of 67° W. Long	Threatened
South Pacific Ocean	South Pacific south of the equator, north of 60° S. Lat, west of 67° W. Long, and east of 139° E. Long.	Endangered
Southeast Indo-Pacific Ocean	Southeast Indian Ocean south of the equator, north of 60° S. Lat, and east of 80° E. Long; South Pacific Ocean south of the equator, north of 60° S. Lat, and west of 139° E. Long	Threatened
Southwest Indian Ocean	Southwest Indian Ocean north of the equator, south of 30° N. Lat, west of 20° E. Long, and east of 80° E. Long	Threatened

All loggerheads inhabiting the North Pacific Ocean are derived primarily, if not entirely, from Japanese beaches (although low level nesting may occur in areas around the South China Sea). Along the Japanese coast, nine major nesting beaches (greater than 100 nests per season) and six “submajor’’ beaches (10– 100 nests per season) were identified. Using information collected from these nine beaches (Kamezaki et al. 2003) found a substantial decline (50–90 percent) in the size of the annual loggerhead nesting population over the last half of the 20th century. Also, nest count data for the last two decades suggests that the North Pacific population is “small” and lacks a robust gene pool when compared to the larger northwest Atlantic and north Indian Ocean loggerhead populations. Small populations are more susceptible to demographic variability which increases their probability of extinction. Available evidence indicates that due to loss of adult and juvenile mortalities from fishery bycatch and, to a lesser degree the loss of nesting habitat, the North Pacific loggerhead population is declining.

In the South Pacific, loggerhead nesting is almost entirely restricted to eastern Australia (primarily Queensland) and New Caledonia, with the majority of nesting occurring in eastern Australia. The total nesting population for Queensland was approximately 3,500 females in the 1976–1977 nesting season (Limpus and Reimer 1994; Limpus 1985), however, by the 1999-2000 season Limpus and Limpus (2003) estimated this population at less than 500 females. This represents an estimated 50 to 80 percent decline in the number of breeding females at various Australian rookeries up to 1990 (Limpus and Reimer 1994) and a decline of approximately 86 percent by 1999 (Limpus and Limpus 2003).

Information from pilot surveys conducted in 2005 in New Caledonia, combined with oral history information collected, suggests a decline in loggerhead nesting with 60-70 loggerheads nesting on the four surveyed New Caledonia beaches during the 2004–2005 nesting season (Limpus et al. 2006). Chaloupka and Limpus (2001) determined that the resident non-breeding loggerhead population on coral reefs of the southern Great Barrier Reef in eastern Australia declined at 3 percent per year from 1985 to the late 1990s. The observed decline was hypothesized as a result of recruitment failure, given few anthropogenic impacts and constant high annual survivorship measured at this foraging habitat (Chaloupka and Limpus 2001). This decline also coincided with a measured decline in new recruits in these foraging areas (Limpus and Limpus 2003). Available evidence indicates that due to loss of adult and juvenile mortalities from fishery bycatch the South Pacific population is declining.

Loggerhead sea turtles nesting densities in the North Indian Ocean are the largest in the eastern hemisphere with the vast majority of these nests in Oman (Baldwin et al. 2003). Nesting is rare in the rest of the northern Indian Ocean. Nesting surveys and tagging data were used to extrapolate the number of females nesting at Masirah Island during 1977-78 resulting in 19,000 to 60,000 turtles (assuming 100 percent nesting success) and a partial survey of the island in 1991 estimated 23,000 nesters (Baldwin 1992; Ross 1998). Comparing the nesting data collected after 2008 when nesting surveys were standardized at Masirah to the 1977-78 and 1991 yielded an estimate of 20,000-40,000 nesters (assuming 50 percent nesting success). These estimates suggest a decline in the nesting population over the past three decades which is consistent with observations by local rangers. Mortality across all life stages, fishery bycatch, and the loss of nesting habitat is likely to cause this population to decline further.

In the southeast Indo-Pacific Ocean, loggerhead nesting is restricted to Western Australia (Dodd Jr. 1988), which is the largest nesting population in Australia (Natural Heritage Trust, 2005 as cited in (NMFS and USFWS 2007). Evidence suggests the nesting population in the Muiron Islands and North West Cape region was depleted before recent beach monitoring programs began although the data are insufficient to determine trends (Nishemura and Nakahigashi 1990; Poiner et al. 1990; Poiner and Harris 1996). Juvenile and adult mortality from fishery bycatch presents the greatest threat to this population’s probability of extinction.

In the Southwest Indian Ocean, the highest concentration of nesting occurs on the coast of Tongaland, South Africa, where surveys and management practices were instituted in 1963 (Baldwin et al. 2003). Nesting beach data from this region from 1965 to 2008 indicates an increasing nesting population between the first decade of surveys, which documented 500–800 nests annually, and the last 8 years, which documented 1,100–1,500 nests annually (Nel 2006). These data represent approximately 50 percent of all nesting within South Africa and are believed to be representative of trends in the region. Loggerhead nesting occurs elsewhere in South Africa and Madagascar, but sampling is not consistent and no trend data are available. This population, although small, is increasing but juvenile mortality from fishery bycatch remains a concern.

Loggerheads in the Northwest Atlantic Ocean comprise one of the two largest nesting assemblages in the world and have been identified as the most significant assemblage in the western hemisphere. Data collected over a period of 10 to 23 years indicates that there has been a significant overall decline in nesting numbers (TEWG 2009; Witherington et al. 2009). The annual number of nests has been declining for all subpopulations of Northwest Atlantic loggerheads for which there were adequate data available. Available evidence indicates that this population is declining due to juvenile and adult mortality from fishery bycatch. Five nesting subpopulations have been identified in the Northwest Atlantic Ocean (NMFS and USFWS 2008). Their status follows:

(1) Northern U.S. (Florida/Georgia border to southern Virginia). The Northern U.S. subpopulation is the second largest unit within the Northwest Atlantic population and has been declining significantly at 1.3 percent annually since 1983 (NMFS and USFWS 2008);

(2) Peninsular Florida (Florida/Georgia border south through Pinellas County, excluding the islands west of Key West, Florida). The most significant declining trend has been documented for the Peninsular Florida subpopulation, where nesting declined 26 percent over the 20-year period from 1989–2008, and declined 41 percent over the period 1998–2008 (NMFS and USFWS 2008; Witherington et al. 2009). This subpopulation represents approximately 87 percent of all nesting effort in the Northwest Atlantic Ocean DPS (Ehrhart et al. 2003);

(3) Dry Tortugas (islands west of Key West, Florida). Data are currently not adequate to assess trends in the annual number of nests for this subpopulation;

(4) Northern Gulf of Mexico (Franklin County, Florida, west through Texas). Data are currently not adequate to assess trends in the annual number of nests for this subpopulation; and

(5) Greater Caribbean (Mexico through French Guiana, the Bahamas, Lesser and Greater Antilles). This is the third largest subpopulation within the Northwest Atlantic population, with the majority of nesting at Quintana Roo, Mexico. The TEWG (2009) reported a greater than 5 percent annual decline in loggerhead nesting from 1995–2006 at Quintana Roo.

In the northeastern Atlantic, the Cape Verde Islands support the only large nesting population of loggerheads in the region (Fretey 2001). Nesting occurs at some level on most of the islands in the archipelago with the largest nesting numbers reported from Boa Vista Island where 833 and 1,917 nests were reported in 2001 and 2002, respectively, and between 1998 and 2002 the local project had tagged 2,856 females (Cruz et al. 2007). More recently, in 2005, about 3,121 females were reported (López-Jurado et al. 2003). Elsewhere in the northeastern Atlantic, loggerhead nesting is non-existent or occurs at very low levels. Population trends could not be determined for the Cape Verde population because of limited data; however, evidence of directed killing of nesting females suggests that this nesting population is under severe pressure and likely significantly reduced from historic levels. Available evidence indicates that this population is declining due to ongoing mortality of mature females and eggs, low hatchling and emergence success and mortality of juveniles and adults from fishery bycatch.

Nesting occurs throughout the central and eastern Mediterranean and sporadic nesting has been reported in the western Mediterranean, however, the vast majority of nesting (greater than 80 percent) occurs in Greece and Turkey (Margaritoulis et al. 2003). The documented annual nesting of loggerheads in the Mediterranean averages about 5,000 nests (Margaritoulis et al. 2003). There is no discernible trend in nesting at the two longest monitoring projects in Greece, Laganas Bay (Margaritoulis 2006) and southern Kyparissia Bay (Margaritoulis and Rees 2001). However, nesting at two beaches, Rethymno Beach, which accounts for approximately 7 percent of all documented loggerhead nesting in the Mediterranean, and Fethiye Beach in Turkey which accounts for 10 percent of nesting in Turkey, showed a declining trend in 1990–2004 and 1993-2004, respectively (Ilgaz et al. 2007). Juvenile and adult mortality from fishery bycatch and the loss of nesting habitat, eggs and hatchlings remain a concern for this population.

In the South Atlantic nesting occurs primarily along the mainland coast of Brazil. Prior to 1980, loggerhead nesting populations in Brazil were considered depleted, however, an increasing trend has been reported from 1988 through 2003 on beaches representing more than 75 percent of all loggerhead nesting in Brazil. A total of 4,837 nests were reported from these survey beaches for the 2003–2004 nesting season (Marcovaldi and Chaloupka 2007). Juvenile mortality from fishery bycatch remains a concern for this population.

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 (Sakamot 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. Analyses of the dive data indicate that most of the dives were very shallow - 70 percent of the dives were no deeper than 5 meters. In addition, the loggerheads spent approximately 40 percent of their time in the top meter and nearly all of their time at depths shallower than 100 meters. On 5 percent 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. (1999b) 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. 1999b). 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). Wood turtles are reported to have sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Patterson 1966).

4.4.11 Olive Ridley Sea Turtle

The olive ridley sea turtle is a small to medium-sized sea turtle; adults typically range between 55 and 80 cm (22 to 31 in) in carapace length and weigh around 45 kg (100 lb). They are olive/ grayish-green (darker in the Atlantic than in the Pacific) with a heart-shaped top shell (carapace) with 5-9 pairs of costal "scutes" with 1-2 claws on their flippers; hatchlings emerge mostly black with a greenish hue on the sides.

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 Pacific 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 (Groombridge 1982; Sternberg and Pritchard 1981).

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 2007). Although they are the most abundant north Pacific sea turtle, surprisingly little is known of the oceanic distribution and critical foraging areas of Pacific ridley turtles.

Most records of olive ridley turtles are from protected, relative shallow marine waters. 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, Pacific 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 that 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 (NMFS and USFWS 1998f). 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 1998f). 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 (Arenas et al. 2000). 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 olive ridley turtle as “endangered” (IUCN 2010).

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). 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 1998f). 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 (NMFS and USFWS 1998f). 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 Pacific ridleys on Nicaragua, Ruiz (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 reports 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 (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 Pacific 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 percent of the eggs were lost due to inundation and erosion (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 1998f), 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).

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, hawksbill, and loggerhead sea turtles: 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. 1999b; 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). Wood turtles are reported to have sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Patterson 1966).

5 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 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, monk seals and sea turtles in the action area. Some of those activities, most notably commercial whaling for large whales, 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 listed species in the action area. The following information summarizes the principal natural and human phenomena in the Hawaiian Islands that are believed to potentially affect the survival and recovery of these species in the wild.

5.1 Natural Mortality

Natural mortality rates in cetaceans, especially large whale species, are largely unknown. Although factors contributing to natural mortality cannot be quantified at this time, there are a number of suspected causes, including 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 (Lambertsen 1986b). 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). 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. Nitta (1991) reported that between 1936 and 1988, 8 humpback whales, 1 fin whale, and 5 sperm whales stranded in the Hawaiian 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. Although these two studies did not specify the cause or causes of death in these cases, we include these strandings in this discussion of sources of natural mortality because the causes of death remain unknown. Most of these stranding events consisted of individual animals and many of the multiple stranding events identified in these reports occurred prior to the mid-1960s (4 of the 8 multiple stranding events identified by Maldini et al. occurred between 1957 and 1959, 3 of 8 occurred in 1976, and 1 occurred in 1981).

Sea turtles are exposed to a wide variety of natural threats. The beaches on which 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.

Green turtles in the northwest Hawaiian 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 percent prevalence in 1995 (Balazs et al. 1998). Preliminary evidence suggests an association between the distribution of fibropapillomatosis in the Hawaiian 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 Hawaiian green turtle populations (Balazs et al. 1998).

Monk seals are threatened by natural predation, disease outbreaks, biotoxins, and agonistic behavior by male monk seals. Monk seals, particularly pups, are also subjected to extensive predation by sharks, which appear to be a particular problem for the monk seals occupying French Frigate Shoals in the Northwest Hawaiian Islands. Monk seal remains have been found in the stomachs of both tiger and Galapagos sharks. Sharks predation has increased significantly in the Northwest Hawaiian Islands, particularly French Frigate Shoals.

5.2 Human-induced Mortality

Sources of human-induced mortality on whales, monk seals, and sea turtles include commercial whaling, subsistence hunting, commercial fishing, ship strikes, and habitat degradation. These sources of mortality are discussed below.

5.2.1 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. 1999a). 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.

5.2.2 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 and sea turtle 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).

To date, no sei whales have been killed in interactions with any eastern North Pacific fisheries, but the true mortality rate must be considered unknown because of unobserved mortality. Sperm whale interactions with the longline fisheries in the Gulf of Alaska are increasing in frequency with the first documented entanglement occurring in June of 1997 (Hill et al. 1999).

In 1999, one fin whale was killed as a result of interactions with gear that is being used in the Bering Sea/Aleutian Island groundfish trawl fishery. Because the size of the fin whale population remains unknown, the effect of that whale's death on the trend of the fin whale population is uncertain.

From 2003 to 2007, there were 86 reports of human-related mortalities or injuries of humpback whales in Alaskan waters. Of these, there were 54 incidents which involved commercial fishing gear, and 23 of those incidents involved serious injuries or mortalities (Allen and Angliss 2010).

Sea turtles are also impacted by commercial fisheries. The foremost threat is the number of sea 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 percent mortality rate (or 33 percent 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. 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. 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.

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. This fishery has interacted with 3 loggerhead and 9 leatherback sea turtles in 2009 and7 loggerhead and 8 leatherback sea turtles in 2010 (NMFS 2011b). These fisheries are expected to continue at similar rates of interaction and deaths into the foreseeable future.

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. Green, hawksbill and Pacific ridley sea turtles are not expected to be captured in the longline fishery.

Historically, monk seals have become entangled in net, line (including monofilament nylon line), net and line combinations, straps, rings (including hagfish or eel traps), and other random items such as discarded lifejackets, buckets (portion of rims), bicycle tires, rubber hoses, etc. (Henderson 1990b). Between 1982 and 2006, a total of 268 entanglements of monk seals were documented, including 118 in fishing gear. There were 57 serious injuries (including 32 from fishing gear) and 8 mortalities (including 7 from fishery items). From 1982 – 2000, there was an estimated minimum rate of 2.3 serious injuries or deaths per year attributable to fishery related marine debris (NMFS 2007b).

5.2.3 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. The number of observed physical injuries to humpback whales as a result of ship collisions has increased in Hawaiian waters (Glockner-Ferrari et al. 1987). On the Pacific coast, a humpback whale is probably killed about every other year by ship strikes (Barlow et al. 1997). From 1996-2002, eight humpback whales were reported struck by vessels in Alaskan waters.

In 1996, a humpback whale calf was found stranded on Oahu with evidence of vessel collision (propeller cuts; NMFS unpublished data). From 1994 – 1998, two fin whales were presumed to have been killed in ship strikes. In 2006-2007, the stranding network in Hawai'i reported eight ship strikes, three of which were reported to have injured the whale involved.

Despite these reports, the magnitude of the risks commercial ship traffic poses to large whales in the Action Area is difficult to quantify or estimate. 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 Action Area.

5.2.4 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 and sea turtles 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, PCBs, and polyaromatic hydrocarbons) and immunosuppression (De Swart et al. 1996; Harder et al. 1992; Ross et al. 1995). 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 (O'Hara and Rice 1996; O'Shea and Brownell 1994).

Very little is known about baseline levels and physiological effects of environmental contaminants on marine turtle populations (Bishop et al. 1991; Witkowski and Frazier 1982). There are a few isolated studies on organic contaminants and trace metal accumulation in green and leatherback sea turtles (Aguirre et al. 1994; Davenport et al. 1990). Mckenzie et al. (McKenzie et al. 1999) measured concentrations of chlorobiphenyls and organochlorine pesticides in marine turtle tissues collected from the Mediterranean (Cyprus, Greece) and European Atlantic waters (Scotland) between 1994 and 1996. Omnivorous loggerhead turtles had the highest organochlorine contaminant concentrations in all the tissues sampled, including those from green and leatherback turtles. It is thought that dietary preferences were likely to be the main differentiating factor among species. Keller et al. (2005) found that chronic exposure of sea turtles to organochlorine contaminants (such as PCBs and pesticides) may modulate the immune response in these animals by suppressing innate immunity and enhancing certain lymphocyte activity. More research is needed on the short- and long-term health and fecundity effects of chlorobiphenyl, organochlorine, and heavy metal accumulation in sea turtles.

Anthropogenic Noise. The marine mammals and sea turtles 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. 1995b).

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; NRC 2000b; NRC 2003c; NRC 2005; Richardson et al. 1995b). Much of this increase is due to increased shipping as ships become more numerous and of larger tonnage (NRC 2003c). Commercial fishing vessels, cruise ships, transport boats, airplanes, helicopters and recreational boats all contribute sound into the ocean (NRC 2003c). 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 2003c). 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. 1995b). 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 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. The National Research Council (NRC 2000b) 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.

5.2.5 US Navy Activities

Navy Exercises. Since 1971, the U.S. Navy has conducted the biennial Rim of the Pacific exercises. These exercises, which historically have lasted for about a month, have involved forces from various nations on the Pacific Rim including Australia, Canada, Chile, Japan, and the Republic of Korea. We have limited information on the particular components of those exercises since their inception, but we assume that most of those exercises involved many of the components that are part of current Rim of the Pacific, although sonar systems and ordnance have evolved and changed over time.

We have limited information on the timing and nature of Rim of the Pacific Exercises prior to 2002 and we have no information on their potential effects on endangered and threatened marine animals in the Hawai'i Range Complex prior to 2006, when we started to consult with the U.S. Navy on the exercises. Several recent Rim of the Pacific exercises have occurred in the Hawai'i Range Complex. Between June and July 2006, the U.S. Navy conducted Rim of the Pacific exercises in the Hawai'i Range Complex. Based on the U.S. Navy’s December 7, 2006, After-Action Report, over the 15 calendar days of the 2006 RIMPAC (Navy 2006b), hull-mounted mid-frequency sonars were employed for a total of 472 hours (with 8 hours of transmission lost to comply with shut-down protocols required by a Marine Mammal Protection Act permit). Over the 15 calendar day of the 2006 RIMPAC, active and passive sonobuoys were deployed for 115 hours (which does not translate to 115 hours of sonar transmissions because some of the sonobuoys were deployed but were not transmitting).

U.S. Navy watchstanders reported marine mammals on 29 occasions (with the exception of two reports of pilot whales, marine mammals were not identified to species). On 12 of those 29 occasions, for a total of 8 hours, mid-frequency sonar associated with the exercise was shut down to avoid exposing marine mammals that had been observed. On 2 other occasions, marine mammals were observed more than 1,000 yards from a vessel while mid-frequency sonar was active.

The After Action Report for the 2006 RIMPAC concluded that (a) there was no evidence of any behavioral effects on marine mammals throughout the exercise; and (b) there were no reported standing events or observations of behavioral disturbance of marine mammals linked to sonar use during the exercise. The observations contained in the report (1) do not identify or estimate the number of endangered or threatened species that might have been exposed to mid-frequency active sonar during the exercise, (2) did not allow the U.S. Navy to evaluate the efficacy of the mitigation measures the U.S. Navy had implemented during the exercises (that is, those measures the Navy had proposed to implement on their own as well as the additional measures they implemented to comply with the MMPA permit), and (3) did not allow the U.S. Navy to evaluate the efficacy of the monitoring program associated with the exercises.

Between June and July 2008, the U.S. Navy conducted another Rim of the Pacific exercise in the Hawai'i Range Complex, with the at-sea portions that involved mid-frequency active sonar occurring between 7 and 31 July 2008. Based on the U.S. Navy's 30 November 2008 After-Action Report, over the 25 calendar days of the 2008 RIMPAC (Navy 2008b), mid-frequency active sonars from hull-mounted (surface vessels), dipping, and DICASS sonobuoys were employed for a total of 547 hours. Of this total, active sonar was employed between the shoreline and the 200-meter bathymetric contour for about 6 hours.

Participants in the 2008 RIMPAC exercises reported 29 sightings of marine mammal groups totaling about 200 animals; dolphins represented 21 or 72 percent of these sightings (125 of the individuals). Six whale groups were sighted during the exercise, all in waters more than 100 nm west of the Island of Hawai'i. An aerial survey over a portion of the area in which the 2008 RIMPAC exercises occurred reported 24 sightings of marine mammal groups involving eight species of small odonotocetes, Hawaiian monk seals, or unidentified dolphins (or sea turtles). A shipboard survey that also occurred in a portion of the area in which the 2008 RIMPAC exercises occurred reported 9 sightings of marine mammal groups consisting of either bottlenose dolphins, rough-toothed dolphins, or Hawaiian spinner dolphins. None of the observers reported unusual behavior or adverse behavioral responses to active sonar exposures or vessel traffic associated with the exercises.

Between July 6-31, 2010, the U.S. Navy conducted another Rim of the Pacific exercise in the Hawai'i Range Complex, with at-sea portions that involved mid-frequency active sonar. Based on the U.S. Navy's October 1, 2010 Annual Range Complex Exercise Report (Navy 2010), there were 47 sightings for a total of 286 marine mammals and 7 sightings for a total of 25 sea turtles. Five whale groups and eight lone whales were sighted during the exercise. None of the observers reported unusual behavior or adverse behavioral responses to active sonar exposures or vessel traffic associated with the exercises. None of these animals occurred at ranges within less than 1,000 yards of mid-frequency sonar use.

The U.S. Navy has also conducted Undersea Warfare Exercises in the Hawai'i Range Complex for several years (see the detailed description of the these exercises in *Description of the Proposed Action*), but the components (number of vessels involved, amount of active sonar produced, etc.) of these exercises can vary widely. For example, an Undersea Warfare Exercise conducted in the Hawai'i Range Complex from 13 to 15 November 2007, involved two ships equipped with AN/SQS-53C, one ship equipped with an/sqs-56, and entailed a total of 77 hours of mid-frequency active sonar from all sources (hull-mounted sonars, dipping sonars, and DICASS sonobuoys; U.S. Navy 2008a). An Undersea Warfare Exercise conducted in the Hawai'i Range Complex from 25 to 27 March 2008, involved four ships equipped with AN/SQS-53C, one ship equipped with AN/SQS-56, and entailed a total of 169 hours of mid-frequency active sonar from all sources (hull-mounted sonars, dipping sonars, and DICASS sonobuoys; U.S. Navy 2008b). An Undersea Warfare Exercise conducted in the Hawai'i Range Complex from 27 to 31 May 2008, involved four ships equipped with AN/SQS-53C, one ship equipped with AN/SQS-56, and entailed a total of 204 hours of mid-frequency active sonar from all sources (hull-mounted sonars, dipping sonars, and DICASS sonobuoys (Navy 2008b). The Undersea Warfare Exercise conducted in the Hawai'i Range Complex from August 7-10, 2010 involved only eight ships. The information regarding the number of ships equipped with active sound sources is recorded but is only reported in the classified addendum to the 2010 Annual Range Complex Exercise Report (Navy 2010).

Monitoring surveys associated with the November 2007 Undersea Warfare Exercises reported 26 sightings of five species during exercise, including green sea turtles and Hawaiian monk seals. None of the marine animals observed from survey vessels or aircraft were reported to have exhibited unusual behavior or changes in behavior during the surveys. Monitoring surveys associated with the March 2008 Undersea Warfare Exercises reported 47 sightings of five species during exercise, including humpback whales (40 sightings of 68 individuals) and an unidentified sea turtle. None of the marine animals observed from survey vessels or aircraft were reported to have exhibited unusual behavior or changes in behavior during the surveys. Monitoring surveys associated with the August 2010 Undersea Warfare Exercises reported zero sightings of marine mammals during the exercise.

Three SINKEXs were conducted in the Hawai'i Range Complex; one each on July 10, 2010, July 14, 2010, and July 17, 2010. Although observation time totaled 259, 316 and 99 hours for the three dates, respectively, no marine mammals were sighted during the exercises.

During the period from August 2010 to August 2011, the Navy conducted two major training exercises in the Hawaii Range Complex. During these exercises there were approximately 31 sightings of an estimated 84 marine mammals; 32 dolphins, 47 whales, 0 pinnipeds and 5 sightings that did not identify the species type. Four marine mammal sightings met the criteria for shut down mitigation - that is the animal was within 200 yards of the vessel or sonar source.

Hull-mounted active sonar was not used within the Humpback Whale Cautionary Area or the “dense humpback areas” inclusive of the 5 km buffer between 15 December 2010 and 15 April 2011. With the exception of EER/IEER explosive sonobuoys, the number of explosive exercises was substantially below 50 percent of the level proposed for use in the previous ESA consultation.

SURTASS LFA Sonar Missions in the Hawai’i Range Complex. In June 2008, NMFS consulted on a proposal by the U.S. Navy to conduct three training missions with the SURTASS LFA sonar system in the Hawai'i Range Complex between January and August 2009. This system is a long-range, low frequency sonar (between 100 and 500 Hertz (Hz)) that has both active and passive components. The SURTASS LFA is part of the U.S. Navy’s Integrated Undersea Surveillance System (IUSS), which is designed to detect, classify and track diesel and nuclear submarines operating in both shallow and deep regions of littoral waters and deep ocean areas.

The active component of the SURTASS LFA sonar system (LFA) consists of up to 18 low-frequency acoustic-transmitting source elements (called projectors) that are suspended from a cable beneath a ship. The projectors transform electrical energy to mechanical energy by setting up vibrations, or pressure disturbances, with the water to produce the active sound (which is called a “pulse” or a “ping”). The SURTASS LFA’s transmitted beam is omnidirectional (full 360 degrees) in the horizontal. The nominal water depth of the center of the array is 400 ft (122 m), with a narrow vertical beam-width that can be steered above or below the horizontal. The source level of an individual projector in the SURTASS LFA sonar array is approximately 215 dB, and the sound field of the array can never have a sound pressure level higher than that of an individual projector. The shallowest water depth that a SURTASS LFA vessel would operate is 100 m (328.1 ft). Signals transmitted by the SURTASS LFA sources are limited to between 100 and 330 Hertz (Hz) with source levels for each of the 18 projectors not more than 215 dB (re: 1 micro Pascal (μPa) at 1 meter (m)) and a maximum duty cycle of 20 percent.

The typical SURTASS LFA sonar signal is not a constant tone, but is a transmission of various signal types that vary in frequency and duration (including continuous wave and frequency-modulated signals). The Navy refers to a complete sequence of sound transmissions as a “ping” which can range from between 6 and 100 seconds, with no more than 10 seconds at any single frequency. The time between pings will typically range from 6 to 15 minutes. The Navy can control the average duty cycle (the ratio of sound “on” time to total time) for the system but the duty cycle cannot be greater than 20 percent; the Navy anticipates a typical duty cycle between 10 and 15 percent.

The passive or listening component of the system (SURTASS) uses hydrophones to detect echoes of the active signal returning from submerged objects, such as submarines. The hydrophones are mounted on a horizontal array that is towed behind the ship. The SURTASS LFA sonar ship maintains a minimum speed of 3.0 knots (5.6 km/hr; 3.4 mi/hr) in order to keep the array properly deployed. The return signals, which are usually below background or ambient noise levels, are then processed and evaluated to identify and classify potential underwater threats.

Missions for SURTASS LFA sonar systems typically occur over a 49-day period, with 40 days of operations and 9 days of transit. Based on a 7.5 percent duty cycle (based on historical LFA operating parameters), the system transmits for about 72 hours per 49-day mission and 432 hours per year for each of the two SURTASS LFA sonar systems. SURTASS LFA sonar vessels operate independently of, or in conjunction with, other naval air, surface or submarine assets. The vessels generally travel in straight lines or racetrack patterns depending on the operational scenario.

Mitigation Associated With The SURTASS LFA Sonar System. To avoid potential injuries to marine mammals (and possibly sea turtles), the Navy proposes to detect animals within an area they call the “LFA mitigation zone” (the area within the 180-dB isopleth of the SURTASS LFA sonar source sound field) before and during low frequency transmissions. NMFS has also added an additional 1-kilometer buffer zone beyond the LFA mitigation zone.

Monitoring has generally (a) commenced at least 30 minutes before the first SURTASS LFA sonar transmission; (b) continued between pings; and (c) continued for at least 15 minutes after completion of a SURTASS LFA sonar transmission exercise or, if marine mammals exhibited abnormal behavior patterns, for a period of time until those behavior patterns returned to normal or until viewing conditions prevented continued observations.

The Navy has used three monitoring techniques: (a) visual monitoring for marine mammals and sea turtles from the SURTASS LFA sonar vessel during daylight hours; (b) use of the passive (low frequency) SURTASS array to listen for sounds generated by marine mammals as an indicator of their presence; and use of high frequency active sonar (High Frequency Marine Mammal Monitoring or HF/M3 sonar) to detect, locate, and track marine mammals (and possibly sea turtles) that might be affected by low frequency transmissions near the SURTASS LFA sonar vessel and the sound field produced by the SURTASS LFA sonar source array.

Visual Monitoring. Visual monitoring includes daytime observations from observers on the SURTASS LFA sonar vessel to detect marine animals. Visual monitoring begins 30 minutes before sunrise, for ongoing transmissions, or 30 minutes before SURTASS LFA sonar is deployed and continues until 30 minutes after sunset or until SURTASS LFA sonar array is recovered. Personnel trained in detecting and identifying marine animals make observations from the vessel. At least one observer qualified by NMFS, trains, tests and evaluates other visual observers. If a marine mammal is detected within the 180-dB LFA mitigation zone or the 1 km (0.54 nm buffer zone extending beyond the LFA mitigation zone, SURTASS LFA sonar transmissions are immediately suspended. Transmissions do not resume less than 15 minutes after:

- All marine mammals have left the area of the LFA mitigation and buffer zones; and
- There is no further detection of any marine mammal within the LFA mitigation and buffer zones as determined by the visual and/or passive or active acoustic monitoring.

Passive acoustic monitoring. The U.S. Navy also uses passive acoustic monitoring for low frequency sounds generated by marine mammals when SURTASS is deployed. The following actions are associated with this monitoring:

- If sounds are detected and estimated to be from a marine mammal, the technician will notify the Officer in Charge who will alert the HF/M3 sonar operator and visual observers;
- If a sound produced by a marine mammal is detected, the technician will attempt to locate the sound source using localization software; and
- If it is determined that the animal will pass within the LFA mitigation zone or 1-km buffer zone (prior to or during transmissions), then the Officer in Charge will order the delay/suspension of transmissions when the animal is predicted to enter either of these zones.

High frequency active acoustic monitoring. The Navy also conducts high frequency active acoustic monitoring (by using an enhanced, commercial-type high frequency sonar) to detect, locate, and track marine mammals (and possibly sea turtles) that could pass close enough to the SURTASS LFA sonar transmit array to exceed the 180-dB mitigation criterion. This Navy-developed HF/M3 sonar operates with a similar power level, signal type, and frequency as high frequency “fish finder” type sonars used worldwide by both commercial and recreational fishermen.

The U.S. Navy ramps up the HF/M3 source slowly to operating levels over a period of no less than 5 minutes: The HF/M3 source will not increase its sound pressure level once a marine mammal is detected; ramp-up may proceed once marine mammals are no longer detected.

HF/M3 sonar, LFA mitigation zone, and sound propagation. The extent of the LFA mitigation zone (i.e., within the 180-dB sound field) is estimated by onboard acoustic modeling and environmental data collected *in situ*. Factored into this calculation are SURTASS LFA sonar source physical parameters of tow speed, depth, vertical steering, signal waveform/wavetrain selection, and peak transmit source level. The HF/M3 sonar is located near the top of the SURTASS LFA sonar vertical line array. The HF/M3 sonar computer terminal for data acquisition/processing/display will be located in the SURTASS Operations Center. The HF/M3 sonar uses frequencies from 30 to 40 kHz with a variable bandwidth (1.5 to 6 kHz nominal); a 3-4 percent (nominal) duty cycle; a source level of 220 dB re 1 μPa at 1 m; a five-minute ramp-up period; and a maximum, nominal detection range of 2-2.5 km (1.08-1.35 nm).

The HF/M3 sonar operates continuously while the SURTASS LFA sonar is deployed. When a marine animal is detected by the HF/M3 sonar, it automatically triggers an alert to the Watch Supervisor, who notifies the Officer in Charge. The Officer in Charge then orders the immediate delay/suspension of SURTASS LFA sonar transmissions until the animal is determined to have moved beyond the mitigation zone. All contacts are recorded and provided to NMFS as part of the long-term monitoring program associated with the proposed action.

Analysis and testing of the HF/M3 sonar operating capabilities indicate that this system substantially increases the probability of detecting marine mammals within the LFA mitigation zone. It also provides an excellent monitoring capability (particularly for medium to large marine mammals) beyond the LFA mitigation zone, out to 2 to 2.5 km (1.08 to 1.35 nm). Recent testing of the HF/M3 sonar has demonstrated a probability of single-ping detection above 95 percent within the LFA mitigation zone for most marine mammals.

Exposure to low-frequency active sonar. The dominant propagation paths for SURTASS LFA signals in low and middle latitudes would consist of convergence zone and bottom interaction (<2000 m or <6,600 ft depths). In most open water conditions, convergence zone propagation will be most prominent. SURTASS LFA signals will interact with the ocean bottom, but those signals will not penetrate coastal waters with appreciable signal strengths because of high bottom and surface losses. Because of spherical spreading, the 215 dB signal from a SURTASS LFA projector would be expected to attenuate by about 60 dB one kilometer from the source and by about 66 dB two kilometers from the source. In ideal oceanic conditions, a SURTASS LFA signal would lose about 120 dB to spherical spreading, so the signal would probably approach or fall below ambient levels about 960 kilometers from a SURTASS LFA source (about 600 miles).

Inside the LFA mitigation zone during a ping, a marine mammal could be exposed to sound levels at or above 180 dB and could experience permanent threshold shifts or other injury. However, the LFA mitigation zone (which, as we discussed in the *Description of the Proposed Action*, uses active and passive sonar to detect the presence of marine animals) was established and designed to prevent marine mammal or sea turtles from being exposed to these energy levels. Given the size of the LFA mitigation zone (extending to approximately 0.75 to 1.00 km [0.40 to 0.56 nm] from the transmitter) and the additional 1-km buffer zone, the detection probabilities associated with the HF/M3 sonar (above 95 percent probability of detecting small dolphins at about 750 m [0.4 nm], whale calves at 1,000 m [0.56 nm] and large whales at more than 1,500 m [0.81 nm]), and the depth of the transmitters, a marine mammal would have a high probability of being detected within the LFA mitigation zone and, as a result, a low probability of being exposed to sound levels greater than 180 dB.

For an animal to be exposed at received levels greater than 180 dB, the animal would have to occur in the same approximately 4-kilometer wide water column as the LFA transmitter, would have to enter the LFA mitigation zone without being detected, and would have to remain in the LFA mitigation zone when the LFA transmitter was operating. Based on the available information, we believe the probability of all of these events occurring, although possible, is extremely improbable.

Further, SURTASS LFA is operated to ensure that sonar sound fields do not exceed 180 dB (re 1 μPa rms) within 12 nautical miles (22 kilometers) of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile (22 kilometer) zone during seasons specified for a particular area. When in the vicinity of known recreational and commercial dive sites, SURTASS

LFA sonar would be operated to ensure that the sound field at these sites would not exceed 145 dB, adding an additional level of protection for marine mammals located in dive sites.

Based on the operations of the HF/M3 sonar during missions the Navy conducted between 2002 and 2006, the HF/M3 sonar appears to effectively detect marine animals within 1 to 2 kilometers of the LFA projectors. Recent testing of the HF/M3 sonar demonstrated a probability of single-ping detection above 95 percent within the LFA mitigation zone for most marine mammals (Navy 2005). For example, during seven of the nine SURTASS LFA missions the Navy conducted in 2004, there were twelve HF/M3 alerts that were identified as possible marine mammal or sea turtle detections. Between February 2005 and February 2006 LFA transmissions were delayed or suspended on 33 occasions: operations on the USNS IMPECCABLE were delayed or suspended four times because of possible marine mammal or sea turtle detections and three times due to HF/M3 failures while operations on the R/V *Cory Chouest* were delayed or suspended 12 times because of possible marine mammal or sea turtle detections, 13 times because the HF/M3 system failed, and once because of a visual sighting of dolphins.

Duration of potential exposure to SURTASS LFA transmissions. Between the third week of January 2009 and mid-August 2009, the Navy conducted 3 missions with the SURTASS LFA sonar system in the Hawai'i Range Complex, with 7 days active during each mission and 24 hours of operations per day. The duration of a typical SURTASS LFA ping would range from 6 to 100 seconds, with no more than 10 seconds at a single frequency; intervals between pings would range from 6 to 15 minutes. Pings would consist of various signal types that vary in frequency (between 100 and 500 Hz) and duration (including continuous wave and frequency-modulated signals). When the system is turned off, no additional energy would enter the ocean's environment.

The duration of an animal's exposure to SURTASS LFA signals would depend on the animal's proximity to the transmitter and the animal's location in the water column. Nevertheless, because of the length of individual pings, individual animals are likely to be exposed to SURTASS LFA transmissions for periods ranging from 6 to 100 seconds.

Mitigation measures to minimize the likelihood of exposing marine mammals to LFA sonar. The Navy proposes to use a monitoring program to avoid potentially exposing marine mammals to LFA transmissions at high decibel levels. As discussed in the *Description of the Proposed Action*, this monitoring program includes visual, passive acoustic, and active acoustic monitoring of a 180 dB mitigation zone and an additional 1 km buffer zone.

The effectiveness of visual monitoring is limited to daylight hours, and its effectiveness declines during poor weather conditions. 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 and Borchers 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). The percentage of animals that will pass unseen is difficult to determine, but 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 effectiveness of passive acoustic detection is considered to be higher than visual monitoring. Thomas et al. (1986) and Clark and Fristrup (1997) concluded that the effective strip width and detection rates for passive acoustic monitoring is greater than that for visual, but the percentage of animals that will be undetected by the methods is unknown. Frequency coverage for this mitigation method using the SURTASS passive array is between 0 and 500 Hz, so vocalizing animals are more likely to be detected than animals that do not vocalize. This would increase the detection rate of gray, humpback, fin, blue, and minke whales, and some of the beaked whale and dolphin species.

The HF/M3 sonar is the final measure the Navy proposes to use to detect animals within 1 to 2 kilometers of the projectors. Recent testing of the HF/M3 sonar demonstrated a probability of single-ping detection above 95 percent within the LFA mitigation zone for most marine mammals. If any of these monitoring methods detects animals within this zone, the projectors would be shut down until an animal moves out of the mitigation zone. Combined with the visual monitoring and passive acoustic monitoring protocols, this should minimize the risk of marine mammals being exposed to sound pressure levels in excess of 180 dB.

The U.S. Navy’s exposure models identified the following numbers of whales by species may be exposed to SURTASS LFA transmissions:

> *Blue Whales*. The U.S. Navy’s exposure models identified 23 instances in which blue whales might be exposed to SURTASS LFA transmissions at received levels ranging between 120 dB and 180 dB during SURTASS LFA missions in the Hawai'i Range Complex.
>
> *Fin Whales*. The U.S. Navy’s exposure models identified 80 instances in which fin whales might be exposed to SURTASS LFA transmissions at received levels ranging between 120 dB and 180 dB during SURTASS LFA missions in the Hawai'i Range Complex.
>
> *Humpback Whales*. The U.S. Navy’s exposure models identified 91 instances in which humpback whales might be exposed to SURTASS LFA transmissions at received levels ranging between 120 dB and 180 dB during SURTASS LFA missions in the Hawai'i Range Complex.
>
> *Sperm Whales*. The U.S. Navy’s exposure models identified 166 instances in which sperm whales might be exposed to SURTASS LFA transmissions at received levels ranging between 120 dB and 180 dB during SURTASS LFA missions in the Hawai'i Range Complex.
>
> *Hawaiian Monk Seals*. Although Hawaiian monk seals generally reside in coastal waters near haulout areas, they forage in deep water and dive to at least 490 m (1,608 ft) (Reeves et al. 1992), which could expose them to low frequency sounds from SURTASS LFA. The U.S. Navy’s exposure models identified 14 instances in which Hawaiian monk seals might be exposed to SURTASS LFA transmissions at received levels ranging between 120 dB and 180 dB during SURTASS LFA missions in the Hawai'i Range Complex.

Based on SURTASS LFA pre-operational and post-operational estimates within the Hawai'i Operating Area within the Hawai'i Range Complex blue whales, humpback whales, fin whales and sperm whales are believed to have been exposed to SURTASS LFA transmissions. These numbers are represented by percentages of each species’ population (Table 7).

Table 7. Estimates of Listed Whale Species Exposed to SURTASS LFA Transmissions from 2008-2009.

Whale Species	Population Estimate	Pre-Operational % Affected with Mitigation 120-180 dB	Post-Operational % Affected with Mitigation 120-180 dB
Blue	1,548	2.95	0
Fin	2,099	7.62	0.86
Sei	-	-	-
Humpback	4,491	2.03	0.0
Sperm	6,919	4.81	0.54

Thus far, the combination of geographic constraints, operating protocols, monitoring measures, and shut-down procedures appear to have prevented most threatened and endangered species of marine mammal and sea turtles from being exposed to SURTASS LFA sonar at received levels exceeding 180 dB. Further, they have prevented these species from being exposed in areas that are critical to their ecology, critical to large portions of their populations, or both. The Navy proposes to continue using these measures and they are likely to perform as well in the future as they have performed thus far. Therefore, based on the evidence available, most marine animals are likely to be exposed to received levels of LFA sonar at or below 180 dB.

From late-August 2009 to August 2010 no missions with the SURTASS LFA sonar system were conducted in the Hawai'i Range Complex and no future operations are expected until new MMPA regulations are promulgated in 2012.

5.2.6 Deep Water Ambient Noise

Urick (1983) provided a discussion of the ambient noise spectrum expected in the deep ocean. Shipping, seismic activity and weather are primary causes of deep-water ambient noise. Noise levels between 20 and 500 Hz appear to be dominated by distant shipping noise that usually exceeds wind-related noise. Above 300 Hz, the level of wind-related noise might exceed shipping noise. Wind, wave, and precipitation noise originating close to the point of measurement dominate frequencies from 500 to 50,000 Hz. The frequency spectrum and level of ambient noise can be predicted fairly accurately for most deep-water areas based primarily on known shipping traffic density and wind state (wind speed, Beaufort wind force, or sea state) (Urick 1983). For frequencies between 100 and 500 Hz, Urick (1983) has estimated the average deep water ambient noise spectra to be 73 to 80 dB for areas of heavy shipping traffic and high sea states, and 46 to 58 dB for light shipping and calm seas.

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.

5.2.7 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. 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; Corkeron 1995; Erbe 2002; Félix 2001; Magalhaes et al. 2002; Richter et al. 2003; Scheidat et al. 2004; Simmonds 2005; Watkins 1986; Williams et al. 2002b). 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.

5.3 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 action area and their role as a 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 the Hawaiian Archipelago 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 remain uncertain.

Our knowledge of the distribution and abundance of populations of endangered and threatened marine animals in the Hawaiian Archipelago varies widely. We have a better understanding of the distribution and abundance of humpback whales, Hawaiian monk seals, and the Hawaiian population of green sea turtles than of any of the other endangered or threatened species that occur in the Hawaiian Islands. For example, there is still almost no information on the distribution and number of blue, fin, and sei whales that occur in the Hawaiian Islands and temporal trends in their abundance; without that information, it would be impossible to determine if these population are increasing or not. Our understanding of the at-sea distribution and abundance of green sea turtles from the Eastern Tropical Pacific, hawksbill, leatherback, loggerhead, and Pacific ridley sea turtles remains very limited and primarily consists of information from their interactions with commercial fisheries in the Hawaiian Islands.

Few of the anthropogenic phenomena in the Hawaiian Archipelago that represent potential risks to whales in Hawaiian waters 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 Hawaiian waters. The second line of evidence consists of reports that suggest that the response of whales to many of the anthropogenic activities in the Hawaiian Archipelago 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 whale 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. (1992), Clapham and Mattila (1993), Clapham (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 have 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. (1981b) 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 (Malme et al. 1983; Richardson et al. 1985b). 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 a 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 at low speeds to reduce visible reactions in these whales.

Beale and Monaghan (2004b) 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 on 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 2004b; Frid 2003; Frid and Dill 2002; Gill and Sutherland 2001; Harrington and Veitch 1992; Lima and Dill. 1990; Romero and Wikelski 2002). 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; Müllner et al. 2004), and the death of individual animals (Daan et al. 1996; Feare 1976).

The strongest evidence 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 and the increased number of humpback whales that are reported to occur in the Hawaiian Islands. In the 1980s, the size of the North Pacific humpback whale population was estimated to range from 1,407 to 2,100 (Baker 1985a; Baker and Herman 1987; Darling and Morowitz 1986). 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 2001). The most recent estimate places the current population of humpback whales in the North Pacific Ocean at about 18,300 whales, not counting calves (Calambokidis et al. 2008). Almost half of the humpback whales that were estimated to occur in wintering areas, or about 8,000 humpback whales, occupy the Hawaiian Islands during the winter months. Despite small numbers that are entangled in fishing gear in the action area, this increase in the number of humpback whales suggests that the activities these whales are exposed to in the Hawaiian Islands have not prevented these whales from increasing their numbers in the action area, although we do not know if more humpback whales might have used the action area in the absence of those stressors. The information that is available does not allow us to reach similar conclusions for the other endangered or threatened cetaceans in the action area.

Similarly, despite continued declines in the Northwest Hawaiian Islands, the increasing rate at which monk seals are sighted in the Main Hawaiian Islands and the increased number of pups born in the Main Hawaiian Islands suggests that the stress regime created by the activities discussed in this Environmental Baseline is not having a negative impact on these seals. In the case of monk seals, however, increases in their occurrence in the Main Hawaiian Islands may represent a re-distribution from the Northwest Hawaiian Islands, which would imply that environmental conditions may merely be worse in the Northwest Hawaiian Islands.

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 green, hawksbill, 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 hawksbill, 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 for leatherback and loggerhead sea turtles. The number of individuals of both 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.

6 EFFECTS OF THE PROPOSED ACTION

In Effects of the Action sections of Opinions, we present the results of our assessment of the probable direct and indirect effects of federal actions that are 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. We organize our effects’ analyses using a stressor identification - exposure – response – risk 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 Baseline 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.

For this Opinion, we define “harassment” as “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 behavior that are likely to result in animals that fail to feed, fail to breed successfully, or fail to complete their life history because those changes may have adverse consequences for populations of those species.

6.1 Potential Stressors

There are several potential stressors associated with the proposed U.S. Navy training exercises in the Hawai’i Range Complex (Table 8). 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 potential stressors may produce multiple stressors. For example, underwater detonations produce pressure waves as well as sound. As a second example, surface vessels represent one potential stressor because of their weight and speed (risk of potential collisions), a second form of potential stressor because of the sounds associated with their passage (bow wave and engine noise), and a third form of potential stressor when they engage their active sonar systems. Animals in the ocean are likely to process all salient acoustic and visual cues associated with vessels involved in Navy training activities and respond based on the perception they form from these cues; their responses will vary depending on their experience, their health status, behavioral state, and circumstances.

The U.S. Navy has conducted training exercises in waters off the main Hawaiian Islands (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 Hawai'i Range Complex and the potential stressors listed in Table 8 would continue to be associated with those exercises.

Table 8. Potential stressors associated with the activities the U.S. Navy proposes to conduct in the Hawai'i Range Complex from January 2012 to January 2014.

Potential Stressor		Proposed Activity			
		USWEX	Multi-Strike	Unit-Level Training	RDT&E
1	Surface vessel traffic	X	X	X	X
2	Aircraft traffic	X	X	X	X
3	Engine noise from Navy ships	X	X	X	X
4	High-frequency active sonar	X	X	X	X
5	Mid-frequency active sonar	X	X	X	X
6	Pressure waves associated with explosions	X	X	X	X
7	Sound fields produced by explosions	X	X	X	X
8	Transmitted sounds from in-air explosions	X	X	X	X
9	Disturbance associated with human presence on beaches (during amphibious exercises)	X	X	X	-
10	Parachutes released during deployment of sonobuoys	X	X	X	X

What follows is a more detailed description of the stressors listed in Table 8 in greater detail. Following those descriptions, we present the results of our exposure analyses, followed by the results of our response analyses. We conclude our effects analyses with an Integration and Synthesis that presents the results of our risk analyses.

6.1.1 Surface Vessel and Submarine Traffic

Most of the activities the U.S. Navy proposes to conduct in the Hawai'i Range Complex involve some level of activity from surface vessels, submarines, or both. Undersea Warfare Exercises typically involve from one to five surface ships equipped with sonar, with one or more helicopters, and a P-3 aircraft searching for one or more submarines. Unit-level or intermediate-level anti-submarine warfare (ASW) tracking exercises include ships, fixed wing aircraft, helicopters, torpedo targets, submarines, and weapons recovery boats or helicopters.

During ASW training activities, ship speeds generally range from 10 to 14 knots; however, these vessels would also operate across a wider spectrum of speeds during other events, such as pursuing and overtaking hostile vessels, evasive maneuvers, and maintenance vessel traffic associated with the proposed training exercises. The full range of naval vessel activity represents a suite of stressors or stress regimes that pose several potential hazards to endangered and threatened species in the Hawai'i Range Complex. First, the size and speed of these vessels pose some probability of collisions between vessels and marine mammals and sea turtles. Second, this amount of traffic represents an acute or chronic source of disturbance to marine animals in the Hawai'i 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

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 vessels and whales.

Although the probability of a collision seems fairly small given the measures that are in place, 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

A number of studies indicate surface vessels represent sources of acute and chronic disturbance for marine mammals (Amaral and Carlson 2005; Au and Perryman 1982; Au and Green 2000; Bain et al. 2006; Bauer 1986; Bejder et al. 1999; Bejder and Lusseau. 2008; Bejder et al. 2009; Bryant et al. 1984; Corkeron 1995; Erbe 2002; Félix 2001; Goodwin and Cotton 2004; Lemon et al. 2006; Lusseau 2003; Lusseau 2006; Magalhaes et al. 2002; Nowacek et al. 2001; Richter et al. 2003; Scheidat et al. 2004; Simmonds 2005; Watkins 1986; Williams et al. 2002b; Wursig et al. 1998). In some circumstances, marine mammals respond to vessels with the same suite of behaviors and tactics used when they encounter predators. It is not clear what environmental cue or cues 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.

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 Cotton 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 Jaakson 1994; Evans et al. 1992; Evans et al. 1994).

For surface vessels, the set of variables that help determine whether marine mammals are likely to be disturbed include: (1) the number of vessels in a marine mammal's perceptual field and the animal's assessment of the risks associated with those vessels; (2) the distance between vessels and marine mammals; (3) the vessel's speed and path; (4) the predictability of the vessel's path; (5) noise associated with the vessel and the rate at which the engine noise increases; and (7) the type of vessel. 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 associated sounds, 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, 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.

Sea turtles would be expected to detect approaching vessels via auditory and/or visual cues based on knowledge of their sensory biology (Ketten and Bartol 2006). Little information is available on how turtles respond to vessel approaches. Hazel et al. (2007) reported sea turtle reaction time was greatly dependent on the speed of the vessel; sea turtles were able to react faster to slower moving vessels than to faster moving vessels. Also, sea turtle reactions to vessels elicited short-term responses. Sea turtle hearing sensitivity is not well studied. Several studies using green, loggerhead, and Kemp's ridley turtles suggest that sea turtles are most sensitive to low-frequency sounds, although this sensitivity varies slightly by species and age class (Bartol et al. 1999a; Ketten and Bartol 2006; Lenhardt et al. 1994; Ridgway et al. 1969).

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 (NRC 2003c). Commercial fishing vessels, cruise ships, transport boats, recreational boats, and aircraft, all contribute sound into the ocean (NRC 2003c). 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, or tonal, and sound pressure levels at a source will vary according to speed, burden, capacity and length (Richardson et al. 1995b). 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.

6.1.2 Disturbance from Aircraft

Most of the activities the U.S. Navy proposes to conduct in the Hawai'i Range Complex also involve some level of activity from aircraft that include helicopters, maritime patrols, and fighter jets. Low-flying aircraft produce sounds that marine mammals can hear when they occur at or near the ocean's surface. Helicopters generally tend to 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.

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. (1995b) 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. 2002; Richter et al. 2006; Smultea et al. 2008; Wursig et al. 1998).

Based on sea turtle sensory biology (Bartol et al. 1999a; Ketten and Bartol 2005; Ketten and Bartol 2006; Lenhardt et al. 1994; Ridgway et al. 1969), sound from low flying aircraft could be heard by a sea turtle at or near the surface. Turtles might also detect low flying aircraft via visual cues such as the aircraft's shadow. Hazel et al. (2007)suggested that green sea turtles rely more on visual cues than auditory cues when reacting to approaching water vessels. This suggests that sea turtles might not respond to aircraft overflights based on noise alone.

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 Hawai'i Range Complex.

6.1.3 Sonar Sound Fields

The Navy plans to employ mid-and high-frequency sonar systems during several of the training events it proposes to conduct in the Hawai'i Range Complex. 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. Tactical military sonars are designed to search for, detect, localize, classify, and track submarines. The Navy typically employs two types of sonars during anti-submarine warfare exercises:

> 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.

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 during military readiness activities in the Hawai'i Range Complex 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. The primary surface ship sonars considered are:

1. The AN/SQS-53 – a computer-controlled, hull-mounted surface-ship sonar that has both active and passive operating capabilities, providing precise information for anti-submarine warfare (ASW) weapons control and guidance. The system is designed to perform direct-path ASW search, detection, localization, and tracking, from a hull-mounted transducer array. The AN/SQS-53 is characterized as a mid-frequency active (MFA) sonar, operating from 1 to 10 kilohertz (kHz); however, the exact frequency is classified. The

AN/SQS-53 sonar is the major component to the AN/SQQ-89 sonar suite, and it is installed on Arleigh Burke Class guided missile destroyers, and Ticonderoga Class guided missile cruisers.

2. The AN/SQS-53 Kingfisher – a modification to the AN/SQS-53 sonar system that provides the surface ship with an object detection capability. The system uses MFA sonar, although the exact frequency range is classified. This sonar system is installed on Arleigh Burke Class guided missile destroyers, and Ticonderoga Class guided missile cruisers.

3. The AN/SQS-56 – a hull-mounted sonar that features digital implementation, system control by a built-in mini-computer, and an advanced display system. The sonar is an active/passive, preformed beam, digital sonar providing panoramic active echo ranging and passive digital multibeam steering (DIMUS) surveillance. 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/SQS-56 is the major component of the AN/SQQ-89 sonar suite and is installed on Oliver Hazard Perry Class frigates.

4. The AN/SQR-19– a tactical towed array sonar (TACTAS) that is able to passively detect adversary submarines at a very long range. The AN/SQR-19, which is a component of the AN/SQQ-89 sonar suite, is a series of passive hydrophones towed from a cable several thousand feet behind the ship. The AN/SQR-19 can be deployed by Arleigh Burke Class guided missile destroyers, Ticonderoga Class guided missile cruisers, and Oliver Hazard Perry Class frigates.

Table 9. Description and attributes of sonar sources proposed for use in the Hawai'i 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	7 m	3.5 kHz	235 dB	154 m	Omni	240° 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

The duration, rise times, and wave form of sonar transmissions that would be used during the proposed 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 sonars 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).

Sonar Systems Associated With Submarines

Tactical military submarines equipped with hull-mounted mid-frequency use active sonar to detect and target enemy submarines and surface ships. The predominant active sonar system mounted on submarines is AN/BQQ-10 sonar that is used to detect and target enemy submarines and surface ships. Two other systems — AN/BQQ-5 and AN/BSY-1/2 — have operational parameters that would affect marine mammals in ways that are similar to the AN/BQQ-10. In addition, Seawolf Class attack submarines, Virginia Class attack submarines, Los Angeles Class attack submarines, and Ohio Class nuclear guided missile submarines also have the AN/BQS-15 sonar system, which uses high-frequency for under-ice navigation and mine-hunting.

1. The AN/BQQ-10 is characterized as mid-frequency active sonar, although the exact frequency range is classified. The AN/BQQ-10 is installed on Seawolf Class fast attack submarines, Virginia Class fast attack submarines, Los Angeles Class fast attack submarines, and Ohio Class nuclear guided missile submarines. The BQQ-10 systems installed on Ohio Class nuclear guided missile submarines do not have an active sonar capability.

2. The AN/BQQ-5 – a bow- and hull-mounted passive and active search and attack sonar system. The system includes the TB-16 and TB-23 or TB-29 towed arrays and Combat Control System MK 2. This sonar system is characterized as mid-frequency active sonar, although the exact frequency range is classified. The AN/BQQ-5 sonar system is installed on Los Angeles Class nuclear attack submarines and Ohio Class ballistic missile nuclear submarines, although the AN/BQQ-5 systems installed on Ohio Class ballistic missile nuclear submarines do not have an active sonar capability. The AN/BQQ-5 system is being phased out on all submarines in favor of the AN/BQQ-10 sonar.

3. The AN/BQS-15 – an under-ice navigation and mine-hunting sonar that uses high-frequency (i.e., greater than 10 kHz) active sonar, although the exact frequencies are classified. These systems are installed on Seawolf Class fast attack submarines, Virginia Class fast attack submarines, Los Angeles Class fast attack submarines, and Ohio Class nuclear guided missile submarines.

4. The AN/WQC-2– an MFA sonar underwater communications system that can transmit either voice or signal data in two bands, 1.5 to 3.1 kHz or 8.3 to 11.1 kHz. The AN/WQC-2, also referred to as the “underwater telephone,” is on all submarines and most surface ships, and allows voice and tonal communications between ships and submarines.

Sonar Systems Associated With Aircraft

Aircraft sonar systems that could be deployed during active sonar events include sonobuoys (tonal [active], listening [passive], and extended echo ranging [EER] or improved extended echo ranging [IEER]) and dipping sonar (AN/AQS-13/22 or AN/AOS-22). Sonobuoys may be deployed by marine patrol aircraft or MH-60R helicopters. 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 215 dB re μPa at 1m) than the AN/AQS -22 P-3 aircraft may deploy sonobuoys while helicopters may deploy sonobuoys or dipping sonars (the latter are used by carrier-based helicopters). A sonobuoy is an expendable device used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Most sonobuoys are passive, but some can generate active acoustic signals as well as listen passively. Dipping sonars are used by MH-60R helicopters. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets. A description of various types of sonobuoys and dipping sonar is provided below.

1. The AN/AQS-13 Helicopter Dipping Sonar – an active scanning sonar that detects and maintains contact with underwater targets through a transducer lowered into the water from a hovering helicopter. It operates at mid-frequency, although the exact frequency is classified. The AN/AQS-13 is operated by MH-60R helicopters.

2. The AN/AQS-22 Airborne Low-Frequency Sonar (ALFS) – the Navy's dipping sonar system for the MH-60R helicopter light airborne multi-purpose system III, which is deployed from aircraft carriers, cruisers, destroyers, and frigates. It operates at mid-frequency, although the exact frequency is classified. The AN/AQS-22 employs both deep- and shallow-water capabilities.

3. The AN/SSQ-62C Directional Command Activated Sonobuoy System (DICASS) – sonobuoy that operates under direct command from ASW fixed-wing aircraft or MH-60R 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. The active sonar operates at mid-frequency, although the exact frequency range is classified. After water entry, 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.

4. The AN/SSQ-110A Explosive Source Sonobuoy – a commandable, air-dropped, high source level explosive sonobuoy. The AN/SSQ-110A explosive source sonobuoy is composed of two sections, an active (explosive) section and a passive section. The upper section is called the "control buoy" and is similar to the upper electronics package of the AN/SSQ-62 DICASS sonobuoy. The lower section consists of two signal underwater sound explosive payloads of Class A explosive weighing 1.9 kg (4.2 lbs) each. The arming and firing mechanism is hydrostatically armed and detonated. Once in the water, the signal underwater sound charges explode, creating a loud acoustic signal. The echoes from the explosive charge are then analyzed on the aircraft to determine a submarine's position. The AN/SSQ-110A explosive source sonobuoy is deployed by marine patrol aircraft.

5. The AN/SSQ-53D/E Directional Frequency Analysis and Recording (DIFAR) – a passive sonobuoy deployed by MPA aircraft and MH-60R helicopters. The DIFAR sonobuoy provides acoustic signature data and bearing of the target of interest to the monitoring unit(s) and can be used for search, detection, and classification. The buoy uses a hydrophone with directional detection capabilities in the very low frequency, low frequency, and mid-frequency ranges, as well as an omnidirectional hydrophone for general listening purposes.

6. The AN/SSQ-125 Advanced Extended Echo Ranging (AEER) Sonobuoy is a third generation of multi-static active acoustic search systems to be developed under the Extended Echo Ranging family of the systems and is being developed as the replacement for the AN/SSQ-110A. The AN/SSQ-125 sonobuoy is composed of two sections, the control section and the active source section. The control section is similar to the upper electronics package of the AN/SSQ-62 DICASS sonobuoy. The lower section consists of the active sonar source. The echoes from pings of the sonar are then analyzed on the aircraft to determine a submarine‘s position. The AN/SSQ-125 sonobuoy will be deployed by maritime patrol aircraft

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.

1. The MK 48 and MK 48 Advanced capability are heavyweight torpedoes deployed on all classes of Navy submarines. MK 48 and MK 48 Advanced torpedoes are inert and considered HF sonar, but the frequency ranges are classified. Due to the fact that both torpedoes are essentially identical in terms of environmental interaction, they will be referred to collectively as the MK 48 in this Opinion.

2. The MK 46 Lightweight Torpedo are ASW torpedoes. They are less than half the size of the MK 48 and can be launched from surface ships, helicopters, and fixed wing aircraft. When used in training, the MK 46 is inert and considered HF sonar, but the exact frequency range is classified. When dropped from an aircraft, the MK 46 may have a parachute, which is jettisoned when it enters the water. The MK 46 torpedo also carries a small sea dye marker (Fluorescein) that marks the torpedo’s position on the surface to facilitate recovery. The MK 46 is planned to remain in service until 2015.

In addition to these torpedoes, the Navy can employ acoustic device counter measures in their training exercises, which include MK-1, MK-2, MK-3, MK-4, noise acoustic emitter, and the AN/SLQ-25A NIXIE. These countermeasures act as decoys by making sounds that simulate submarines to avert localization or torpedo attacks.

6.1.4 Explosions and Underwater Detonations

The U.S. Navy plans to continue to employ several kinds of explosive ordnance in the Hawai'i Range Complex (Table 10). 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 shock wave and blast noise from explosions are of most concern to marine animals. Depending on the intensity of the shock wave and size and depth of the animal, an animal can be injured or killed. Further from the blast, an animal may suffer non-lethal physical effects. Outside of these zones of death and physical injuries, marine animals may experience hearing related effects with or without behavioral responses.

Explosive Source Associated With The Improved Extended Echo Ranging (IEER) System. One of the systems the Navy proposes to use as part of the proposed active sonar training is the AN/SSQ-110A explosive source sonobuoy that is composed of two sections, an active (explosive) section and a passive section. The lower, explosive section consists of two signal underwater sound explosive payloads of Class A explosive weighing 1.9 kg (4.2 lbs) each. The arming and firing mechanism is hydrostatically armed and detonated. Once in the water, the signal underwater sound charges explode, creating a loud acoustic signal. The use of time-delay firing devices during mine neutralization activities creates the risk that animals not observed when the charge is set, subsequently swim into the blast zone of the charge.

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).

The number of endangered or threatened species that might be exposed to explosions associated with this ordnance treats 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 10. Explosive ordnance, net weight and depths of detonations of the ordnance (Navy 2007a; Navy 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 Hawai'i 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 SINKEX's 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. Weapons are generally fired until the target is sunk although a torpedo may be used to sink the target if the target is still afloat after all munitions have been expended. Since the targets of these exercises could sink at any time during the exercise, the actual number of weapons used in each sinking exercise can vary widely. In the representative case, however, all of the ordnances are assumed to be expended; which results in a scenario in which marine animals in the area being exposed at the maximum levels of received energy. Because SINKEXs are one of the cases in which simply 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 (Table 11). To the degree that an actual SINKEX involves more or less ordnance, those estimates would vary upward or downward.

Table 11. Representative sequence of weapons fired during a Sinking Exercise (Navy 2007a; Navy 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.

One of the systems the U.S. Navy proposes to employ as part of the proposed active sonar training include explosive charges that provide a sound source. The AN/SSQ-110A Explosive Source Sonobuoy is composed of two sections, an active (explosive) section and a passive section. The lower, explosive section consists of two signal underwater sound explosive payloads of Class A explosive weighing 1.9 kg (4.2 lbs) each. The arming and firing mechanism is hydrostatically armed and detonated. Once in the water, the signal underwater sound charges explode, creating a loud acoustic signal.

The number of endangered or threatened species that might be exposed to explosions associated with this ordnance treats 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 animals 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.

6.1.5 Disturbance Associated with Human Presence on Beaches

Hawaiian monk seals might also occur on beaches and in nearshore areas where demolition exercises, amphibious exercises, and gunnery exercises would occur during some of the major training exercises the U.S. Navy proposes to conduct in the Hawai'i Range Complex. However, the U.S. Navy’s protocols for surveying these areas one hour prior to conducting these exercises and either relocating or delaying an exercise if those surveys discover monk seals (see Section 2.5.2), makes it unlikely that monk seals will be exposed to potential hazards associated with the conduct of exercises. As a result, we do not believe these activities are likely to disturb Hawaiian monk seals and will not consider this potential stressor further.

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 Hawai'i Range Complex have been or will be addressed in separate consultations with the U.S. Fish and Wildlife Service.

6.1.6 Parachutes Associated with 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 ft^2). 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.

6.2 Exposure Analysis

Our exposure analyses are designed to determine whether listed resources are likely to co-occur with any direct and indirect beneficial and adverse effects that these actions have on the environment 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 Hawai'i Range Complex. 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 Hawai'i 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 animals reported by Navy watchstanders would not correspond to the number of marine animals actually exposed to Navy activities in the Hawai'i 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 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 Hawai'i 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 Hawai'i 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. For example, based on aerial surveys of the main Hawaiian Islands conducted from February to March between 1993 and 2003, Mobley (2004) reported average encounter rates of 0.005 sightings per kilometer. During aerials surveys conducted in association with the 2006 Rim of the Pacific Exercises, Mobley (2006) encountered toothed whales at a rate of 0.004 sightings per kilometer. Mobley (2006) reported that he encountered toothed whales in deeper waters (greater than 1,000 fathoms or 1,829 m) in the region between and north of the Islands of Oahu and Molokai (from about 21° 15´ N latitude to about 22° 15´ N) at a rate of 0.002 sightings per kilometer of his flight transects.

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 Hawai'i Range Complex. Many of the exercises and other activities the U.S. Navy proposes will begin and end without encountering any marine animals.

6.2.1 Exposure to Vessel and Submarine 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, partially because the Navy’s use of active sonar for training purposes is always associated with moving vessels and partially because the data on vessel movements that are not related to active sonar are not available. Nevertheless, we assume that any individuals of the endangered or threatened species that occur in the Action Area during major training exercises (USWEX or Multi-Strike) 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.

We assume U.S. Navy vessels involved in training exercises and other activities would encounter marine mammals at rates similar to those reported by Mobley (2008). In deeper waters (water greater than 1,000 m in depth), marine mammals might be encountered at rates of about 0.002 to 0.004 sightings per ship kilometer. Closer to shore, vessels might encounter marine mammals at higher rates: about 0.005 sightings per ship kilometer (Mobley 2004). To estimate the number of endangered marine mammals that might be exposed to vessel traffic we assumed that endangered marine mammals that occurred between 600 meters and 2 kilometers of a ship that is transmitting active sonar would not only be exposed to received levels between 170 and 180 dB, they would also be aware of other cues associated with the surface vessel such as sounds produced by its engine and those produced as its hull moves through the ocean’s surface, among others. That is, we assumed that the estimated number of animals exposed at received levels out to 170 to 180 dB (see Table 15, last three columns) would also be exposed to the vessels that were transmitting active sonar.

6.2.2 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 (USWEX or Multi-Strike Group Exercise) 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.

6.2.3 Exposure to Sonar Sound Fields

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 Hawai'i Range Complex: (1) the method the U.S. Navy and NMFS' Permits Division used in their 2007-2008 Environmental Impact Statement on the Hawai'i Range Complex and (2) an exposure model NMFS' ESA ICs 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. The data necessary to estimate the number of sea turtles that might be exposed to active sonar was not available so we used the Navy's estimates.

These approaches represent two different kinds of interactions. The first approach 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 based on an acoustic threshold. The other approach estimated the number of times individual animals are likely to be exposed to active sonar, regardless 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" in terms of the ESA would be a subset of the number of animals that are exposed to the action. This is 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).

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 exposed 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 and Borchers 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 and at detecting marine mammals at greater distances than Navy watchstanders (in these cases, watchstanders of the Navies of other countries, who may not have training that is comparable to U.S. Navy watchstanders), 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; Stone 2001; Stone 2003a; Stone 2003b; Stone and Tasker 2006). The U.S. Navy is conducting trials involving Navy watchstanders and marine mammal observers to determine the effectiveness of the watchstanders and the degree to which they are likely to minimize the probability of exposing marine mammals to mid-frequency active sonar. Such trials have occurred during 2009 and 2010. While several recommendations have been forwarded by the U.S. Navy to improve communication and cooperation between watchstanders and other Navy personnel (e.g., Navy watchstanders, helicopter pilots, and other Navy assets that detect marine mammals visually), and boat and ship operators, no conclusions regarding effectivenss have been drawn to date.

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 might not 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; 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 safety zones triggered by visual observations would still allow significant numbers of marine mammals and sea turtles to be exposed to mid-frequency active sonar transmissions because most of these will not be detected visually at the ocean's surface.

In addition, the U.S. Navy continues to recognize the "Humpback Whale Cautionary Area". This area contains the highest densities of humpback whales when those whales occur in the Hawaiian Islands. Historically, the U.S. Navy has rarely or infrequently conducted training activities involving active sonar in this area. Further, the U.S. Navy has committed to require a higher-level of clearance before training activities are authorized to occur in this cautionary area between 15 December and 15 April (the activity would require the personal authorization of the Commander of the U.S. Pacific Fleet and that authorization cannot be delegated).

We assume that the Navy’s commitment would reduce the probability of endangered or threatened marine mammals and sea turtles being exposed to mid-frequency active sonar in this area, but that assumption does not allow us to estimate the probability of activities occurring in that, the nature of any activities that might occur in the area and the nature of the activities that would not occur in the area, the number of activities that might occur in the area, or the degree to which the measure might reduce the number of humpback whales exposed to active sonar in that area in the future. However, for the purposes of this assessment, we assume that activities involving surface vessels employing active sonar are not likely to occur in this cautionary area and that humpback whales in this cautionary area are not likely to be exposed to mid-frequency active sonar at received levels greater than 140 dB from 15 December through 15 April.

U.S. Navy Exposure Estimates

The U.S. Navy’s approach to estimating the number of marine mammals that might be exposed to activities focuses on a suite of representative provinces based on sound velocity profiles, bathymetries, and bottom types. Within each of these provinces, they 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 calculated 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). 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; Finneran et al. 2003; Finneran et al. 2005; Finneran and Schlundt. 2004; Schlundt et al. 2000b), data from a reconstruction of an incident in which killer whales were probably exposed to mid-frequency active sonar (Fromm 2004), and a suite of studies of the response of baleen whales to low-frequency sound sources (Nowacek et al. 2004).

The approach the U.S. Navy and the Permits Division used to estimate the number of endangered and threatened marine mammals that might be “taken” as a result of being exposed to active sonar on an annual basis produced the following results:

Blue Whales

The U.S. Navy did not model the number of blue whales that might be exposed to training events in the Hawai'i Range Complex because they believe few blue whales occur in the Hawai'i Range Complex. No density information is available for blue whales in Hawaiian waters and blue whales have not been seen during surveys in the Hawai'i

Range Complex. Therefore, the Navy and NMFS Permits Division assumed that no blue whales would be exposed to active sonar during the proposed activities.

Fin Whales

During the Undersea Warfare, Multi-Strike, other anti-submarine warfare exercises the U.S. Navy plans to conduct in the Hawai'i Range Complex, the U.S. Navy identified 46 instances annually in which fin whales might exhibit behaviors that NMFS would classify as harassment. No fin whales would accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity. We assume that these whales would represent individuals from the Hawaiian population (or "stock") of fin whales. We assume that any age or gender might be exposed to those received levels.

Humpback Whales

During the Undersea Warfare, Multi-Strike, other anti-submarine warfare exercises the U.S. Navy plans to conduct in the Hawai'i Range Complex, the Navy and the Permits Division identified 9,894 instances annually in which humpback whales might be exposed to received levels that cause them to exhibit behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the MMPA). In addition, the Navy initially estimated that 199 humpback whales might accumulate energy sufficient to result in temporary shifts in hearing sensitivity, but none of these whales would accumulate energy sufficient to result in permanent losses in hearing sensitivity. When the mitigation measures were considered, the Navy estimated that no humpback whales would experience temporary shifts in hearing sensitivity.

Because of the annual migratory pattern of humpback whales, we would assume that these exposure events would occur between October and April or May each year. We assume that any age or gender might be exposed to these received levels. If the U.S. Navy conducts training activities in the summer months, humpback whales would not be exposed.

Sei Whales

During the Undersea Warfare, Multi-Strike, other anti-submarine warfare exercises the Navy exposure approach identified 46 instances annually in which sei whales might be exposed to received levels that cause them to respond in behaviors that NMFS would classify as harassment (as that term is defined for the purposes of the MMPA). No sei whales would accumulate energy sufficient to result in temporary or permanent shifts in hearing sensitivity.

Sperm Whales

During the other anti-submarine exercises the Navy's estimates identified 800 instances annually in which sperm whales might be exposed to received levels that cause them to exhibit behaviors that NMFS would classify as harassment. This estimate includes 9 instances annually in which sperm whales might accumulate energy sufficient to result in temporary shifts in hearing sensitivity. No sperm whales would accumulate energy sufficient to result in permanent losses in hearing sensitivity. When the mitigation measures were considered, the Navy estimated that no sperm whales would experience temporary shifts in hearing sensitivity.

The sperm whales that might be exposed to the proposed activities would represent individuals from a Hawaiian population (or "stock"). Sperm whales are widely distributed throughout the Hawaiian Islands year-round. Sperm whale clicks recorded from hydrophones off Oahu confirm the presence of sperm whales near the Hawaiian Islands throughout the year. The primary area in which sperm whales occur is seaward of the shelf break in the Hawaiian Islands Operating Area. Sperm whales rarely occur between the shore and the shelf break.

Hawaiian Monk Seals

During the Undersea Warfare, Multi-Strike, other anti-submarine warfare exercises the Navy identified 121 instances annually in which Hawaiian monk seals might be exposed to received levels that cause them to exhibit behaviors that NMFS would classify as harassment. Three of these monk seals would accumulate energy sufficient to result in temporary shifts in hearing sensitivity. When the mitigation measures were considered, the Navy concluded that no monk seals would experience temporary shifts in hearing sensitivity.

Exposure Estimates Developed by ESA IC

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, we 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 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 of prey a predator is likely to encounter during a hunt. NMFS adapted this component of the Holling's disc equation by treating the Navy vessels as the "predators" in the model. The sensory field (2r, in square kilometers) we used 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 spend 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 Hawaiian monk seals), or the amount of time a marine mammal would not occur in a "sonar shadow" created by one of the islands (for example, humpback whales that occur in the Maui basin). 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.

We used this equation to model three separate exposure scenarios:

1. 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 and the Permits Division's models), which we conducted for all endangered and threatened marine mammals;

2 A scenario that assumed that marine mammals would, in fact, try to avoid exposure to active sonar transmissions. This scenario assumed that marine mammals would avoid received levels greater than 195 dB at a faster rate than they would avoid lower received levels; we simulated avoidance by reducing marine mammal densities exponentially over time;

3. A scenario for humpback whales and assumed that humpback whale densities varied over the winter season in Hawai'i. We only developed this scenario for humpback whales because they are the only species for which the necessary data were available. Specifically, this scenario assumed that humpback whale densities during the winter months would be described by a standard normal distribution with densities increasing from zero starting in October, reaching a maximum between late-February through March, then declining to zero again through the spring.

Every scenario assumed ship speeds of 10 knots (or 18.25 kilometers per hour), which is the same assumption contained in the Navy's model. All scenarios were based on the ensonified area estimates that the Navy presented in its EIS for the Hawai'i Range Complex (Navy 2008a). Finally, every scenario was based on the Navy's estimates of the number of hours each type of active sonar would be used in the different exercises.

In addition, based on the results of a comprehensive program to establish the population size and abundance of humpback whales in the North Pacific Ocean, Calambokidis et al. (2008) provisionally estimated that about 10,000 humpback whales occupied waters off the Hawaiian Islands during the winter months. This estimate of humpback whale abundance is almost twice the abundance estimate the U.S. Navy and the Permits Division used for their models. To facilitate comparisons with the Navy's and the Permits Division's estimates, we calculated probable exposures assuming humpback whale densities of 0.2186 (the same density the Navy used) and densities of 0.4868 (to reflect the updated abundance estimates).

Further, by assuming that humpback whales have a constant density of 0.2186 for all winter months, the Navy's models effectively assume that all humpback whales arrive in Hawai'i on the same day, remain in Hawai'i until the spring, and leave Hawai'i at the same time. However, several studies establish that humpback whales "trickle" into Hawaiian waters with small percentages of whales occurring in autumn (as early as late September or early October in some years), increasing percentages occurring through the winter, peak percentages occurring from mid-February to mid-April (with year-to-year variation), then declining through the spring as whales migrate to foraging areas (Au et al. 2000; Craig et al. 2003). Their arrival appears to be related to their reproductive status: juvenile whales and females without calves arrive first followed by females with calves and male humpback whales (Craig et al. 2003; Gabriele and Frankel. 2002). Individual whales remain in Hawaiian waters for about 6 to 8 weeks (Craig 2001; Darling and Cerchio 1993), so all of the humpback whales that are estimated to occur in Hawaiian waters do not occur there at the same time.

To reflect this information, we constructed our exposure model based on the assumptions that humpback whale densities vary from October to late May and can be described by a standard normal distribution (as the data collected by Au et al. 2000 suggest) with humpback whale densities increasing slowly during late autumn and early winter, reaching a maximum in March, and declining again through the spring.

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 produced the following results (see Table

12 for summaries of these estimates and comparisons of these estimates with the other approaches discussed in the preceding text).

Blue Whales

Although blue whales are rarely sighted in these waters, acoustic monitoring has recorded blue whales off Oahu and the Midway Islands (Barlow 1994; McDonald and Fox 1999a; 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 (McDonald and Fox 1999a; Thompson and Friedl 1982). Although there are no specific estimates of the density of blue whales in waters off the Hawaiian Islands, their density in the North Pacific Ocean has been estimated as 0.0002 whales per square kilometer (Ferguson and Barlow 2001; Ferguson and Barlow 2003). We based our exposure estimates on this density.

The analyses from our first scenario identified 489 instances annually in which blue whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 286 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would be about 58.52 percent of the total volume). Another 136 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures, 67 instances, would occur at received levels greater than 160 dB.

The second scenario (which assumed that animals would try to avoid continued exposure to active sonar transmissions) identified no instances in which blue whales might be exposed to mid-frequency active sonar at any received level.

Table 12. Total estimated annual exposure events in the Hawai'i Range Complex and estimated number of endangered marine mammals by intervals of received levels. Estimates for all species except humpback whales are based on the first scenario (animals would not move to avoid initial or continued exposure). The estimates for humpback whales based on the first, second, and third scenario are presented as S1, S2, and S3, respectively.

Species	Estimate	140 - 150 dB	150 - 160 dB	160 - 170 dB	170 - 180 dB	180 - 190 dB	>190 dB
Blue whale	489	286	136	40	19	5	2
Fin whale	1,712	1002	477	139	66	16	7
Humpback (S1)	12,881	7538	3588	1048	498	121	53
Humpback (S2)	2,674	1565	745	217	103	25	11
Humpback (maximum for S3)	11,872	6947	3307	966	459	111	48
Sei	105	61	29	9	4	1	0
Sperm	6,850	4008	1908	557	265	64	28
Monk seal	122	71	34	10	5	1	0

Fin Whales

The analyses from our first scenario identified 1,712 instances annually in which fin whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 1,002 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 477 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures, 228 instances, would occur at received levels greater than 160 dB.

Our second scenario (which assumed that animals would try to avoid continued exposure to active sonar transmissions) identified no instances in which fin whales might be exposed to mid-frequency active sonar at any received level.

Humpback Whales

The analyses based on annual exposures, from our first scenario identified 12,881 instances in which humpback whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 7,538 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 3,588 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures, 1,720 instances, would occur at received levels greater than 160 dB.

Using humpback whale densities of 0.4868, the second scenario (which assumed that animals would try to avoid continued exposure to active sonar and that their density remains constant during their tenure in Hawai'i) identified 2,674 instances annually in which humpback whales in the nearshore areas of the main Hawaiian Islands might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB during each of the five Undersea Warfare Exercises the U.S. Navy plans to conduct in the Hawai'i Range Complex. In addition to the results displayed in Table 15, the second scenario identified another 273 instances in which humpback whales might be exposed at received levels between 195 and 215 dB and two instances in which humpback whales might be exposed at received levels greater than 215 dB during each USWEX exercise.

If we assume humpback whale densities of 0.4868 in waters less than 183 meters in depth and 0.0008 in waters greater than 183 meters in depth (based on the results of (Barlow and Forney 2007), the annual estimates produced by the third scenario (which assumed that animals would not try to avoid continued exposure to active sonar but that their density varies during their tenure in Hawai'i and that they are not likely to be exposed in the Maui basin from 15 December through 15 April) depended on the number of Undersea Warfare Exercises the U.S. Navy is likely to conduct over the next year, whether the U.S. Navy would conduct a Multi-Strike Group Exercise, and when these exercises are likely to occur. Depending on when exercises actually occur, the estimates produced by the third scenario varied from a low of no instances in which humpback whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB (if all of the exercises occurred when humpback whales were not in Hawai'i) to a maximum of 11,872 instances (if all exercises occurred when humpback whales reach peak densities; see Table 12). Because this scenario required us to speculate on when exercises would occur, we discounted the estimates produced by this scenario.

Based on the information that is available, we would not expect humpback whales to be exposed to sound fields produced by active sonar associated with all of the training exercises and other activities that would occur each year in the Hawai'i Range Complex. For example, monitoring surveys associated with the November 2007 Undersea Warfare Exercises did not report any sightings of humpback whales while monitoring surveys associated with the March 2008 Undersea Warfare Exercises reported 40 sightings of 68 humpback whales during the exercise. Monitoring surveys associated with the August 2010 Undersea Warfare Exercises conducted from August 7-10, 2010, reported zero sightings of marine mammals during the exercise. All of these reports are substantially lower than the estimates produced by the first and second scenarios.

Sei Whales

The analyses from our first scenario identified 105 instances annually in which sei whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 61 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 29 instances would involve exposures at received levels between 150 and 160 dB each year. The balance of the exposures, 14 instances, would occur at received levels greater than 160 dB.

The second scenario (which assumed that animals would try to avoid continued exposure to active sonar transmissions) identified no instances in which sei whales might be exposed to mid-frequency active sonar at any received level.

Sperm Whales

The analyses from our first scenario identified 6,850 instances annually in which sperm whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 4,008 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 1,908 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures, 914 instances, would occur at received levels greater than 160 dB.

During each of the exercises the U.S. Navy plans to conduct, the second scenario (which assumed that animals would try to avoid continued exposure to active sonar transmissions) identified 4 instances in which sperm whales might be exposed to mid- frequency active sonar at received levels between 140 and 195 dB. Two to three of those sperm whales would be exposed at received levels between 140 and 150 dB.

Hawaiian Monk Seals

The analyses for annual exposures from our first scenario identified 122 instances annually in which monk seals might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 71 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 34 instances each year would involve exposures at received levels between 150 and 160 dB. The balance of the exposures, 16 instances, would occur at received levels greater than 160 dB.

The second scenario (which assumed that animals would try to avoid continued exposure to active sonar transmissions) identified no instances in which monk seals would be exposed to mid-frequency active sonar at any received level during the next 24 months.

6.2.4 Reconciliation of Exposure Estimates

The approaches discussed above produced different outcomes because of differences in assumptions applied in each model. The approach the Navy used in its NEPA documents that was carried forward in the MMPA regulations by NMFS Permits Division estimated the proportion of marine mammals that might be “taken” through behavioral harassment (as that term is defined for the purposes of the MMPA) or noise-induced hearing loss as a result of being exposed to active sonar. The approach NMFS ESA IC Division used estimated the number of instances in which individual animals might be exposed to active sonar at particular received levels in one of three categories (140 to 195 dB, 195 to 215 dB, and greater than 215 dB) regardless of their probable physical, physiological, or behavioral responses to that exposure. Although the estimates produced by the different approaches are not actually comparable, the results also are not necessarily incompatible. Below we reconcile the approaches to estimate the number of annual instances in which individuals of the different endangered species might be exposed to active sonar.

For all of the endangered marine mammals we have discussed thus far, we start with the exposure estimates produced by our first scenario for all species except humpback whales. These estimates would tend to overestimate the actual number of instances in which these species (blue, fin, sei, and sperm whales and Hawaiian monk seals) might be exposed to mid-frequency active sonar if:

- Most anti-submarine warfare exercises occur in waters 200 and 400 meters in depth and rarely occur in waters as shallow as 100 meters.
- Fewer animals are found in waters 200 and 400 meters deep.
- Modeling assumed a depth of 100 meters and sound propagation loss would be greater at 200 and 400 meter depths compared to 100 meter depth.
- The data available on the probable responses of marine mammals to these exercises (which we summarize in the Response Analyses, which follow this subsection of our Opinion) leads us to conclude that most individuals of these species are likely to avoid continued exposure to mid-frequency active sonar.

Humpback whales pose a different problem, largely because we have more information regarding this species and the time humpback whales are likely to spend in the action area. The U.S. Navy’s models assume there are about 4,491 humpback whales in the Hawai'i Operating Area each year (based on data from (Mobley 2001), which led the Navy to model humpback whale densities as 0.2186 animals per square kilometer. However, recent estimates of the abundance of humpback whales in waters off the Hawaiian Islands (Calambokidis et al. 2008) suggest that the U.S. Navy’s density estimate is probably less than half of the true density. Because exposure models are very sensitive to assumptions about animal densities, this reduced density estimate would cause them to underestimate the actual number of whales that might be exposed (if we adjust the Navy’s estimate to account for updated abundance estimates, as many as 11,940 humpback whales might experience behavioral harassment as a result of being exposed to active sonar and 112 might experience temporary threshold shifts each year).

Further, the Navy’s estimates assume that humpback whales arrive in waters off Hawai'i en masse, reach their maximum density instantaneously, and remain at that density while they remain in Hawai'i. These assumptions would cause the Navy's models to substantially overestimate the number of humpback whales that might be exposed to active sonar.

Finally, the Navy's model assumes that humpback whales would not try to avoid being exposed to active sonar, the area of a naval exercise (particularly a major exercise), or both. Available data suggest that most marine mammals try to avoid areas of high anthropogenic noise in the form of sonar and areas with vessel traffic. Although this assumption would be important for a model that is trying to estimate the number of individual animals that might accumulate acoustic energy sufficient to cause temporary or permanent shifts in hearing sensitivity (it would be difficult to construct and run a model that allowed each individual in a population of animals and ships to move while keeping track of the amount of acoustic energy each individual animal accumulated over time), this assumption would also cause the Navy's models to substantially overestimate the number of humpback whales that might be exposed to active sonar.

Based on the evidence available, humpback whales arrive in Hawai'i incrementally through the fall and winter, reach their maximum densities between January and March, and then decline incrementally during the spring. In addition, humpback whale densities appear to be much higher in waters less than 183 meters in depth than in deeper waters (densities of about 0.0008 individuals per square kilometer based on Barlow and Forney 2007), so exercises that occur in waters between 2,000 and 4,000 meters in depth are less likely to expose high densities of humpback whales to high received levels of active sonar. We believe the estimates produced by our third scenario are more likely to represent the number of instances in which humpback whales might be exposed to mid-frequency active sonar because it incorporates the patterns of abundance and migration by these whales in waters off the Hawaiian Islands better than alternative scenarios.

We believe the estimates produced by our second and third scenarios are more likely to represent the number of instances in which humpback whale might be exposed to mid-frequency active sonar than estimates based on the assumptions that (1) humpback whales would try to avoid initial or continued exposure to active sonar and (2) that humpback whales do not exist at maximum densities throughout their tenure in Hawai'i. The second scenario is more representative because it assumes that humpback whales are most likely to avoid initial or continued exposure to active sonar. The third scenario is representative because it captures patterns of abundance and migration by these whales in waters off the Hawaiian Islands better than the alternatives. However, both models are sensitive to our assumptions about the rate at which whale densities would change in response to initial or continued exposure and when training activities would actually occur (that is, the scenarios are sensitive to assumptions about whether they would be evenly distributed throughout the year, would occur primarily during periods of low humpback whale density, or during periods of high humpback whale density).

Based on the information that is available, we would not expect humpback whales to be exposed to sound fields produced by active sonar associated with all of the training exercises and other activities that would occur in the Hawai'i Range Complex each year. For example, monitoring surveys associated with the November 2007 Undersea Warfare Exercises did not report any sightings of humpback whales while monitoring surveys associated with the March 2008 Undersea Warfare Exercises reported 40 sightings of 68 humpback whales during the exercise while the August 2010 exercise reported no sightings of any listed species. Nevertheless, for the purposes of our analyses and assuming that humpback whales would be exposed to active sonar associated with all training exercises that occur during their tenure in Hawai'i, we would expect each USWEX exercise would result in between 1,682 and 5,448 instances in which humpback whales might be exposed to active sonar (between 8,410 and 27, 240 instances of exposure) while the other 32 annual anti-submarine warfare exercises would result in between 991 and 6,425 instances in which humpback whales might be exposed to active sonar.

Finally, we assume that the humpback whales that might be exposed to mid-frequency active sonar between their arrival in waters off Hawai'i might be any gender, age, or reproductive condition. However, historic patterns suggest that immature humpback whales and females without calves would arrive in the Maui Basin and Penguin Banks before females with calves, pregnant females, and males; as discussed previously, the pattern off the Island of Hawai'i is different (females without calves arrive before immature whales) and may be different in other areas of Hawai'i. Because humpback whales do not tend to reside in waters off Hawai'i for more than 6 to 8 weeks, we would not expect individual whales to be exposed to major training exercises (for example, Undersea Warfare Exercises or Multi-Strike Group Exercises) more than once, although individual whales might be exposed to multiple unit-level or intermediate-level training exercises.

6.2.5 Exposure to Underwater Detonations and Explosions

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 presentation in Tables 9 and 10) as well as the explosives associated with the EER/IEER/AEER systems.

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 Hawai'i 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 Hawai'i Range over the next 24 months, 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 U.S. navy training exercises (See Table 13).

If the mitigation measures the Navy plans to employ are as effective in the Hawai'i 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.

Table 13. Estimates of the number of marine mammals that might be exposed to pressure waves or received levels associated with explosions annually. Numbers in parentheses are corrected to consider the effects of mitigative measures (from U.S. Navy 2008a).

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
Fin whale	0	0	0	0
Sei whale	0	0	0	0
Humpback whale	5	12 (4)***	1 (0)	0
Sperm whale	9	5 (4)***	0	0
Monk seal	0	3 (0)***	0	0
Total	**14**	**20(8)**	**1**	**0**

TTS = temporary threshold shift; TM = Tympanic membrane injury

**** These animals are likely to be seen by watchstanders, and mitigation implemented, however the exclusion zone for the two largest explosive charges is not large enough to avoid all TTS, so estimated TTS takes potentially associated with those charges remain*

6.2.6 Exposure to Parachutes Associated with Sonobuoys

When AN/SQS-62 DICASS sonobuoys impact the water surface after being deployed from aircraft, their 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 ft^2). 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.

Sea turtles in the Hawai'i Range Complex might encounter one or more parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. An interaction could be fatal to a sea turtle if it were entangled and drowned or if it swallowed a parachute. 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 Hawai'i 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 this species and parachutes seems to have a very small probability. Given this, the probability of a sea turtle interacting with a parachute is discountable, and we will not consider this further in this Opinion

6.3 Response Analysis

Our 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 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) and the SOCAL-10 behavioral response studies for large whales; however, those studies are still in their infancy and no data from those studies were available from the analyses we conducted in this consultation. Preliminary results based primarily on clearly observable behavior in the field and from initial data assessment indicate variable responses, depending on species, type of sound, and behavioral state during the experiments. Some observations in certain conditions suggest avoidance responses, while in other cases subjects seemed to not respond, at least overtly (Southall et al. 2011).

Without substantial 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 marine animals we are considering in this Opinion.

6.4 Potential Responses of Listed Species to Stressors

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

1. Responses that are influenced by an animal's assessment of whether (a) an animal detects 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 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 trade-offs (Beale and Monaghan 2004b; 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 such as risk of physical damage, mask signal reception, and impair call/song transmission.

Below we discuss the potential responses of listed species to the stressor we have identified associated with the Navy's proposed activities.

6.4.1 Potential Responses to Collisions

Collisions with surface vessels are a well-established threat to endangered and threatened marine mammals and sea turtles (Clapham et al. 1999; Jensen and Silber 2003b; Laist et al. 2001; Panigada et al. 2006a; Silber et al. 2009). Numerous individuals of all of the endangered and threatened marine mammals considered in this Opinion have been struck, killed, or both in collisions with surface vessels; that is, as a result of being struck by the bow or hull of ship or as a result of being struck by the ship‘s propellers.

Historically, U.S. Navy vessels have struck and killed endangered and threatened whales along the Atlantic and Pacific Coasts of the United States. Jensen and Silber (2004) published 23 reports of whales having been struck by U.S. Navy vessels between 1945 and 2001. Seven of these 23 records represented whales that had been struck by Navy vessels along the Atlantic coast, from Canada south to Key West, Florida, while the remainder was struck off Canada, the Pacific Coast, or in transit to or from the Pacific Coast. In the winter of 2004, a U.S. Navy vessel struck another whale off the Atlantic coast and U.S. Navy vessels struck two fin whales in the Southern California Range Complex in 2009. Thus far, we have no reports of U.S. Navy vessels having struck endangered or threatened marine mammals or sea turtles on or in transit to the Hawai’i Range Complex.

To reduce the probability of collisions, the U.S. Navy proposes to employ measures that would increase a whale‘s or sea turtle’s probability of being detected by surface vessels or submarines that are underway on the ocean‘s surface. These measures involve all naval vessels and aircraft, including all helicopters, under the control of the U.S. Navy in searching for marine mammals during training exercises and reporting any marine mammals that are observed. Vessels are expected to implement actions, where feasible, to avoid interactions with marine mammals, including maneuvering away from the marine mammal or slowing the vessel.

It would be possible, but highly unlikely, that a marine mammal or sea turtle could be struck by a submarine while it is under water. It would also be possible, but is highly unlikely, for a torpedo or a target to strike a marine mammal or sea turtle. Large or slow-moving species would be more at risk of being struck than smaller, faster swimmers. However, after reviewing the U.S. Navy’s use of torpedoes in training and testing exercises over the past 30 years, there have been no recorded or reported cases of a marine mammal or sea turtle being struck. Historically there has not been a reported torpedo striking a marine mammal or sea turtle within the vicinity of the Hawai’i Range Complex.

6.4.2 Potential Responses to Disturbance

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 Cotton 2004; Lusseau 2006). However, several authors suggest that the noise generated during motion is probably an important factor (Blane and Jaakson 1994; Evans et al. 1992; Evans et al. 1994). These studies suggest that the behavioral responses of marine mammals to surface vessels are similar to their behavioral responses to predators.

Based on the suite of studies of cetacean behavior to vessel approaches (Amaral and Carlson 2005; Au and Perryman 1982; Au and Green 2000; Bain et al. 2006; Bauer 1986; Bejder et al. 1999; Bejder and Lusseau. 2008; Bejder et al. 2009; Bryant et al. 1984; Corkeron 1995; Erbe 2002; Félix 2001; Goodwin and Cotton 2004; Lemon et al. 2006; Lusseau 2003; Lusseau 2006; Magalhaes et al. 2002; Nowacek et al. 2001; Richter et al. 2003; Scheidat et al. 2004; Simmonds 2005; Watkins 1986; Williams et al. 2002b; Wursig 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. 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; 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).

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; Lusseau 2006; Williams et al. 2006) than when it engages in frequent course changes (Evans et al. 1994; Lusseau 2006; Williams et al. 2002a).

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 2006).

7. The type of vessel (displacement versus planing), which marine mammals may interpret as evidence of a vessel's maneuverability (Goodwin and Cotton. 2004).

8. The behavioral state of the marine mammals (David 2002; Lusseau 2003; Wursig 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; Lusseau 2006) (Van Parijs and Corkeron 2001; Williams et al. 2002a). 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 (Baker and Herman 1989; Edds and Macfarlane 1987; Evans et al. 1992; Kruse 1991). 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 (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. 2002). Baker et al. (1983) reported that humpbacks in Hawai'i responded to vessels at distances of 2 to 4 km. Richardson et al. (1985b) 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 distance 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 allowed 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 (USWEX or 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; 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) 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.

The estimates that follow assume that any endangered and threatened cetaceans that occur between 600 meters and two kilometers of vessels engaged in training exercises in the Hawai'i Range Complex might respond to those vessels (this distance roughly corresponds with a received level of 180 dB), 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 26 instances in which blue whales might occur between 600 meters and two kilometers of surface vessels involved in major training exercises annually, the whales are likely to avoid being exposed to the vessel traffic in two of those instances and are likely to change their behavior in response to their exposure in another two 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 of 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 21 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 89 instances in which fin whales might occur between 600 meters and two kilometers of surface vessels involved in major training exercises annually, the whales are likely to avoid being exposed to the vessel traffic in 16 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 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 672 instances (model scenario 1) in which humpback whales might occur between 600 meters and two kilometers of surface vessels involved in major training exercises annually, the whales are likely to avoid being exposed to the vessel traffic in 124 of those instances and are likely to change their behavior in response to their exposure in another 41 instances. Like blue and fin 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 of 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 cows that are accompanied by neonates or calves. 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 to the whales (the responses might represent an approach or attentive movement, a small change in orientation in the waters, etc.).

We assume these humpback whales would respond to both the active sonar, and other mid-frequency and low-frequency 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.

Probable Responses of Sei Whales to Vessels

Of the five instances in which sei whales might occur between 600 meters and two kilometers 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 1 of those 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), particularly cows or social groups that are accompanied by calves. 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 to the whales (the responses might represent an approach or attentive movement, a small change in orientation in the waters, etc.).

Probable Responses of Sperm Whales to Vessels

Of the 357 instances in which sperm whales might occur between 600 meters and two kilometers 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 66 of those instances and are likely to change their behavior in response to their exposure in another 22 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 of 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 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 these 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.

Probable Responses of Hawaiian Monk Seals to Vessels

As with the cetacean species, we would expect Hawaiian monk seals to engage in avoidance behavior when surface vessels move toward them. Hawaiian monk seals would likely reduce their visibility at the water's surface and move horizontally away from the source of disturbance or adopt erratic swimming strategies. Most animals finding themselves in confined spaces, such as shallow bays, during vessel approaches tended to move towards more open, deeper waters. We assume that this movement would give them greater opportunities to avoid or evade vessels as conditions warranted.

Probable Response of Sea Turtles

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.

6.4.3 Potential Responses 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. (1995b) 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. 2002; Richter et al. 2006; Smultea et al. 2008; Wursig et al. 1998). Richardson et al. (1985a) 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. 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 (2008) reported that the sperm whales formed a semi-circular “fan” formation that was similar to defensive formations reported by other investigators.

In a review of aircraft noise effects on marine mammals, Luksenburg and Parsons (2009) determined that the sensitivity of whales and dolphins to aircraft noise may depend on the animals’ behavioral state at the time of exposure (e.g. resting, socializing, foraging or travelling) as well as the altitude and lateral distance of the aircraft to the animals. While resting animals seemed to be disturbed the most, low flying aircraft with close lateral distances over shallow water elicited stronger disturbance responses than higher flying aircraft with greater lateral distances over deeper water (Patenaude et al. 2002; Smultea et al. 2008).

6.4.4 Potential Responses to Active Sonar

Of all of the stressors we consider in this Opinion, the potential responses of marine mammals upon being exposed to low- and mid-frequency active sonar have received the greatest amount of attention and study. Despite decades of study, it is important to acknowledge that empirical evidence on the responses of free-ranging marine animals to active sonar is very limited. The narratives that follow this introduction summarize the best scientific and commercial data and other evidence available on the responses of other species to active sonar or other acoustic stimuli. Based on this body of information, we identify the probable responses of endangered and threatened marine animals to active sonar transmissions that would be associated with the training activities the U.S. Navy proposes to conduct in the Hawai'i Range Complex.

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 Hawai'i 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.

Injury

For the purposes of this assessment, "injuries" represent 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 (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 (Cudahy and Ellison 2002; Ketten et al. 2004) and tissue damage resulting from gas and fat embolic syndrome (Fernández et al. 2005; Jepson et al. 2003). 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 (2002) 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 Schlundt et al. 2000b) 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 (1994) 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. (2004b; 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 as a result of their exposure to sound fields produced by active sonar per se.

Noise-Induced Loss of Hearing Sensitivity. Noise-induced loss of hearing sensitivity 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. These losses in hearing sensitivity rarely affect the entire frequency range an ear might be capable of detecting, instead, they affect the frequency ranges that are roughly equivalent to or slightly higher than the frequency range of the noise itself.

Nevertheless, most investigators who study TTS in marine mammals report the frequency range of the “noise”, which would change as the spectral qualities of a waveform change as it moves through water, rather than the frequency range of the animals they study. Without information on the frequencies of the sounds we consider in this Opinion at the point at which it is received by endangered and threatened marine mammals, we assume that the frequencies are roughly equivalent to the frequencies of the source.

Acoustic exposures can result in three main forms of noise-induced losses in hearing sensitivity: permanent threshold shift, temporary threshold shift, and compound threshold shift (Ward et al. 1998; Yost 2007). When permanent loss of hearing sensitivity, or PTS, occurs, there is physical damage to the sound receptors (hair cells) in the ear that can result in total or partial deafness, or an animal’s hearing can be permanently impaired in specific frequency ranges, which can cause the animal to be less sensitive to sounds in that frequency range. Traditionally, investigations of temporary loss of hearing sensitivity, or TTS, have focused on sound receptors (hair cell damage) and have concluded that this form of threshold shift is temporary because hair cell damage does not accompany TTS and losses in hearing sensitivity are short-term and are followed by a period of recovery to pre-exposure hearing sensitivity that can last for minutes, days, or weeks. More recently, however, Kujawa and Liberman (2009) reported on noise-induced degeneration of the cochlear nerve that is a delayed result of acoustic exposures that produce TTS, that occurs in the absence of hair cell damage, and that is irreversible. They concluded that the reversibility of noise induced threshold shifts, or TTS, can disguise progressive neuropathology that would have long-term consequences on an animal’s ability to process acoustic information. If this phenomenon occurs in a wide range of species, TTS may have more permanent effects on an animal‘s hearing sensitivity than earlier studies would lead us to recognize.

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. Most of the few studies available have reported the responses of captive animals exposed to sounds in controlled experiments. Schlundt et al. (2000b), see also Finneran et al. (2003; 2001) 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. (2000b), 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.

Finneran et al. (2003; 2001) conducted TTS experiments using 1-second duration tones at 3 kHz. The test method was similar to that of Schlundt et al. (2000b) except the tests were conducted in a pool with a very low ambient noise level (below 50 dB re 1 μPa2/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. Richardson et al.(1995b) hypothesized that marine mammals within less than 100 meters of a sonar source might be exposed to mid-frequency active sonar transmissions at received levels greater than 205 dB re 1 Pa which might cause TTS. However, there is no empirical evidence that exposure to active sonar transmissions with this kind of intensity can cause PTS in any marine mammals; instead the probability of PTS has been inferred from studies of TTS (see Richardson et al. 1995b).

On the other hand, Kujawa and Liberman (2009) argued that traditional testing of threshold shifts, which have focused based on recovery of threshold sensitivities after exposure to noise, would miss acute loss of afferent nerve terminals and chronic degeneration of the cochlear nerve, which would have the effect of permanently reducing an animal's ability to perceive and process acoustic signals. Based on their studies of small mammals, Kujawa and Liberman (2009) reported that two hours of acoustic exposures produced moderate temporary threshold shifts but caused delayed losses of afferent nerve terminals and chronic degeneration of the cochlear nerve in test animals.

Despite the extensive amount of attention given to threshold shifts by researchers, environmental assessments conducted by the U.S. Navy and seismic survey operators, and its use in permits issued by NMFS' Permits Division, it is not certain that threshold shifts are as common as this level of attention might imply. Several variables affect the amount of loss in hearing sensitivity: the level, duration, spectral content, and temporal pattern of exposure to an acoustic stimulus as well as differences in the sensitivity of individuals and species. All of these factors combine to determine whether an individual organism is likely to experience a loss in hearing sensitivity as a result of acoustic exposure (Ward et al. 1998; Yost 2007). In free-ranging marine mammals, an animal's behavioral responses to a single acoustic exposure or a series of acoustic exposure events would also determine whether the animal is likely to experience losses in hearing sensitivity as a result of acoustic exposure. Unlike humans whose occupations or living conditions expose them to sources of potentially-harmful noise, in most circumstances, free-ranging animals are not likely to remain in a sound field that contains potentially harmful levels of noise unless they have a compelling reason to do so (for example, if they must feed or reproduce in a specific location). Any behavioral responses that would take an animal out of a sound field or reduce the intensity of its exposure to the sound field would also reduce the animal‘s probability of experiencing noise-induced losses in hearing sensitivity.

More importantly, the data on captive animals and the limited information from free-ranging animals suggests that temporary noise-induced hearing losses do not have direct or indirect effect on the longevity or reproductive success of animals with this affliction. Like humans, free-ranging animals might experience short-term impairment in their ability to use their sense of hearing to detect environmental cues about their environment while their ears recover from the temporary loss of hearing sensitivity. Although we could not locate information about how animals that experience noise-induced hearing loss might alter their behavior or the possible consequences of any altered behavior on the lifetime reproductive success of those individuals, the limited information available would not lead us to expect temporary losses in hearing sensitivity to incrementally reduce the lifetime reproductive success of animals. Based on the information available, and given the speeds at which Navy vessels operate during the activities they propose to conduct in the Hawai'i 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; however, as we have discussed previously, the U.S. Navy's protective measures, which are designed to detect all objects (including large whales (and other objects) in their path to protect the ships from being damaged during a collision for safety of navigation, are also likely to prevent large whales from being exposed to received levels sufficient to cause hearing losses.

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 2000a). 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.

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. 1995b).

Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses produced by echosounders and submarine sonar (Watkins 1985; Watkins and Schevill 1975). 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. 1995a). 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, 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. (Au et al. 1985; Au et al. 1974; Au et al. 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 Hawaiian monk seals and 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). As a result, we assumed 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 the hearing sensitivities of sperm whales, which overlap the frequency range of mid-frequency active sonar, sonar transmissions might mask environmental cues at the lower range of sperm whale hearing, but are unlikely to mask most sounds because of the narrow frequency bandwidth and short duration of the sonar signal.

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), acquiring mates (Krakauer et al. 2009; Ryan 1985), assessing other members of their species (Owings et al. 2002; Parker 1974), evading predators (Greig-Smith 1980), and defending resources (Zuberbuhler 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 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 (Brumm 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 2004; Patricelli and Blickley 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 2004; Patricelli and Blickley 2006) (Patricelli and Blickley 2006). In some instances, the vocal adjustment may depend on when a competing signal occurs in a vocal sequence; for example, Egnor et al. (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, vocalizing 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*. 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 (2003a) 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*. 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 their voices while talking or singing in the face of high, background levels of sound (Lombard 1911).

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 levels of background noise.

3. *Adjust temporal structure of vocalizations*. 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 percent 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 percent 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 need to increase the duration of their vocalization to avoid masking by the boat noise.

4. *Adjust the temporal delivery of vocalizations*. Animals responding in this way change when they vocalize or change 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 behaviors 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 behaviors) 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, the 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 singing 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 and Blickley 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, they 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 conspecific females ((Brumm 2004; Slabbekoorn and Peet 2003b; 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 the 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 Hawaiian monk seals and 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 exercises 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 the hearing sensitivities of sperm whales, which overlap the frequency range of mid-frequency active sonar, sonar transmissions might temporarily reduce the active space of some 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

(Goold and Jones 1995; Weilgart and Whitehead 1993). Ridgway and Carder (Ridgway and Carder 2001) measured low-frequency, high amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a neonate sperm whale.

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 of these vocal adjustments sperm whales would have to make would also be temporary.

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 2006; Selye 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. 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 a 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 2000) and altered metabolism (Elsasser et al. 2000), reduced immune competence (Blecha 2000) and behavioral disturbance. Increases in the circulation of glucocorticosteroidscirculation of glucocorticosteroids (cortisol, corticosterone, and aldosterone in marine mammals) have been equated with stress for many years (Romano et al. 2004).

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. 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 impair 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 diverts 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" (McEwen and Wingfield 2003). This pathological state will last until the animal replenishes its biotic reserves sufficient to restore normal function.

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; Lankford et al. 2005). 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. (2004) 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 TTSs would be accompanied by physiological stress responses because terrestrial animals exhibit those responses under similar conditions (NRC 2003b). 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.

6.4.5 Potential Behavioral Responses to Stressors

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 2004a; Frid 2003; Frid and Dill 2002; Gill and Sutherland 2001; Harrington and Veitch 1992; 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 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; Giese 1996; Müllner et al. 2004), 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 U.S. Navy vessels, sound fields 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. (1995b) 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 Hawaiian 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, although 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 that had been fitted with D-tags were exposed to mid-frequency active sonar (Source A: a 1.0 s upsweep 209 dB at 1 - 2 kHz every 10 seconds for 10 minutes; Source B: with a 1.0 s upsweep 197 dB at 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 seemed 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.

In the Caribbean, sperm whales avoided exposure to mid-frequency submarine sonar pulses, in the range 1000 Hz to 10,000 Hz (IWC 2005). 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 1997a; Stone 1998; Stone 2000; Stone 2001; Stone 2003a). 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 2003a). The analysis of the combined data from all years indicated that baleen whales stayed farther from airguns during periods of shooting (Stone 2003a) . 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 2003a).

Sperm whales responded to military sonar, apparently from a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins 1985).

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 area 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 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 beluga 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 and Carder 1997; Schlundt et al. 2000b), and to shorter broadband pulsed signals (Finneran et al. 2000; Finneran et al. 2002b). 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 (Finneran et al. 2002d; Schlundt et al. 2000b). 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 $_{\mathrm{rms}}$ 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; Finneran et al. 2002b). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran et al. 2002d). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway and Carder 1997; Schlundt et al. 2000b). 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. (2000b).

Richardson et al. (1995b) and Richardson and Wursig (1997) 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. (1995b) 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. 1995b). 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. (2002) 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 (Allen and Read. 2000; Lusseau 2004). 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. (2009; 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; Beale and Monaghan 2004b; Frid and Dill 2002; Gill and Sutherland 2001; 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 exposure to mid-frequency active sonar (or, at least, some components of the sound source), 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 animals 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 et al. 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. 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, this could 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 protect 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 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.

A recent paper by Cowan and Curry (2008) suggests that acoustic exposures might cause cetaceans to engage in involuntary dives triggered by a “dive reflex” or “alarm reaction” which is a marine mammal’s reaction to a situation or stimulus that the animal perceives as representing a serious threat. This dive reflect is a behavioral response that is primarily an autonomic reaction that does not involve the physiological changes that accompany voluntary dives (reflexive apnea, decreased heart rate or diving bradycardia, reduction of cardiac output and vasoconstriction with markedly decreased perfusion of gut, liver, kidneys and skeletal muscle and a substantial increase in production of lactic acid in these tissues). In cetaceans, mobilization for a dive means breath-holding and re-directing the flow of blood away from non-vital to vital oxygen dependent organs (i.e., the brain and heart) which is not injurious as long as the change involve coordinated cardiovascular adjustments, are not extreme, and are not protracted. If these adjustments are not coordinated, Cowan and Curry (2008) hypothesized that massive release of adrenergic hormone from the adrenal medulla would occur producing a “sympathetic storm” that is accompanied by spasm of small intramural coronary arteries and myocardial ischemia. This ischemia may be associated with arrhythmia and death of the animal or, in animals that survive, it may result in patchy death of myocytes followed by scarring or it may occur without evidence of residual injury.

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 as a result of their exposure to sound fields produced by active sonar per se. 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.

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; Müllner et al. 2004), 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 that 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; Cooper 1997). The probability of flight 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 2003; Frid and Dill 2002), 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 2003; 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) (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. In the case of humpback whales, lactating females with calves should spend more time in a resting state because of high energetic costs of lactating and their inability to compensate for those costs by feeding (humpback whales generally do not feed in their calving areas). Marine mammals that have been disturbed by anthropogenic noise and vessel approaches are commonly reported to shift from resting behavioral states to active behavioral states, which would imply that they 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 vessels 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, most of the endangered whales that are being considered in this Opinion are likely to avoid being exposed to the exercises or, if they are exposed, are likely to avoid continued exposure to the exercises. Blue, fin, humpback, sei, and sperm whales would probably be alerted to the start of an exercise by low-frequency sounds produced by Navy surface vessels entering an area to begin an exercise. Because the main Hawaiian Islands do not appear to be an important feeding area or calving area for fin, sei, and sperm whales, they seem likely to try to avoid an area in which surface vessels are moving at tactical speeds accompanied by active sonar transmissions, low-frequency sounds produced by aircraft and helicopters, sonobuoys, and submarines.

The main Hawaiian Islands are an important breeding and calving area for humpback whales, however. If breeding, adult humpback whales try to avoid being exposed to mid-frequency active sonar and that avoidance behavior prevented them from breeding, the avoidance behavior would have reduced the fitness of any humpback whales that made this trade-off (avoiding the sonar rather than breeding). Adult humpback whales with calves do not seem likely to try to avoid continued exposure if they are accompanied by very young calves because swimming at speeds that would allow them to avoid exposures would separate them from calves that could not sustain such swimming speeds. Their inability to avoid further exposure, however, seems likely to produce stress responses because they would want to avoid the sonar but their circumstances would prevent them from doing so.

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. 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 (Beauchamp and Livoreil 1997; Fritz et al. 2002; Saino 1994).

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 1997; 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 1985). For example, Madsen (1985) reported that pink-footed geese (*Anser brachyrhynchus*) in undisturbed habitat gained body mass and had about a 46 percent 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 percent 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 103kJ/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 (Cowlishaw et al. 2004; Lima 1998; Lima and Dill. 1990). 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 Hawai'i 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 Hawai'i 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

Under some circumstances, some of the 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. 1995b).

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. 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).

6.4.6 Stranding Events

In what follows, we address the evidence bearing on assertions from several non-governmental organizations (NGOs) and scientific investigators 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. Later they published 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. Claims asserting low-frequency active sonar as causal (for example Frantzis 1998) 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, 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 (Best 1982; Eaton 1979; Geraci et al. 1976; Odell et al. 1980). 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 predispose them to 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). 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 (Creel 2005; Fair and Becker 2000; Moberg 2000; Relyea 2009a; 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 experimental 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 a species that was listed as threatened or endangered (and was unrelated to active sonar exposures), 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 (IWC 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 International Whaling Commission 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 (Frantzis 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, 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 2005).

Between 1960 and 2006, 48 strandings (68 percent) involved beaked whales, 3 (4 percent) involved dolphins, and 14 (20 percent) involved whale species. Cuvier’s beaked whales were involved in the greatest number of these events (48 or 68 percent), followed by sperm whales (7 or 10 percent), and Blainville’s and Gervais’ beaked whales (4 each or 6 percent). Naval activities that might have involved active sonar are reported to have coincided with 9 (13 percent) or 10 (14 percent) of those stranding events. Between the mid-1980s and 2003 (the period reported by the 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 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 acutorostrata*) 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 that have been reported. Of those 85 mass stranding events, 29 represent stranding events that occurred before 1958; 25 of those 29 (about 34 percent) 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 (D’Amico and Verboom 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 (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 (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. (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 (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 sonars 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 hemorrhage and congestion in the right lung and both kidneys (Freitas 2004), as well as evidence of intracochlear and intracranial hemorrhage similar to that observed in the Bahamas beaked whales (Ketten et al. 2004).

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- 10 kHz, (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 (Fernandez 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 (Fernandez et al. 2005). Macroscopic examination revealed that the whales had severe, diffuse congestion and hemorrhages, especially in the fat in the jaw, around the ears, in the brain (e.g. multifocal subarachnoid hemorrhages) and in the kidneys (Fernandez 2004; Fernandez et al. 2004c). 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 (Fernandez 2004; Fernandez et al. 2004a; Fernandez et al. 2004c; Jepson et al. 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 (Martin et al. 2004).

Gulf of California (2002). In September 2002, marine mammal researchers 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 22 km 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 (5-500 Hz, 259 dB re: 1mPa Peak-to-Peak (p-p); Federal Register, 2003); (2) sub-bottom profiler (3.5 kHz, 200 dB SPL; Federal Register, 2004); and (3) multi-beam sonar (15.5 kHz, 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 (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 Hawaiian 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 were probably contributing factors 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 Hawaiian 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 unusual aggregation 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 unusual aggregation 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 percent of the total number of stranded animals and see Figure 3), other beaked whales (including *Mesoplodon europeaus, M. densirostris,* and *Hyperoodon ampullatus*) comprise 14 percent 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 mammal 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 (Nitta 1991) reported that between 1936 and 1988, 8 humpback whales, 1 fin whale, and 5 sperm whales stranded in the Hawaiian Archipelago. In a partial update of that earlier report, Maldini et al. (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 Hawaiian 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 1971 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 39-year period since 1971. With one exception, there is little evidence of a pattern in the record of stranding events reported for the main Hawaiian 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 Hawaiian 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 Hawaiian 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 Hawaiian 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 Hawaiian Islands and were not likely to be detected if they did strand.

Finally, the apparent absence of stranding events coincident with the 39 years of antisubmarine warfare training exercises in waters off the main Hawaiian 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).

6.5 Probable Response of Listed Species

Although we identified potential stressors and potential responses to those stressors, we must still assess the probability that an animal will respond to the stressor. We are able to numerically estimate (albeit with some uncertainty in those numbers) potential exposures to mid-frequency active sonars associated with the training exercises and other activities the U.S. Navy plans to conduct. We assume that animals that are exposed to sonars are also exposed to the other stressors described.

6.5.1 Probable Responses to Mid-Frequency Active Sonar

Based on the evidence available, the mid-frequency active sonars associated with the training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex annually is 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. Most of the evidence available suggests that active sonar associated with the Navy's activities are not likely to kill or fatally injure endangered or threatened marine animals in the Hawaiian Islands as a result of direct exposure or as an indirect result of an exposure event: if marine animals were likely to be killed as a direct or indirect result of being exposed to this sonar, we would have received more reports of such deaths or fatal injuries at some point in the relatively long history of Navy training in the Hawaiian Islands. Similarly, 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 U.S. Navy training exercises and other activities conducted in the Hawai'i Range Complex.

In this case, the absence of such reports given the number of exercises the Navy has conducted in the Hawai'i Range Complex 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 Hawai'i 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 Hawai'i 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 would 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.

Probable Responses of Blue Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the twenty-four month period beginning in January 2012, the first scenario identified 489 instances each year in which blue whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB.

In the event blue whales are exposed to mid-frequency sonar, the information available on blue whales suggests that they are not likely to hear mid-frequency (1 kHz–10 kHz) active sonar (or other sounds in the mid-frequency band). Blue whale vocalizations include a variety of sounds described as low frequency moans or long pulses in the 10-100 Hz band (Clark and Fristrup 1997; Cummings and Thompson 1971; McDonald et al. 1995a; Rivers 1997; Thompson and Friedl 1982). 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 Responses of Fin Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the twenty-four month period beginning in January 2012, the first scenario identified 1,712 instances each year in which fin whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB. No fin whales are expected to be exposed to received levels greater than 195 dB associated with these other training activities.

Fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Edds 1988a; Thompson et al. 1992; Watkins 1981a; Watkins et al. 1987). 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 of their vocalizations reach as high as 190 dB (McDonald et al. 1995a; Patterson and Hamilton 1964; Thompson et al. 1992; Watkins et al. 1987). 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 (Clarke and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald et al. 1995a). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999a). 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) active sonar.

Probable Response of Humpback Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the twenty-four month period beginning in January 2012, our first scenario identified 12,881 instances each year in which humpback whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 7,538 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 3,588 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures would occur at received levels greater than 160 dB. Nevertheless, we believe these are overestimates because we would not expect humpback whales to be exposed to sound fields produced by active sonar associated with all of the training exercises and other activities that would occur in the Hawai'i Range Complex over the next twenty-four months.

We assume that the humpback whales that might be exposed to active sonar could be any gender, age, or reproductive condition. However, historic patterns suggest that immature humpback whales and females without calves would arrive in the Maui Basin and Penguin Banks before females with calves, pregnant females, and males; as discussed previously, the pattern off the Island of Hawai'i is different (females without calves arrive before immature whales) and may be different in other areas of Hawai'i. Because humpback whales do not tend to reside in waters off Hawai'i for more than 6 to 8 weeks, we would not expect individual whales to be exposed to major training exercises (for example, Undersea Warfare Exercises) multiple times, although individual whales might be exposed to multiple unit-level or intermediate-level training exercises.

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 (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 and Whitehead. 1983).

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 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 (Richardson et al. 1995a; Winn et al. 1970);

2. Social sounds in the breeding areas that extend from 50Hz – more than 10 kHz with most energy below 3kHz (Richardson et al. 1995a; Tyack 1983); and

3 Feeding area vocalizations that are less frequent, but tend to be 20Hz – 2 kHz with estimated source levels in excess of 175 dB re 1 uPa-m (Richardson et al. 1995a; Thompson et al. 1986).

> Sounds often associated with possible aggressive behavior by males (Silber 1986; Tyack and Whitehead. 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. They concluded 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 sonars the U.S. Navy would employ 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 1989). 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. 1993b; Todd et al. 1996b). 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. 1996b). The explosions may also have increased the number of humpback whales entangled in fishing nets (Todd et al. 1996b). Frankel and Clark (2000) 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.

Based on our analyses of the data available, the humpback whales involved in about 13 percent of the exposure events (about 1,755 of 12,881 exposure events annually) are not likely to respond to their exposure. The humpback whales involved in another 1,791 annual 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 humpback whales involved in about 97 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, humpback 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. Humpback whales involved in another 877 exposure events would engage in evasive travel which would involve faster swimming speeds, deeper dives, and short times at surface. We assume that cows with calves are more likely to exhibit these responses to an exposure than adult males or non-breeding cows. Humpback whales involved in about 609 annual 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 Responses of Sei Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twenty-four months, the first scenario identified 105 instances each year in which sei whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB. No sei whales would be exposed to received levels greater than 195 dB associated with these other training activities.

As discussed in the Status of the Species section of this Opinion, specific information on sounds produced by sei whales, their sensitivity to sounds in their environment, or their vocal behavior is limited. 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 a 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. 1995b).

During visual and acoustic surveys conducted in the Hawaiian Islands in 2002, Rankin and Barlow (2007a) 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 vocalizations 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 Hawaiian 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. 2008).

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

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twenty-four months, the first scenario identified 6,850 instances each year in which sperm whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB, 1 instance each year in which sperm whales might be exposed at received levels between 195 and 215 dB, and one instance each year in which sperm whales might be exposed at received levels greater than 215 dB.

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 (Goold and Jones 1995; Weilgart and Whitehead 1993). 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 1985; Watkins and Schevill 1975), pingers (Watkins and Schevill 1975), the Heard Island Feasibility 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 Schevill 1975). Goold Goold 1999a (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 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. 2000a), and to shorter broadband pulsed signals (Finneran et al. 2002a; Finneran et al. 2000). 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 (Finneran et al. 2002a; Schlundt et al. 2000a). 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; Finneran et al. 2002c). Test animals occasionally vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran et al. 2002d). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway and Carder 1997; Schlundt et al. 2000a).

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. (1995a) 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 (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 2003). 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 1997b; Stone 1998; Stone 2000; Stone 2001; Stone 2003a). 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 2003a). The results from these waters seem to show that some sperm whales tolerate seismic surveys.

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.

Based on our analyses of the data available, the sperm whales involved in about 13 percent of the exposure events (about 933 of 6,850 annual exposure events) are not likely to respond to their exposure. The sperm whales involved in another 953 annual 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 52 of the annual 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 467 annual 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 324 annual 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 Hawaiian Monk Seals

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twenty-four months, the first scenario identified 122 instances each year in which Hawaiian monk seals might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB. No monk seals would be exposed to received levels greater than 195 dB associated with these other training activities.

Of the 121 instances each year in which NMFS exposure models identified Hawaiian monk seals that might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB, about 71 of those instances would involve exposures at received levels between 140 and 150 dB and another 34 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures would occur at received levels greater than 160 dB.

The information available does not allow us to assess the probable responses of Hawaiian monk seals after they are exposed to mid-frequency active sonar transmissions. In the past, we have assumed the Hawaiian monk seals do not seem likely to respond to those transmissions; however, the U.S. Navy has concluded that at least one of these monk seals each year might accumulate acoustic energy sufficient to produce a temporary shift in its 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 a Hawaiian monk seal that experiences 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 Hawai'i Range Complex over the next twenty-four months. Further, although the information on the hearing capabilities of sea turtles is limited, the information available suggests that the auditory capabilities of sea turtles are centered in the low-frequency range (<1 kHz) (Bartol et al. 1999b; Lenhardt 1994; Lenhardt et al. 1983; Ridgway et al. 1969). 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). Wood turtles are reported to have sensitivities up to about 500 Hz, followed by a rapid decline above 1000 Hz and almost no responses beyond 3000 or 4000 Hz (Patterson 1966).

We assume that these sensitivities to sound apply to the hardshell turtles (i.e., green, hawksbill, 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 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. Unlike the sound source McCauley et al. (2000) used, the sonar the U.S. Navy proposes to use during the training and other activities it proposes to conduct in the Hawai'i Range Complex transmits at frequencies that are substantially higher than the hearing thresholds of sea turtles. As a result, sea turtles are not likely to respond upon being exposed to mid-frequency active sonar.

6.5.2 Probable Responses of Listed Species to Underwater Detonations

For marine mammal species, pressure waves from an explosion can impact air cavities, such as lungs and intestines causing instantaneous or proximate mortality. Extensive hemorrhaging of the lungs due to underwater shock waves may cause death to a marine mammal through suffocation (Hill 1978). Other common injuries which may result in mortality include circulatory failure, broncho-pneumonia in damaged lungs, or peritonitis resulting from perforations of an animal‘s intestinal wall (Hill 1978). The degree of injury associated with impulse is believed to be directly proportional to mammal mass (Yelverton et al. 1973), therefore, conservative criteria for the impulse effect are based on the lowest possible affected mammalian weight (e.g. dolphin calves)(Navy 1998).

Non-lethal injuries include slight lung hemorrhage and tympanic membrane rupture from which the mammal is expected to recover (Richmond et al. 1973; Yelverton et al. 1973). Eardrum damage criteria are based upon a limited number of small charge tests (Richmond et al. 1973; Yelverton et al. 1973). Ranges for the percentage by which tympanic membranes rupture in response to underwater explosions can be calculated by a conservative tympanic membrane damage model (U.S. Navy 1996). General criteria for damage to marine mammal tympanic membranes have been reported to occur at impulse levels down to 20 psi-msec (Yelverton et al. 1973). Because the hearing anatomy of sea turtles is different from marine mammals, these calculations may not apply to turtles.

Most impact analyses have focused on large shipshock explosions in nearshore waters (for example, the USS SEAWOLF) or deep offshore waters (for example, USS WINSTON S CHURCHILL or the MESA VERDE (LPD 19)). Based upon information provided in the final environmental impact statement for the USS SEAWOLF shock trial (Navy 1998), the Navy developed two criteria to determine if signals generated by detonations would acoustically harass marine mammals: (1) an energy-based temporary threshold shift injury criterion of 182 dB re 1 uPa^2-sec derived from bottlenose dolphins; and (2) a 12 - lbs/in2 (psi) peak pressure cited by Ketten (1995) as associated with the safe outer limit (for the 10,000 lb charge for the minimal, recoverable auditory trauma (i.e., temporary threshold shifts).

The U.S. 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 Hawai'i 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.

Despite these protective measures, the U.S. Navy identified five instances each year in which humpback whales might be exposed to pressure waves or sound fields associated with underwater detonations at received levels that would cause behaviors that would be considered behavioral harassment (as that term is defined by the MMPA) and another four instances each year in which humpback whales might be exposed at received levels that might temporarily cause noise-induced hearing losses. In addition, the Navy identified nine instances each year in which sperm whales might be exposed to pressure waves or sound fields associated with underwater detonations at received levels that would cause behaviors that would be considered behavioral harassment (as that term is defined by the MMPA) and another four instances each year in which sperm whales might be exposed at received levels that might temporarily cause noise-induced hearing losses. The Navy identified three instances each year in which Hawaiian monk seals might be exposed at received levels sufficient to temporarily cause noise-induced hearing loss. The Navy's analyses and our analyses did not estimate the number of instances in which one or more species of sea turtle might be exposed to pressure waves or sound fields associated with underwater detonations.

Humpback whales were not reported to change the short-term behavior or distribution in feeding areas in response to explosions with received levels of about 150dB re 1 µPa/Hz at 350Hz (Lien et al. 1993a; Todd et al. 1996a). However, at least two individuals were probably killed by the high-intensity, impulse blasts and had extensive mechanical injuries in their ears (Ketten et al. 1993; Todd et al. 1996a). The explosions may also have increased the number of humpback whales entangled in fishing nets as they avoided the area in which the detonations occurred (Todd et al. 1996a).

Klima et al. (1988) conducted an experiment in which Kemp's ridley and loggerhead turtles were placed in cages at four distances from an 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; ridley turtles 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=578w0.28 (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 w1/3, 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 NMFS for platform removal operations using explosives. The revised equation is R = 560 w1/3. 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. 1993).

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 turtles) suggest that they could be capable of hearing low frequency sounds (Lenhardt 1994; Moein et al. 1993; Ridgway et al. 1969). 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 >100 Hz (which are the acoustical harassment ranges predicted for odontocetes) would be conservative for sea turtles.

Moein et al. (1993) 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.

6.6 Effects Resulting from Interaction 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. 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 Hawai'i 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 "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 (2000; 2009b) 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 (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. Navy proposes to conduct in the Hawai'i Range Complex will continue to introduce a suite of potential stressors into the marine and coastal ecosystems of the main Hawaiian Islands: 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 Hawai'i 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 waters off the main Hawaiian Islands. More importantly, endangered and threatened marine animals that occur in the Hawai'i Range Complex would be exposed to combinations of stressors produced by the Navy's activities at the same time they are exposed to stressors from other human activities and natural phenomena.

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 produced by commercial shipping, recreational boating, and construction activities occurring along the coastlines, among others. 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 2008a). That assessment concluded that the "cumulative impacts" of mid-frequency sonar would be "extremely small" because the exercises would occur for relatively short periods of time, for relatively short periods of time in any given area; the sources of active sonar would not be stationary; and 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 and other agencies plan to conduct in waters off Hawai'i during the same time interval. Over the next twenty-four months, the U.S. Navy plans on conducting Undersea Warfare Exercises in the Hawai'i Range Complex. Each of those exercises are expected to last for about 72 to 96 hours and involve about 140 hours of mid-frequency active sonar, 100 dips of dipping sonar, and 130 sonobuoys. Blue, fin, humpback, sei, sperm whales, and Hawaiian monk 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 next twenty-four months, individual blue, fin, sei, sperm whales, Hawaiian monk seals, and humpback whales (seasonally) are likely to be exposed to the activities associated with five Undersea Warfare Exercises; about 180 anti-submarine warfare tracking exercises, 19 bombing exercises; 18 anti-surface warfare torpedo exercises; and about 250 anti-submarine warfare torpedo exercises in addition to a stress regime that include close approaches for research, exposure to whale watch vessels; exposure to fisheries and fishing gear; and other natural and anthropogenic stressors.

Richardson et al. (1995b) 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), National Research Council (NRC 2003c), 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 Hawai'i 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 Hawai'i would not reduce the performance of the humpback whales that winter in waters off Hawai'i. 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 Hawai'i (for example, the Hawaiian nesting aggregation of green sea turtles has increased in abundance over the past 30 years as well).

Other inferences, however, that would undercut that inference are also consistent with the evidence. If humpback whales in waters off Hawai'i were an isolated and resident population, it would be appropriate to infer that the existing stress regime has not reduced their performance as a population. Because that is not the case and the humpback whales that winter in Hawai'i migrate there from foraging areas across the North Pacific Ocean (humpback whales have been reported to migrate to Hawai'i from foraging areas in Russian, the Bering Sea, Aleutian Islands, western Gulf of Alaska, southeast Alaska, and British Columbia) (Calambokidis et al. 2008). One inference that is consistent with the data is that the increase in humpback whales reflects conditions in foraging areas that allow their numbers to increase despite conditions in Hawai'i (the corollary being that as those conditions change, the population’s performance would change). Another inference that is consistent with the evidence available is that humpback whales continue to migrate to Hawai'i during the winter because these are their traditional wintering areas or because conditions in alternative wintering areas are worse.

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 Hawai'i, and other natural and anthropogenic stressors in the Action Area. The evidence available suggests that the population of at least humpback whales that winters 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.

6.7 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 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, we 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. We 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.

6.8 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 et al. 2000; Mills and Beatty 1979; Stearns 1977; 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.

The following discussions summarize the probable risks the training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twelve-months pose to threatened and endangered species that are likely to be exposed to those transmissions. These summaries integrate the results of the exposure and response analyses we presented previously with background information from the Status of the Species section of this Opinion to assess the potential risks the training is likely to pose to endangered and threatened individuals, the population or populations those individuals represent, and the "species" that have been listed pursuant to the Endangered Species Act of 1973, as amended. Because the second and third exposure scenarios (which assume that animals would avoid continued exposure to active sonar and that humpback whale densities varied over time, respectively) required us to speculate on when exercises would occur, the exposure estimates we report in this section of the document are based on estimates produced by the first scenario.

6.8.1 Blue Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex annually over the next twenty-four months, the first scenario identified 489 instances in which blue whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB; about 286 of those instances would involve exposures at received levels between 140 and 150 dB. Another 136 of those instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures would occur at received levels greater than 160 dB.

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 proposed activities. Most marine mammals would only be exposed periodically or episodically, if at all, to the proposed activities. 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 Hawai'i Range Complex in small numbers, an estimate of 489 exposures is probably an over-estimate of the actual exposure even if it represents the best estimate available. Nevertheless, blue whales are not likely to respond to mid-frequency active sonar because they are not likely to hear those sonar transmissions.

Blue 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 ways that approximate their responses to whale watching vessels. 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.

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. 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 those whales.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twenty-four months are not likely to adversely affect the population dynamics, behavioral ecology, and social dynamics of individual blue whales in ways or to a degree that would reduce their fitness. 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 Hawai'i Range Complex would not appreciably reduce the blue whales' likelihood of surviving and recovering in the wild.

6.8.2 Fin Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twelve months, the first scenario identified 1,712 annual instances in which fin whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB; about 1,002 of those instances would involve exposures at received levels between 140 and 150 dB. Another 477 of those instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures (233) would occur at received levels greater than 160 dB.

As with blue whales, this is probably an over-estimate of 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 Hawai'i Range Complex. Most marine mammals would only be exposed periodically or episodically, if at all, to the proposed activities. 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 Hawai'i Range Complex in low densities, an estimate of 1,712 exposures is probably a substantial over-estimate of the actual exposure even if it represents 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. 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 Hawai'i 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. 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. If we assume that a similar proportion of fin whales would react to the vessel noise and traffic as would react to other sound stimuli, then about 198 fin whales each year would be expected to make minor adjustments to their behavior. However, because of the relatively short duration of the different exercises and the small number of times the exercises are likely to be repeated over the twenty-four month period, we do not expect these responses of fin whales to reduce the fitness of the fin whales that occur in the Hawai'i Range Complex.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the twenty-four month period beginning in January 2012 are not likely to adversely affect the population dynamics, behavioral ecology, and social dynamics of individual fin whales in ways or to a degree that would reduce their fitness. 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 Hawai'i Range Complex over the next two years are not likely to appreciably reduce the fin whales’ likelihood of surviving and recovering in the wild.

6.8.3 Humpback Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai’i Range Complex over the next two years, our first scenario identified 12,881 instances in which humpback whales might be exposed to mid-frequency active sonar at received levels between 140 and 195 dB. Of these, more than half (58.52 percent or 7,538 exposure events) would involve exposures at received levels between 140 and 150 dB (primarily because the volume of water that would be ensonified at these received levels would represent about 58.52 percent of the total volume). Another 3,588 instances would involve exposures at received levels between 150 and 160 dB. The balance of the exposures would occur at received levels greater than 160 dB. Nevertheless, we believe these are overestimates because we would not expect humpback whales to be exposed to sound fields produced by active sonar associated with all of the training exercises and other activities that would occur in the Hawai'i Range Complex on an annual basis.

We assume that the humpback whales that might be exposed to active sonar between their arrival in and departure from waters off Hawai'i might be any gender, age, or reproductive condition. However, historic patterns suggest that immature humpback whales and females without calves would arrive in the Maui Basin and Penguin Banks before females with calves, pregnant females, and males; as discussed previously, the pattern off the Island of Hawai'i is different (females without calves arrive before immature whales) and may be different in other areas of Hawai'i. Because humpback whales do not tend to reside in waters off Hawai'i for more than 6 to 8 weeks, we would not expect individual whales to be exposed to major training exercises (for example, Undersea Warfare Exercises) multiple times, although individual whales might be exposed to multiple unit-level or intermediate-level training exercises.

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 (Richardson et al. 1995a; 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 and Whitehead. 1983).

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 (Richardson et al. 1995a; 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).

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. 1993b; Todd et al. 1996b). 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. 1996b). The explosions may also have increased the number of humpback whales entangled in fishing nets (Todd et al. 1996b). Frankel and Clark (1998b) 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 most of the activities the U.S. Navy plans to conduct in the Hawai'i Range Complex would occur before humpback whales arrive into waters off the Hawaiian Islands. 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.

The U.S. Navy also identified five instances in which humpback whales might be exposed to pressure waves or sound fields associated with underwater detonations at received levels that would cause behaviors that would be considered behavioral harassment (as that term is defined by the MMPA) and in another four instances in which humpback whales might be exposed at received levels that might temporarily cause noise-induced hearing losses.

Humpback whales were not reported to change the short-term behavior or distribution in feeding areas in response to explosions with received levels of about 150dB re 1 µPa/Hz at 350Hz (Lien et al. 1993a; Todd et al. 1996a). 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. 1996a). The explosions may also have increased the number of humpback whales entangled in fishing nets as they avoided the area in which the detonations occurred (Todd et al. 1996a).

Based on our analyses of the data available, the humpback whales involved in about 13 percent of the exposure events (about 1,755 of 12,881 exposure events) are not likely to respond to their exposure. The humpback whales involved in another 1,791 exposure events would make 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 humpback whales involved in about 97 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, humpback 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. Humpback whales involved in another 877 exposure events would engage in evasive travel which would involve faster swimming speeds, deeper dives, and short times at surface. We assume that cows with calves are more likely to exhibit these responses to an exposure than adult males or non-breeding cows. Humpback whales involved in about 609 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. These behavioral responses are almost certain to affect the energetics of the humpback whales involved, particularly cows that are nursing calves because they nursing requires a substantial amount of energy and because humpback whales do not feed in the Hawaiian Islands, which would allow them to compensate for any increases in energy demands.

As discussed in the Environmental Baseline section of this Opinion, the strongest evidence 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 and the increased number of humpback whale that are reported to occur in the

Hawaiian Islands. In the 1980s, the size of the North Pacific humpback whale population was estimated to range from 1,407 to 2,100 (Baker 1985a; Baker and Herman 1987; Darling and Morowitz 1986). 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). The most recent estimate places the current population of humpback whales in the North Pacific Ocean at about 18,300 whales, not counting calves (Calambokidis et al. 2008). Almost half of the humpback whales that were estimated to occur in wintering areas, or about 8,000 humpback whales, occupy the Hawaiian Islands during the winter months.

Despite the 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 Hawaiian Islands 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 Hawai'i Range Complex, including vessel traffic, aircraft traffic, active sonar, and underwater detonations, for more than a generation. Although we do not know if more humpback whales might have used the action area or the reproductive success of humpback whales in the Hawai'i Range Complex would be higher absent their exposure to these activities, the rate at which humpback whales occur in the Hawaiian Islands suggests that humpback whale numbers have increased substantially in these important calving areas 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 humpback whale counts in Hawai'i are increasing.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twelve months are not likely to adversely affect the population dynamics, behavioral ecology, and social dynamics of individual humpback whales in ways or to a degree that would reduce their fitness. 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 Hawai'i Range Complex over the next twelve months would not be expected to appreciably reduce the humpback whales' likelihood of surviving and recovering in the wild.

6.8.4 Sei Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twelve months, the first scenario identified 105 instances in which sei whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB. No sei whales would be exposed to received levels greater than 195 dB associated with these other training activities.

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 Hawai'i Range Complex in ways that approximate their responses to whale watching vessels. 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; Corkeron 1995; Erbe 2002; Félix 2001; Magalhaes et al. 2002; Richter et al. 2003; Scheidat et al. 2004; Simmonds 2005; Watkins 1986; Williams et al. 2002b). 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. If we assume that a similar proportion of sei whales would react to the vessel noise and traffic as would react to sonar stimuli if they could hear it, then about 12 sei whales each year would be expected to make minor adjustments to their behavior. However, because of the relatively short duration of the different exercises and the small number of times the exercises are likely to be repeated from within the two year period, we do not expect these responses of sei whales to reduce the fitness of the sei whales that occur in the Hawai'i Range Complex.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next two years are not likely to adversely affect the population dynamics, behavioral ecology, and social dynamics of individual sei whales in ways or to a degree that would reduce their fitness. 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 Hawai'i Range Complex over the next 12 months would not be expected to appreciably reduce the sei whales' likelihood of surviving and recovering in the wild.

6.8.5 Sperm Whales

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twenty-four months, the first scenario identified 6,850 instances annually in which sperm whales might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB, 1 instance in which sperm whales might be exposed at received levels between 195 and 215 dB, and one instance in which sperm whales might be exposed at received levels greater than 215 dB.

If exposed to mid- and high-frequency active 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 (Goold and Jones. 1995; Weilgart et al. 1993; Weilgart and Whitehead. 1997). 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 (Cranford 1992; Norris and Harvey. 1972). 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 (Goold and Jones. 1995; Weilgart and Whitehead. 1993). 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- and high-frequency active sonar, sonar transmissions might temporarily reduce the active space of sperm whale vocalizations. Most of the energy of sperm whale 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 (Goold and Jones 1995; Weilgart et al. 1993)). Ridgway and Carder (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 1975), pingers (Watkins 1975), the Heard Island Feasibility Test (Bowles 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 et al. 1993). 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. 2000a), and to shorter broadband pulsed signals (Finneran et al. 2002a; Finneran et al. 2000). 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 (Finneran et al. 2002a; Schlundt et al. 2000a). 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. 2002a; Finneran et al. 2000). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran et al. 2002a). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway et al. 1997; Schlundt et al. 2000a). 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. (2000a).

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. 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). 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 1997b; Stone 1998; Stone 2000; Stone 2001; Stone 2003a). 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 2003a). 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 et al. 1985; Watkins and Schevill 1975). 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 behavior (Miller et al. 2009).

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. (1995a) 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.

Based on our analyses of the data available, the sperm whales involved in about 13 percent of the annual exposure events (about 933 of 6,850 exposure events) are not likely to respond to their exposure. The sperm whales involved in another 953 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 52 of the exposure events each year 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 467 exposure events each year would engage in evasive travel which would involve faster swimming speeds, deeper dives, and short times at surface. Sperm whales involved in about 324 exposure events each year 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.

The U.S. Navy's analyses identified nine instances in which sperm whales might be exposed to pressure waves or sound fields associated with underwater detonations at received levels that would cause behaviors that would be considered behavioral harassment (as that term is defined by the MMPA) and another four instances in which sperm whales might be exposed at received levels that might temporarily cause noise-induced hearing losses.

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 Hawai'i Range Complex over the next twelve months, particularly active sonar transmissions, ship traffic, and explosions, would represent individuals from a Hawaiian population (or "stock"). Sperm whales are widely distributed throughout the Hawaiian Islands year-round. Sperm whale clicks recorded from hydrophones off Oahu confirm the presence of sperm whales near the Hawaiian 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 Hawaiian Islands Operating Area. Sperm whales rarely occur from the shore to the shelf-break, so they are not likely to be exposed in the shallower coastal waters around the main Hawaiian Islands.

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. 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 communicating, 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 major training exercises and other anti-submarine warfare activities (TRACKEX and TORPEX) the U.S. Navy plans to conduct in the Hawai'i 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 in ways that 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 being 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; Corkeron 1995; Erbe 2002; Félix 2001; Magalhaes et al. 2002; Richter et al. 2003; Scheidat et al. 2004; Simmonds 2005; Watkins 1986; Williams et al. 2002b). 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 Hawai'i Range Complex over the next two years are not likely to adversely affect the population dynamics, behavioral ecology, and social dynamics of individual sperm whales in ways or to a degree that would reduce their fitness. 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 Hawai'i Range Complex over the next two years would not be expected to appreciably reduce the sperm whales' likelihood of surviving and recovering in the wild.

6.8.6 Hawaiian Monk Seals

During the major training exercises and other anti-submarine warfare activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twelve months, the first exposure scenario identified 122 instances in which Hawaiian monk seals might be exposed to mid-frequency active sonar transmissions at received levels between 140 and 195 dB. No monk seals would be exposed to received levels greater than 195 dB associated with these other training activities.

The information available does not allow us to assess the probable responses of Hawaiian monk seals after they are exposed to mid-frequency active sonar transmissions. In the past, we have assumed the Hawaiian monk seals do not seem likely to respond to those transmissions because the sonar that would be used during the anti-submarine warfare exercises transmits at frequencies above the hearing thresholds for Hawaiian monk seals. However, the U.S. Navy has concluded that at least one of these monk seals might accumulate acoustic energy sufficient to produce a temporary shift in its 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 a Hawaiian monk 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, monk seals are likely to try to avoid being exposed to vessel traffic, active sonar, and sound-producing exercises such as gunnery exercises or sink 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 Hawaiian monk seals (for example, engine noise, helicopter rotors, ordnance discharges, explosions, or some combination of these), but these relatively shy animals are likely to avoid the general area in which an exercise would occur by remaining close to a shoreline or on a beach. This avoidance will not prevent monk seals from being exposed to received levels of active sonar or explosions, but it would prevent monk seals from being exposed at received levels that would injure a monk seal, cause them physiological distress, or alter their reproductive success.

As discussed in the Environmental Baseline section of this Opinion, Hawaiian monk seals have been exposed to U.S. Navy training activities in the Hawai'i Range Complex, including vessel traffic, aircraft traffic, active sonar, and underwater detonations, for more than a generation. Although we do not know if more monk seals might have used the action area or the reproductive success of monk seals in the Hawai'i Range Complex would be higher absent their exposure to these activities, the rate at which Hawaiian monk seals occur in the Main Hawaiian Islands suggests that monk seals numbers 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 monk seal counts in the Main Hawaiian Islands are increasing.

Based on the evidence available, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next twenty-four months are not likely to adversely affect the population dynamics, behavioral ecology, and social dynamics of individual Hawaiian monk seals in ways or to a degree that would reduce their fitness. 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 monk seals would not be likely to reduce the viability of those populations of Hawaiian monk 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 Hawai'i Range Complex over the twelve-month period beginning in the first week of January 2009 would not be expected to appreciably reduce the monk seals’ likelihood of surviving and recovering in the wild.

NMFS proposed an expansion of critical habitat for Hawaiian monk seals in 2011 (76 FR 32026) to include near shore areas of the main Hawaiian Islands but excluded Navy training areas near Puuloa Training Range and the Naval Defensive Sea Area. However, other areas proposed for critical habitat designation may be impacted by Navy activities (76 FR 32026). If critical habitat is designated as proposed, then reinitiation of consultation under the ESA may be necessary.

6.8.7 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 Hawai’i Range Complex over the next twelve months.

Further, although the information on the hearing capabilities of sea turtles is limited, the information available suggests that the auditory capabilities of sea turtles are centered in the low-frequency range (<1 kHz) (Bartol et al. 1999b; Lenhardt 1994; Lenhardt et al. 1983; Ridgway et al. 1969). 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. 1999a).

The sonar the U.S. Navy proposes to use during the training and other activities it proposes to conduct in the Hawai'i Range Complex transmits at frequencies that are substantially higher than the hearing thresholds of sea turtles. As a result, sea turtles are not likely to respond upon being exposed to mid-frequency active sonar and, therefore, sea turtles are not likely to be adversely affected by mid-frequency active sonar.

We conclude that training exercises and other activities the U.S. Navy plans to conduct in the Hawai'i Range Complex over the next two years are not likely to interact with a sufficient number of adult or sub-adult sea turtles, if they interact with any sea turtles at all, to reduce the viability of the nesting aggregations those sea turtles 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, those activities would not be expected to appreciably reduce the likelihood of green, hawksbill, leatherback, or loggerhead or olive ridley sea turtles surviving and recovering in the wild by reducing their reproduction, numbers, or distribution.

7 CONCLUSION

After reviewing the current status of endangered blue whales, fin whales, humpback whales, sei whales, sperm whales, Hawaiian monk seals, green sea turtles, hawksbill sea turtles, leatherback sea turtles, loggerhead sea turtles, olive ridley sea turtles, the environmental baseline for the action area, the effects of the proposed military readiness activities, and the cumulative effects, it is NMFS’ biological and conference 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 Hawai'i Range Complex from January 2012 to January 2014, is not likely to jeopardize the continued existence of these threatened and endangered species under NMFS jurisdiction. NMFS also concludes that critical habitat that has been designated for Hawaiian monk seals will not be destroyed or adversely modified.

NMFS proposed an expansion of critical habitat for Hawaiian monk seals in 2011 (76 FR 32026) to include near shore areas of the main Hawaiian Islands but excluded Navy training areas near Puuloa Training Range and the Naval Defensive Sea Area. However, other areas proposed for critical habitat designation may be impacted by Navy activities (76 FR 32026). If critical habitat is designated as proposed, then reinitiation of consultation under the ESA may be necessary.

8 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit 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 and Conservation Division so they become binding conditions of any permit or Letter of Authorization issued to the U.S. Navy, as appropriate, in order for the exemption in section 7(o)(2) to apply. The NMFS Permits and Conservation Division has a continuing duty to regulate the activity covered by this Incidental Take Statement. If NMFS Permits and Conservation 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.

8.1 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 empirical Bayesian analysis to estimate 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 to 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.” 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 annual number of instances in which endangered or threatened marine mammals and sea turtles 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 Hawai'i Range Complex from January 2012 through January 2014.

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	0	0	0	0
Fin Whale	22	0	0	22
Humpback Whale	1,487	9	0	1,496
Sei Whale	1	0	0	1
Sperm Whale	791	9	0	800
Hawaiian Monk Seal	121	0	0	121
Green Sea Turtle	0	0	0	0
Hawksbill Sea Turtle	0	0	0	0
Leatherback Sea Turtle	0	0	0	0
Loggerhead Sea Turtle	0	0	0	0
Olive Ridley Sea Turtle	0	0	0	0
Totals	**2,422**	**18**	**0**	2,440

***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 resting, milling, or other behavioral states that require lower energy expenditures to traveling, avoidance, or other 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 14 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 vessels involved in training exercises.

8.2 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 Hawai'i 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 ESA is not likely to jeopardize the continued existence of blue, fin, humpback, sei, or sperm whales, Hawaiian monk 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.

8.3 Reasonable and Prudent Measures

NMFS 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 Hawai'i Range Complex over the next twenty-four months.

8.4 Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, as amended, NMFS' Permits and ConservationDivision 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)).

Annual Hawai'i Range Complex Exercise Report

The Navy shall submit an Annual Exercise Report on October 1, 2012 and October 1, 2013, (covering data gathered through August 1 of each year respectively). This report shall contain the information identified below.

(1) MFAS/HFAS Major Training Exercises - This section shall contain the following information for Major Training Exercises (MTES, which include RIMPAC, USWEX, and Multi Strike Group) conducted in the Hawai'i 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, 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) Total hours (from December 15 through April 15) of hullmounted active sonar operation occurring in the dense humpback areas generally shown on the Mobley map (see 73 FR 35510, 35520) plus a 5-km buffer, but not including the Pacific Missile Range Facility. The Navy shall work with NMFS to develop the exact boundaries of this area.

(iii) Total estimated annual hours of hull-mounted active sonar operation conducted in Humpback Whale Cautionary area between December 15 and April 15.

(vi) 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 RIMPAC, USWEX, or Multi-Strike Group 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 Hawai'i Range Complex. The Navy shall either include (in the

Hawai'i Range Complex annual report) the Cumulative Impact Report, as described above, or provide a brief annual progress update on the status of the Cumulative Report.

(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 Hawai'i Range Complex); 2) the required exclusion zone (1 nm for SINKEX in Hawai'i Range Complex); (3) the required observation distance (if different than the exclusion zone (2 nm for SINKEX in Hawai'i Range Complex); 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/AEER Summary. This section shall include an annual summary of the following IEER information:

- (i) Total number of IEER/AEER events conducted in the Hawai'i Range Complex
- (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 (identified in 50 C.F.R. §216.170 and in condition 4(a)(2)) that are conducted in the Hawai'i Range Complex
- (ii) Total annual expended/detonated rounds (missiles, bombs, etc.) for each explosive type

Sonar Exercise Notification

The Navy shall submit to the NMFS Office of Protected Resources either an electronic (preferably) or verbal report within fifteen calendar days after the completion of any major exercise (RIMPAC, USWEX, or Multi Strike Group) indicating:

- (1) Location of the exercise
- (2) Beginning and end dates of the exercise
- (3) Type of exercise (e.g., RIMPAC, USWEX, or Multi Strike Group)

9 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 recommendation 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 ESA IC 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 ESA IC Division informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Permits and Conservation Division of the Office of Protected Resources should notify the ESA IC Division of any conservation recommendations they implement in their final action.

10 REINITIATION NOTICE

This concludes formal and conference consultation on the U.S. Navy’s proposal to undertake military readiness activities in the Hawai'i Range Complex from January 2012 through January 2014 and NMFS Permits and Conservation Division’s proposal to issue a Letter of Authorization pursuant to the governing MMPA regulations that would authorize the “take” of marine mammals in association with those 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.

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