UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, Maryland 20910

JUN 2 6 [illegible]

Memorandum For: P. Michael Payne
Chief, Conservation and Education Division
Office of Protected Resources

From: Angela Somma
Chief, Endangered Species Division
Office of Protected Resources

Subject: Programmatic biological opinion on military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex from June 2010 to June 2015 and the Permits Division's proposal to issue regulations to authorize the U.S. Navy to "take" marine mammals incidental to those training activities

Enclosed is the National Marine Fisheries Service's (NMFS) Programmatic Biological Opinion on the effects of the U.S. Navy's proposal to conduct military readiness activities on the Mariana Islands Range Complex from June 2010 to June 2015 and the Permits Division's proposal to issue regulations that would establish a framework whereby the U.S. Navy may "take" marine mammals incidental to those military readiness activities. We have prepared this biological opinion pursuant to section 7(a)(2) of the Endangered Species Act, as amended (16 U.S.C. 1536(a)(2)).

This Opinion concludes that military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex, are likely to adversely affect endangered or threatened species that are likely to occur on those ranges complexes, but those activities are not likely to jeopardize the continued existence of those species. This Opinion also concludes that readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is not likely to adversely affect critical habitat that has been designated for these species.

This Opinion concludes that the Permits Division's proposal to issue regulations to authorize the U.S. Navy to "take" marine mammals incidental to the Navy's training activities is not likely to jeopardize the continued existence of endangered or threatened species.

This biological opinion does not exempt any "take" of endangered or threatened species that might result from the military readiness activities the U.S. Navy plans to conduct; instead, any biological opinion we issue after completing section 7 consultation on any Letters of Authorization that NMFS' Permits, Conservation, and Education Division decides to issue to the U.S. Navy would include an incidental take statement.

The U.S. Navy and NMFS would normally be required to reinitiate formal consultation on the proposed military readiness activities on the Mariana Islands Range Complex, where either agency retains discretionary involvement or control over the action 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, Action Agencies are normally required to reinitiate section 7 consultation immediately. However, because this Biological Opinion did not exempt any "take" of endangered or threatened species, any "take" of endangered or threatened species that might result from the proposed training activities will be considered in subsequent biological opinions that accompany any Letters of Authorization the National Marine Fisheries Service issues on the proposed training activities.

If you have questions regarding the opinion, contact me or Craig Johnson at (301) 713-1401.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, Maryland 20910

JUN 28 2010

Memorandum For: The Record

From: for James H. Lecky
Director, Office of Protected Resources

Subject: Programmatic biological opinion on military readiness activities the U.S. Navy proposes to conduct on Mariana Islands Range Complex from June 2010 to June 2015 and the Permits Division's proposal to issue regulations to authorize the U.S. Navy to "take" marine mammals incidental to those training activities

Enclosed is the National Marine Fisheries Service's (NMFS) Programmatic Biological Opinion on the effects of the U.S. Navy's proposal to conduct military readiness activities on the Mariana Islands Range Complex from June 2010 to June 2015 and the Permits Division's proposal to issue regulations that would establish a framework whereby the U.S. Navy may "take" marine mammals incidental to those military readiness activities. We have prepared this biological opinion pursuant to section 7(a)(2) of the Endangered Species Act, as amended (16 U.S.C. 1536(a)(2)).

This biological opinion does not exempt any "take" of endangered or threatened species that might result from the military readiness activities the U.S. Navy plans to conduct; instead, any biological opinion we issue after completing section 7 consultation on any Letters of Authorization that NMFS' Permits, Conservation, and Education Division decides to issue to the U.S. Navy would include an incidental take statement.

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

Agency: United States Navy, Pacific Fleet; National Marine Fisheries Service's Office of Protected Resources – Permits, Conservation, and Education Division

Activities Considered: Military readiness activities on the Mariana Islands Range Complex from June 2010 to June 2015

Promulgation of regulations to authorize the U.S. Navy to "take" marine mammals incidental to training on the Mariana Islands Range Complex from June 2010 to June 2015

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

Approved by: [signature] for J. H. Lecky

Date: June 28, 2010

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 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 (1) the United States Navy – Pacific Fleet (hereafter, the U.S. Navy), as the executive agent responsible for the Mariana Islands Range Complex, which proposes to undertake training and research, development, test, and evaluation activities, and make range enhancements on the Mariana Islands Range Complex and (2) NMFS' Office of Protected Resources – Permits, Conservation, and Education Division, which proposes to promulgate regulations that would establish a framework whereby the U.S. Navy may "take" marine mammals incidental to those military readiness activities. The consulting agency for these proposals is NMFS' Office of Protected Resources - Endangered Species Division. This document represents NMFS' programmatic biological opinion (Opinion) on the effects of these proposals on endangered and threatened species and critical habitat that has been designated for those species.

This Opinion has been prepared in accordance with section 7 of the ESA and is based on information provided in the U.S. Navy's Draft Environmental Impact Statement/Overseas Environmental Impact Statement, Mariana Islands Range Complex (U.S. Navy 2009), the U.S. Navy's biological assessment for the Mariana Islands Range Complex (2009), applications for the proposed Marine Mammal Protection Act permits and permit amendments, published and unpublished scientific information on the biology and ecology of threatened and endangered marine mammals and endangered and threatened sea turtles that occur off the coasts of Mariana Islands and published information that are discussed in greater detail in the *Approach to the Assessment* section of this Opinion.

This Biological Opinion is also based on information contained in consultation records developed for a series of consultations on SURTASS LFA, including the January 2001 *Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar* (Navy 2001), the October 1999 *Biological Assessment for the Employment of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar* (Navy 1999); a February 1999 report on Marine Vertebrates and Low Frequency Sound: Technical Report for LFA EIS prepared by the Marine Mammal and Seabird Ecology Group of the University of California, Santa Cruz, Institute of Marine Sciences (Croll *et al*. 1999); NMFS' May 30, 2002, biological opinion on the U.S. Navy's proposed use of SURTASS LFA sonar; NMFS' regulations to authorize the Navy to take marine mammals incidental to its employment of SURTASS LFA sonar; a series of biological opinions on the U.S. Navy's annual missions with SURTASS LFA sonar; and the U.S. Navy's annual reports from the operations of SURTASS LFA sonar from 2002 through 2009 (U.S. Navy 2003, 2004, 2005, 2006, 2007, 2008, 2009). This Opinion has been prepared in accordance with section 7 of the ESA and associated implementing regulations.

Consultation History

In August 2008, the U.S. Navy submitted an application for a letter of authorization to "take" marine mammals incidental to military readiness activities on the Mariana Islands Range Complex to NMFS' Permits, Education, and Conservation Division. That original request was intended to address readiness activities the U.S. Navy planned to conduct on the range complex from January 2010 through December 2014.

On 29 December 2008, the U.S. Navy published its Draft Environmental Impact Statement and Overseas Environmental Impact Statement for the Mariana Islands Range Complex. Between February and November 2009, the U.S. Navy submitted four updates or amendments to its 2008 application for a letter of authorization to "take" marine mammals incidental to military readiness activities on the Mariana Islands Range Complex to NMFS' Permits, Education, and Conservation Division.

On 20 October 2009, the National Marine Fisheries Service's Permits, Conservation and Education Division published proposed regulations to govern the unintentional taking of marine mammals incidental to activities conducted in theMariana Islands Range Complex for the period of June 2010 through June 2015. The Permits Division provided the National Marine Fisheries Services' Endangered Species Division with a copy of its draft final regulations for these activities on 10 February 2010.

On 5 April 2010, the National Marine Fisheries Service's Endangered Species Division provided the U.S.

Navy and the Permits Division with copies of its draft biological opinion on the Mariana Islands Range Complex extension and associated Marine Mammal Protection Act authorizations. On 20 April 2010, the Endangered Species Division received the U.S. Navy's comments on its draft biological opinion.

BIOLOGICAL OPINION

Description of the Proposed Action

This biological opinion addresses two separate, but related activities: (1) a proposal by the U.S. Navy (as the executive agent for the Mariana Islands Range Complex) to continue training and research, development, test, and evaluation activities on and make range improvements to the Mariana Islands Range Complex over a five-year period beginning in June 2010 and ending in June 2015; (3) NMFS' Permits, Conservation, and Education Division's (Permits Division) proposal to promulgate regulations governing the "take" of marine mammals (50 CFR Part 216) to allow these branches of the U.S. military to "take" marine mammals incidental to readiness activities on the Mariana Islands Range Complex. The U.S. Navy is the lead agency for this consultation and, in most cases, will be referred to as the action agency in this Opinion.

The purpose of the proposed readiness activities is to meet the requirements of the U.S. Navy's Fleet Response Training Plan and allow U.S. military personnel to remain proficient in anti-submarine warfare and mine warfare skills. The purpose of the Permits Division's regulations is to establish a framework whereby, pursuant to the MMPA, the U.S. Navy may obtain authorizations to "take" marine mammals incidental to military readiness activities on the Mariana Islands Range Complex.

1.1 Mariana Islands Range Complex

As part of the U.S. Navy's preferred alternative (Alternative 1 in their EIS.OEIS; U.S. Navy 2009), the U.S. Navy proposes to continue the and research, development, test, and evaluation activities it currently conducts on the Mariana Islands Range Complex while increasing the frequency and intensity of particular training activities (see Table 1 for a list of the the U.S. Navy proposes to conduct in the range complex); the U.S. Navy also proposes to make improvements to the range complex. The Permits Division proposes to promulgate regulations governing the "take" of marine mammals (50 CFR Part 216) to allow NMFS to issue annual letters of authorization that would allow the U.S. Navy to "take" marine mammals for a five-year period beginning in June 2010 and ending in June 2015 incidental to these training activities.

The following narratives summarize the information the U.S. Navy provided on the various readiness activities it plans to conduct in the Mariana Islands Range Complex each year over the five-year duration of the proposed regulations. Each narrative describes each of the various activities the U.S. Navy plans to conduct in the range complex as part of its preferred alternative (Alternative 1 of the U.S. Navy's Environmental Impact Statement; U.S. Navy 2009), although we provide more emphasis on specific activities that are directly relevant to our assessment of the potential direct or indirect effects of those activities on endangered or threatened species or critical habitat that has been designated for those species. Readers interested in detailed descriptions of the various training activities, particularly ordnance and other equipment employed during the training, should refer to the U.S. Navy's Mariana Islands Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement (U.S. Navy 2009), particularly

Appendix D of that document, and applications for the proposed MMPA permits.

1.1.1 Air Warfare

Air warfare encompasses exercises and events that train ship and aircraft crews to employ the Navy's various weapons systems against aircraft or other targets that are designed to simulate aerial threats to U.S. Navy aerial, surface, or land-based platforms. These training activities include air combat maneuvers, air-to-air missile and gunnery exercises, and surface-to-air missile exercises.

AIR COMBAT MANEUVERS. Air Combat Maneuvers include basic flight maneuvers in which aircraft engage in offensive and defensive maneuvering against each other. These maneuvers typically involve two aircraft; however, based upon the training requirement, air combat maneuvers may involve over a dozen aircraft. For the purposes of this document, training activities are defined by the term 'sortie' which a single operation by two or more aircraft, that use a range or operating area and engages in complete flights (i.e., takeoff and final landing).

Air Combat Maneuvers activities on the Mariana Islands Range Complex primarily consist of unit-level training that typically involves two aircraft, operating at altitudes from 5,000 to 30,000 ft. Participants typically begin their maneuvers at distances of 2 to 3 nm from one another and, throughout an "engagement," normally remain in visual range of one another (6 to 8 nm). Aircraft airspeeds will range from very low (less than 100 kts) to high subsonic (less than 600 kts).

These maneuvers typically last for about one hour and no ordnance is released during sorties. The U.S. Navy plans to conduct about 720 of these sorties each year in the Mariana Islands Range Complex (an increase from the 360 sorties that are conducted each year under current training schedules). These events would occur primarily off Guam in W-517, with maritime areas off the Mariana Islands greater than 12nm from land and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1 and 2).

AIR INTERCEPT CONTROL EXERCISES. In these training exercises, air intercept controllers that are embarked in ships, aircraft, or on the ground, use air search radars to track "friendly" strike fighter interceptor and "threat" aircraft which typically travel at altitudes substantially higher than 15,000 feet. When a "threat" aircraft is detected by a controller's air search radar, "friendly" strike fighters intercept and engage the "threat" aircraft; the aircraft involved in these exercises may travel at peeds greater than 450 kts. No high explosive ordnance is used during these exercises, but Combat Arms and Training Maintenance may be used when strike fighters participate (which complete air-to-air missile exercises or air-to-air gunnery exercises). These events typically consists of several intercepts, with 2 – 4 aircraft per sortie, conducted over one to two hours.

The U.S. Navy proposes to conduct about 40 events and 80 sorties on W-517; in airspace beyond 12 nm of Guam or the Commonwealth of the Mariana Islands, or in Air Traffic Control Assigned Airspaces.

AIR-TO-AIR MISSILE OR GUNNERY EXERCISES. In these training events, missiles are fired from aircraft against unmanned aerial target drones such as BQM-34s, BQM-74s, or Tactical Air Launched Decoys that are 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.

These training events typically involve flights of 2 to 4 aircraft operating between 15,000 and 25,000 feet at speeds of about 450 knots. Sorties last about one hour and are conducted in a warning area at sea outside of 12 nm. Each year, the U.S. Navy plans to conduct about 6 sorties involving 6 AIM-7 Sparrow missiles and 1,500 rounds of 20mm or 25 mm ordnance (an increase from the 4 sorties conducted under current training schedules) and 6 sorties involving 6 AIM-9 Sidewinder or AIM-120 missiles and 1,500 rounds of 20mm or 25 mm ordnance (an increase from the 4 sorties conducted under current training schedules). These training events would occur primarily off Guam in W-517, with maritime areas off the Mariana Islands greater than 12nm from land and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1 and 2 for maps depicting these areas).

SURFACE-TO-AIR MISSILE EXERCISES. In these training exercises , surface ships engage in-coming missiles and aircraft with defensive missiles. Each year, the U.S. Navy plans to conduct about 2 of these missile exercises involving two AIM-7 Sparrow, RIM-116, or RIM-67 SM-II ER missiles. These training events would occur primarily off Guam in W-517, with maritime areas off the Mariana Islands greater than 12nm from land and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1 and 2 for maps depicting these areas).

1.1.2 Amphibious Warfare

Amphibious warfare training exercises consist of amphibious assault U.S. Marine air ground task force operations, amphibious assault operations, and firing exercises (see Table 1).

AMPHIBIOUS RAID. In amphibious raids, marine forces make incursions into or temporarily occupy areas that are designated as "hostile territory" for particular purposes over a specific time interval, then withdraw from the area. A Marine amphibious raid force typically consists of aviation, infantry, engineering, and fire support forces. A typical amphibious raid consists of a reinforced company (100-150 personnel) landed by small boat or mechanized assault craft on a beachhead, or inserted by assault support aircraft into a landing zone; after their mission has been accomplished, the company would be extracted and returned to ships in the Expeditionary Strike Group.

These training events typically involve 1 amphibious assault ship (general purpose) or amphibious assault ship (multipurpose); 1 amphibious transport dock; and 1 dock landing ship, and a tailored Marine air ground task force. The U.S. Navy proposes to conduct 2 of these training events per year in the Mariana Islands Range Complex, primarily at Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR), and Polaris Point Field; Orote Point Airfield; Field; Sumay Cove and mvr Marina Ramp; Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor, North Field

FIRING EXERCISE (Land). These training operations fire live and inert ordnance to land-based targets or sites. They are often supported by target shapes such as tanks, truck, trains, or aircraft to make the exercise more realistic for the spotters and ships involved in exercises. The U.S. Navy proposes to conduct 8 of these training events per year in the Mariana Islands Range Complex (on Farallon de Medinilla), each training event involves 100 rounds of high-explosive ordnance.

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
AIR WARFARE				
Air Combat Maneuvers	FA-18; AV-8B; F-15; F16; F-35	Captive Air Training Missile (Combat Arms and Training Maintenance) or Telemetry Pod	720 sorties (2-4 aircraft per sortie)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12nm from land; Air Traffic Control Assigned Airspaces
Air Intercept Control Exercise	FA-18, F-15	Search and fire control radars	80 sorties (2-4 aircraft per sortie) in 40 training events	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12nm from land; Air Traffic Control Assigned Airspaces
Missile Exercise/Gunnery Exercise Air to Air	FA-18; EA-18; AV-8B; F-3, Tactical Air-Launched Decoy Target	AIM-7 Sparrow (Non Explosive).20mm or 25 mm cannon.	6 sorties (2-4 aircraft) (6 missiles; 1,500 rounds)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12nm from land; Air Traffic Control Assigned Airspaces
		AIM-9 Sidewinder (HE)/AIM-120 (HE or Inert). 20mm or 25 mm cannon	6 sorties (2-4 aircraft) (6 missiles; 1,500 rounds)	
MISSILEX (Ship to Air)	Multi-purpose Aircraft Carrier (Nuclear), Amphibious Assault Ship (multipurpose), Guided Missile Cruiser, Guided Missile Destroyer; Aerial Target Drone (BQM-74E)	RIM-7 Sea Sparrow RIM-116 RAM RIM-67 SM-II ER	2 (2 missiles)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12nm from land; Air Traffic Control Assigned Airspaces
AMPHIBIOUS WARFARE				
Amphibious Assault Marine Air Ground Task Force	1 Amphibious Assault Ship (general purpose) or Amphibious Assault Ship (multipurpose), 1 Amphibious Transport Dock, 1 Dock Landing Ship, 1 Guided Missile Cruiser or Guided Missile Destroyer, and 2 Guided Missile Frigate, Includes temporary Fuel and Armament Replenishment Point	4-14 AAV/EFV or LAV/LAR; 3-5 LCAC; 1-2 LCU; 4 H-53; 12 H-46 or 10 MV-22; 2 UH-1; 4 AH-1; 4 AV-8, includes FARP construction	4 events (assault, offload, `backload)	Primary Site(s): Tinian Military Leased Area; Unai Chulu, Dankulo and Babui (beach) and Tinian Harbor; North Field. Secondary Site(s): Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Sumay Cove and MWR Ramp; Tipalao Cove and Dadi Beach
Amphibious Raid Special Purpose Marine Air Ground Task Force	1 Amphibious Assault Ship (general purpose) or Amphibious Assault Ship (multipurpose); 1 Amphibious Transport Dock; and 1 Dock Landing Ship. Tailored Marine Air Ground Task Force	4-14 AAV/EFV or LAV/LAR; 0-5 LCAC; 0-2 LCU; 4 H-53; 12 H-46 or 10 MV-22; 2 UH-1; 4 AH-1; 4 AV-8	2 Events (raid, offload, backload)	Primary Site(s): Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Field; Sumay Cove and MWR Marina Ramp; Tipalao Cove and Dadi Beach Secondary Site(s): Tinian Military Leased Area; Unai Chulu, Dankulo, and Babui (beach) and Tinian Harbor; North Field
Firing Exercise (Land)	Guided Missile Cruiser, Guided Missile Destroyer	5" Guns and High Explosive shells	8 Events (800 rounds)	Farallon de Medinilla (R-7201)
ANTI-SUBMARINE WARFARE				
Tracking Exercise (Helicopters)	SH-60B, SH-60F SUB/ MK-30/ EMATT	AQS-22, SSQ-62 DICASS sonobuoy	18 Events; 2 hours per helicopter	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >3 nm from land
Tracking Exercise (Maritime Patrol Aircraft)	Fixed Wing Maritime Patrol Aircraft Submarine/MK-30/ EMATT	SSQ-62 DICASS EER/IEER/AEER	8 Events; 4 hours per Maritime Patrol Aircraft	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >3 nm from land
Tracking Exercise (Surface Ship)	Guided Missile Cruiser/ Guided Missile Destroyer / Guided Missile Frigate SUB/ MK-30/ EMATT	SQS-53 SQS-56 sonar	30 Events 4 hours per ship	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >3 nm from land
Tracking Exercise (Submarine)	Submarine (nuclear propulsion); Submarine (Guided Missile) MK-30	BQQ sonar	10 Events 4 hours per submarine	Primary Site(s): Guam Maritime, >3 nm from land Secondary Site(s):: W-517
Torpedo Exercise (Maritime Patrol Aircraft – Helicopter)	Maritime Patrol Aircraft / SH-60B/F, SUB/ MK-30/ EMATT TRB / MH-60S/ RHIB	AQS-22 / DICASS sonobuoy Recoverable Exercise Torpedo	4 events 2 hours per event	Primary Site(s): Guam Maritime, >3 nm from land Secondary Site(s):: W-517
Torpedo Exercise (Surface Ship)	Guided Missile Cruiser/ Guided Missile Destroyer / Guided Missile Frigate SUB/ MK-30/ EMATT TRB / MH-60S/ RHIB	SQS-53 SQS-56 sonar Recoverable Exercise Torpedo	3 Events 4 hours per event	Primary Site(s): Guam Maritime, >3 nm from land Secondary Site(s):: W-517

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
Torpedo Exercise (Submarine)	Submarine (nuclear propulsion); Submarine (Guided Missile) MK-30 TRB / MH-60S	BQQ sonar MK-48 Exercise Torpedo	10 Events; 4 hours per event	Primary Site(s): Guam Maritime, >3 nm from land Secondary Site(s):: W-517
ELECTRONIC COMBAT				
Chaff Exercises	SH-60; MH-60; HH-60; MH-53	RR-144A/AL	14 sorties (420 rounds)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12nm from land; Air Traffic Control Assigned Airspaces
	FA-18; EA-18; AV-8B; Maritime Patrol Aircraft; EA-6	RR-144A/AL	32 sorties (320 rounds)	
	F-15; F-16; F-35; C-130	RR-188	500 sorties (5,000 rounds)	
	Guided Missile Cruiser, Guided Missile Destroyer, Guided Missile Frigate, Amphibious Assault Ship (general purpose), Amphibious Assault Ship (multipurpose), Amphibious Transport Dock, Dock Landing Ship	MK 214 (seduction); MK 216 (distraction)	16 (90 canisters)	
Flare Exercise	SH-60; MH-60; HH-60; MH-53	MK 46 MOD 1C; MJU-8A/B; MJU-27A/B; MJU-32B; MJU-53B; SM-875/ALE	14 sorties (420 rounds)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12nm from land; Air Traffic Control Assigned Airspaces
	FA-18; EA-18; AV-8B; Maritime Patrol Aircraft; EA-6		32 sorties (320 rounds)	
	F-15; F-16; F-35; C-130	MJU-7; MJU-10; MJU-206	500 sorties (5,000 rounds)	
EXPEDITIONARY WARFARE				
Military Operations In Urban Terrain (mout)	Marine Corps Infantry Company: AH-1, UH-1; H-46 or MV- 22; H-53; AAV, LAV, HMMWV, Truck	5.56 mm blanks/Simunitions	5 events 7-21 days per event	Primary Site(s): Guam; AAFB South; Finegayan Communication Annex; Barrigada Housing; Northwest Field Secondary Site(s):: Tinian; Rota; Saipan
	Air Force RED HORSE SQUADRON: Truck, HMMWV; MH-53; H-60		4 events 3-5 days per event	
	Navy Naval Expeditionary Combat Command Company, HMWWV, Truck		4 events 3-5 days per event	
	Army Reserve/GUARNG Company; HMWWV, Truck		4 events 3-5 days per event	
FORCE PROTECTION AND ANTI-TERRORISM				
Anti-terrorism	Navy Base Security Air Force Security Squadron Marine Corps FAST Platoon Trucks; HMMWV; MH-60	5.56 mm blanks/Simulations	80 events 1 day per event	Primary Site(s): Tarague Beach Shoot House and Combat Arms and Training Maintenance Range; Polaris Pt.; Northwest Field. Secondary Site(s):: Kilo Wharf; Finegayan Comm. Annex; Navy Munitions Site; AAFB Munitions Site, Rota Municipality
Embassy Reinforcement Exercise	SEAL or Army Platoon, Marine Corps Company or Platoon, Trucks, HMMWV, C-130, H-60, H-53	5.56 mm blanks/Simulations	50 events 2 -3 days per event	Primary Site(s): Orote Pt.Airfield, apra Harbor, Northern and Southern Land Navigation Area; Secondary Site(s): Orote Pt. Triple Spot, Orote Pt. CQC, Kilo Wharf, Rota Municipality
Force Protection	Air Force Squadron or Platoon; Naval Expeditionary Combat Command SEABEE Company or Platoon; USAR Engineer Company or Platoon Tents; Trucks; HMMWV; Generators	5.56 mm blanks/Simulations	75 Events 1-2 days per event	Primary Site(s): Guam, Northwest Field; Northern Land Navigation Area; Barrigada Annex Secondary Site(s):: Orote Pt. Airfield; Polaris Pt. Field; Tinian North Field, Rota Municipality

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
MAJOR TRAINING EXERCISES				
Joint Expeditionary Exercise (Carrier and Expeditionary Strike Groups)	**Vessels:** Aircraft Carrier - nuclear, CG, Guided Missile Frigate, Guided Missile Destroyer, Amphibious Assault Ship (general or multipurpose), Dock Landing Ship, and Amphibious Transport Dock, TAOE, submarines, T-AGO **Fixed-Wing Aircraft:** FA-18; EA-6B, F-35, E-2, P3-P8, AV-8B; C-130, Air Force bomber, F-15/16/22, A-10, E-3, KC-10/135/130 **Rotary Aircraft**: SH-60; MH-60; HH-60; MH-53; CH-53; ch-46, ah-1, UH-1, MV-22 **Unmanned Aerial Systems**: Ship-based; Ground-based **Landing Craft**: Landing Craft- Air Cushion, Landing Craft - Utility, Combat Rubber Raiding Craft **Ground Combat Elements**: Amphibious Assault Vehicle, Light armored vehicle, HMMWV, Ground Personnel **Logistics Combat Elements**: Trucks, Dozer, Forklifts, Reverse Osmosis Purification Unit, Rigid Hull Inflatable Boat, Ground Personnel	Numerous (see text)	1 Event per year 10 days per event	Primary Site(s): Tinian; Secondary Site(s): Guam, Rota, Saipan, Farallon de Medinilla, nearshore to over-the-horizon
Joint Multi-strike Group Exercise (3 Carrier Strike Groups + Air Force)	**Vessels:** Aircraft Carrier - nuclear, CG, Guided Missile Frigate, Guided Missile Destroyer, TAOE, submarines, T-AGO **Fixed-Wing Aircraft:** FA-18; EA-6B, E-2, P3-P8, Air Force bomber, F-15/16/22, E-3, KC-10/135/130 **Rotary Aircraft**: SH-60; MH-60; HH-60; MH-53; **Unmanned Aerial Systems**: Ship-based; Ground-based	Numerous (see text)	1 Event per year 10 days per event	Primary Site(s): Mariana Islands > 12 km offshore ; Secondary Site(s): Farallon de Medinilla
Marine Air Ground Task Force Exercise (STOM/ NEO)	**Vessels:** Guided Missile Frigate, Guided Missile Destroyer, Amphibious Assault Ship (general or multipurpose), Dock Landing Ship, and Amphibious Transport Dock, TAOE, submarines **Fixed-Wing Aircraft:** FA-18; F-35, EA-6B, E-2, P3-P8, AV-8B; C-130, Air Force bomber, F-15/16/22, A-10, E-3, KC-10/135/130 **Rotary Aircraft**: SH-60; MH-60; CH-53; CH-46, AH-1, UH-1, MV-22 **Unmanned Aerial Systems**: Ship-based; Ground-based **Landing Craft**: Landing Craft- Air Cushion, Landing Craft-Utility, Combat Rubber Raiding Craft **Ground Combat Elements**: Amphibious Assault Vehicle, Light armored vehicle, HMMWV, Ground Personnel **Logistics Combat Elements**: Trucks, Dozer, Forklifts, Reverse Osmosis Purification Unit, Rigid Hull Inflatable Boat, Ground Personnel	Numerous (see text)	4 Events per year 10 days per event	Primary Site(s): Tinian; Secondary Site(s): Guam, Saipan, Farallon de Medinilla, nearshore to –over-the-horizon
Special Purpose Marine Air Ground Task Force Exercise (HADR/ NEO)	**Vessels:** Amphibious Assault Ship (general or multipurpose), Dock Landing Ship, and Amphibious Transport Dock,	Numerous (see text)	2 Events per year 10 days per event	Primary Site(s): Guam; Secondary Site(s): Tinian, Rota, Saipan

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
	Fixed-Wing Aircraft: C-130 **Rotary Aircraft**: CH-53; CH-46, AH-1, UH-1, MV-22 **Unmanned Aerial Systems**: Ground-based **Landing Craft**: Landing Craft- Air Cushion, Landing Craft - Utility, Combat Rubber Raiding Craft **Ground Combat Elements**: Amphibious Assault Vehicle, Light armored vehicle, HMMWV, Ground Personnel **Logistics Combat Elements**: Trucks, Dozer, Forklifts, Reverse Osmosis Purification Unit, Rigid Hull Inflatable Boat, Ground Personnel			
Urban Warfare Exercise	**Vessels:** Aircraft Carrier - nuclear, CG, Guided Missile Frigate, Guided Missile Destroyer, Amphibious Assault Ship (general or multipurpose), Dock Landing Ship, and Amphibious Transport Dock, **Fixed-Wing Aircraft:** C-130 **Rotary Aircraft**: CH-53; ch-46, ah-1, UH-1, MV-22 **Unmanned Aerial Systems**: Ship-based; Ground-based **Ground Combat Elements**: Amphibious Assault Vehicle, Light armored vehicle, HMMWV, Ground Personnel **Logistics Combat Elements**: Trucks, Dozer, Forklifts, Reverse Osmosis Purification Unit, Rigid Hull Inflatable Boat, Ground Personnel	Numerous (see text)	5 Events per year 7-21 days per event	Primary Site(s): Guam; Secondary Site(s): Tinian, Rota, Saipan
MINE WARFARE				
Floating mine neutralization	EOD Personnel, RHIB, CRRC, Small craft	Floating mine shape, 5 – 10 lb new	20 events (2 – 8 hours each)	Primary Site(s): Agat Bay, Secondary Site(s): – Piti
Mine Laying Exercise	Fighter, Bomber, Maritime Patrol Aircraft (B-1, B-2, B-52, FA-18, P-3, P-8A)	Mk-62, Mk-56 (inert)	3 events	Primary Site(s) W-517; Secondary Site(s): MI Maritime, >12 nm from land
Underwater demolition	EOD Personnel, RHIB, CRRC, Small Craft	Bottom/mid-moored mine shape 5 – 20 lb new	30 Events (2 – 8 hours each)	Primary Site(s): Agat Bay, Secondary Site(s):: Apra Harbor (10lb new maximum
SPECIAL WARFARE				
Breaching	SEAL, EOD, Army, or Marine Corps platoon or squad	Breach house (1.5 lbs new; C4 maximum per door)	20 Events (2 – 8 hours each, 30 lbs new or C4)	Navy munitions site Breacher House
Direct Action	SEAL Tactical Air Control Party; RHIB; Small Craft.	M-16, M-4, M-249 SAW, M-240G, .50 cal, M-203 (5.56 /7.62 mm/ .50 cal round/ 40mm HE)	3; events 1 day (3,000 rounds)	Farallon de Medinilla (R-7201)
	SEAL, NECC, Marine Corps, Army, or Air Force platoon or squad	5.56 mm blanks/Simunitions 9mm (Orote Pt. Combat Qualification Center) 1.5 lb NEW C4 (Navy Munitions Site Breaching House)	40 Events 2-8 hours; (15,000 9mm; 15 lb NEW C4)	Primary Site(s): Orote Pt. Combat Qualification Center and Navy Munitions Site Breacher House Secondary Site(s):: Tarague Beach CQC and Navy Munitions Site Breacher House.
Hydrographic Surveys	SEAL, EOD, or Marine Corps Platoon/Squad; Small Craft; RHIB; CRRC; H-60	scuba	6	Farallon de Medinilla; Tinian; Tipalao Cove Secondary Site(s):: Haputo Beach; Gab Gab Beach; Dadi Beach
Insertion/Extraction	SEAL, EOD, Army, Air Force, or Marine Corps Platoon/Squad; Small Craft; RHIB; CRRC; H-60 H-46 or MV-22	Square Rig or Static Line; Fastrope; Rappel; scuba	150 Events 2 to 8 hours per event	Primary Site(s): Orote Pt. Airfield; Northwest Field; Orote Pt. Triple Spot; Apra Harbor; Gab Gab Beach Secondary Site(s):: Orote Pt. CQC; Finegayan DZ; Haputo Beach; Munitions Site Breacher House;

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
				Polaris Pt. Field; Orote Point. KD Range
Military Operations In Theater (mout) Training	SEAL or EOD platoon or squad; HMWWV, Truck	5.56 mm blanks/Simunitions	8 Events (3-5 days per event)	Primary Site(s): Guam; AAFB South; Finegayan Communication Annex; Barrigada Housing; Navy Munitions Site Breaching House Secondary Site(s):: Tinian; Rota; Saipan
Parachute Insertion	SEAL, EOD, Army, or Air Force platoon or squad, C-130, CH-46, H-60	Square Rig or Static Line	12 Events (2 to 8 hours per event)	Primary Site(s): Orote Point Airfield; Northwest Airfield; Orote Point Triple Spot Secondary Site(s):: Finegayan DZ; Apra Harbor; Navy Munitions Site Breacher House
SPECIAL/EXPEDITIONARY WARFARE				
Airfield Expeditionary	Air Force RED HORSE Squadron; Naval Expeditionary Combat Command SEABEE Company. Marine Corps Combat Engineer Company USAR Engineer Dozer, Truck, Crane, Forklift, Earth Mover, HMMWV. C-130; H-53. Includes temporary Fuel and Armament Replenishment Point	Expeditionary Airfield Repair and Operation	12 events	Primary Site(s): Northwest Field Secondary Site(s):: Orote Pt. Airfield; Tinian North Airfield
Field Training Exercise	Army or Naval Expeditionary Combat Command SEABEE Company/Platoon	Tents; Trucks; HMMWV; Generators	100 events 2-3 days per event	Primary Site(s): Guam, Northwest Field; Northern Land Navigation Area Secondary Site(s):: Orote Pt. Airfield; Polaris Pt. Field; Tinian North Field.
Humanitarian Assistance/Disaster Relief Operation (HADR)	Amphibious Shipping (1-Amphibious Assault Ship (multipurpose); 1-Amphibious Transport Dock; 1-Dock Landing Ship); Marine Corps Special Purpose Marine Air Ground Task Force	HMMWV; Trucks; Landing Craft (LCAC/ LCU); AAV/ LAV; H-46 or MV-22	2 events	Primary Site(s): Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Northwest Field; Sumay Cove and MWR Marina Ramp Secondary Site(s):: Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor; North Field.Rota Airfield/West Harbor
Intelligence, Surveillance, Reconnaissance	U.S. Navy SEAL, Army, Marine Corps, or Air Force Platoon/Squad	Night Vision; Combat camera; 5.56 mm blanks/Simunition	16 events 8– 24 hours per event	Primary Site(s): Guam; Northwest Field; Barrigada Housing; Finegayan Comm. Annex; Orote Pt. Airfield.Secondary Site(s):: Tinian, Rota, Saipan
Land Demolitions (IED Discovery/Disposal)	NECC, Marine Corps or Air Force eod, platoon or squad; HMWWV	Improvised Explosive Device (IED) Shapes	120 events (2 – 8 hours each)	Primary Site(s): Guam, Orote Point Airfield, Orote Point cqc; Polaris Point Field; Andersen South; Northwest Field sec; Northern or Southern Land Navigation Area; Munitions Site Breacher House; Tinian mla
Land Demolitions (UXO Discovery/Disposal)	NECC, Marine Corps or Air Force eod, platoon or squad; HMWWV, Truck	Unexploded Ordnance (UXO)	200 events	Primary Site(s): Navy Munitions Site, EOD Disposal Site (limit 3,000lbs NEW per event); Secondary Site(s): AAFB EOD Disposal Site (limit100 lbs per event) and Northwest Field (limit20 lbs NEW per event)
Maneuver (Convoy; Land Navigation)	Marine Corps or Army Company or Platoon	Trucks; HMWWV;AAV/LAV	16 events 8–24 hours	Primary Site(s): Northwest Field; AAFB South; Northern and Southern Land Navigation Area; Tinian MLA Secondary Site(s):: Finegayan Annex; Barrigada Annex; Orote Pt. Airfield
Non-Combatant Evacuation Operation	Amphibious Shipping (1-Amphibious Assault Ship (multipurpose); 1-Amphibious Transport Dock; 1-Dock Landing Ship); Marine Corps Special Purpose Marine Air Ground Task Force	HMMWV; Trucks; Landing Craft (LCAC/ LCU); AAV/ LAV; H- 46 or MV-22	2 events	Primary Site(s): Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Northwest Field; Sumay Cove and MWR Marina Ramp Secondary Site(s):: Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor; North Field, Rota Airfield/West Harbor
Seize Airfield	SEAL, Marine Corps, or Army Company or Platoon; Air Force Squadron; C-130; MH-53; H-60; HMWWV; Truck	5.56 mm blanks/Simunitions	12 Events (1-3 day per event)	Primary Site(s): Northwest Field; Secondary Site(s):: Orote Pt. Airfield; Tinian North Field, Rota Airfield
STRIKE WARFARE				
Bombing Exercise (Land)	FA-18; AV-8B; B-1; B-2; B-52; F-15; F- 16; F-22; F-35, A-10	High Explosive Bombs 500 lbs	500 annually	Farallon de Medinilla (R-7201)

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
		High Explosive Bombs: 750 / 1,000 lbs / 2,000 lbs	1,650 annually	
		Inert Bomb Training Rounds □ 2,000 lbs	2,800 annually	
		Total Sorties (1 aircraft per sortie):	1,300 sorties	
Gunnery Exercise (Air to Ground)	FA-18; AV-8B; F-15; F-16; F-22; F-35, A-10; MH-60R/S; SH- 60B; HH-60H; AH-1, AC-130	20- or 25-mm cannon	20,000 rounds	
		30-mm cannon (A-10)	1,500 rounds	
		40-mm or 105-mm cannon (AC-130)	200 rounds	
Missile Exercise (Air to Ground)	FA-18; AV-8B; F-15; F-16; F-22; F-35, A-10; MH-60R/S; SH- 60B; HH-60H; AH-1	TOW; MAVERICK; HELLFIRE	60 annually	
Combat Search and Rescue	SH-60; MH-60; HH-60; MH-53; CH-53; C-17; C-130; V-22	Night Vision	60 sorties	Tinian North Field: Guam Northwest Field Secondary Site(s):: Orote Point Airfield; Rota Airport
SURFACE WARFARE				
Bombing Exercise (Air to Surface – Inert Only)	Fixed Wing Fighter/Bomber/Maritime Patrol Aircraft (MK 58 Smoke target or towed sled or small hull target)	MK 82 I; BDU-45; MK 76 (Inert Rounds)	24 events 1 – 2 hours (72 rounds)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12 nm from land; Air Traffic Control Assigned Airspaces
Bombing Exercise (Air to Surface – Live Rounds)	Fixed Wing Fighter/Bomber/Maritime Patrol Aircraft (MK 58 Smoke target or towed sled)	MK 82/83/84 series and JDAM (Live Rounds)	4 events	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12 nm from land; Air Traffic Control Assigned Airspaces
Gunnery Exercise (Surface-to-Surface – small arms)	Ship, RHIB, small craft. Barrel or Inflatable target	M-16, M-4, M-249 SAW, M-240G, .50 cal, M-203 (5.56 /7.62 mm/ .50 cal. round/ 40mm TP)	32 events (16,000 rounds)	Primary Site(s): MI Maritime, >3 nm from land Secondary Site(s):: W-517
Gunnery Exercise (Surface-to-Surface Ship)	Ships and Maritime Patrol Aircraft, Barrel, Inflatable Targets	.50 cal machine gun	5 events (12,000 rounds)	Primary Site(s): W-517; Secondary Site(s):: MI Maritime, >12 nm from land
		.25 mm machine gun	5 events (8,000 rounds)	
	Guided Missile Cruiser and Guided Missile Destroyer. Barrel or Inflatable target or towed sled	5" gun	8 events (320 rounds)	
	Guided Missile Frigate Barrel or Inflatable target or towed sled	76 mm	4 events (120 rounds)	
Gunnery Exercise (Air to Surface)	SH-60; HH-60; MH-60R/S; UH-1; CH-53; FA-18; AH-1W; F-15; F16; F-22; F-35, AV-8B; A-10 (Barrel or MK-58 smoke target)	7.62 mm machine gun	200 (40,000 rounds)	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >12 nm from land; Air Traffic Control Assigned Airspaces
		.50 cal machine gun	20 (4,000 rounds)	
		20 mm cannon	100 (10,000 rounds)	
		25 mm cannon	40 (4,000 rounds)	
		30 mm cannon	15 (1,500 rounds)	
Missile Exercise (Air to surface)	Fixed Wing Fighter/Bomber/Maritime Patrol Aircraft (MK 58 Smoke target or towed sled or small hull target)	HELLFIRE (Live Rounds)	2 rounds	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >50 nm from land; Air Traffic Control Assigned Airspaces

Table 1. Activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex each year over the next five years (adapted from Table 2-6 and Appendix D of U.S. Navy 2009)

Range Operation	Platform(s)	System or Ordnance	Proposed Action	Location
Missile Exercise (Air to surface CATMEX Inert Only)	Fixed Wing Fighter/Bomber/Maritime Patrol Aircraft (MK 58 Smoke target or towed sled or small hull target)	Laser Designation and Tracking with Captive Air Training Missile	60 events	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >50 nm from land; Air Traffic Control Assigned Airspaces
Sinking Exercise	Ship hulk or barge	HARM [2]; SLAM-ER [4] HARPOON [5]; 5" Rounds (400); HELLFIRE [2]; MAVERICK [8]; GBU-12 [10]; GBU-10 [4]; MK-48 [1]; Underwater Demolitions [2 - 100lb]	2	Primary Site(s): W-517 Secondary Site(s):: MI Maritime, >50 nm from land; Air Traffic Control Assigned Airspaces
Visit, Board, Search, and Seizure or Maritime Interception Operations	RHIB, Small craft, Ship, H-60	not applicable	6 Events (2 – 3 hours each)	Primary Site(s): Apra Harbor; Secondary Site(s):: MI Maritime

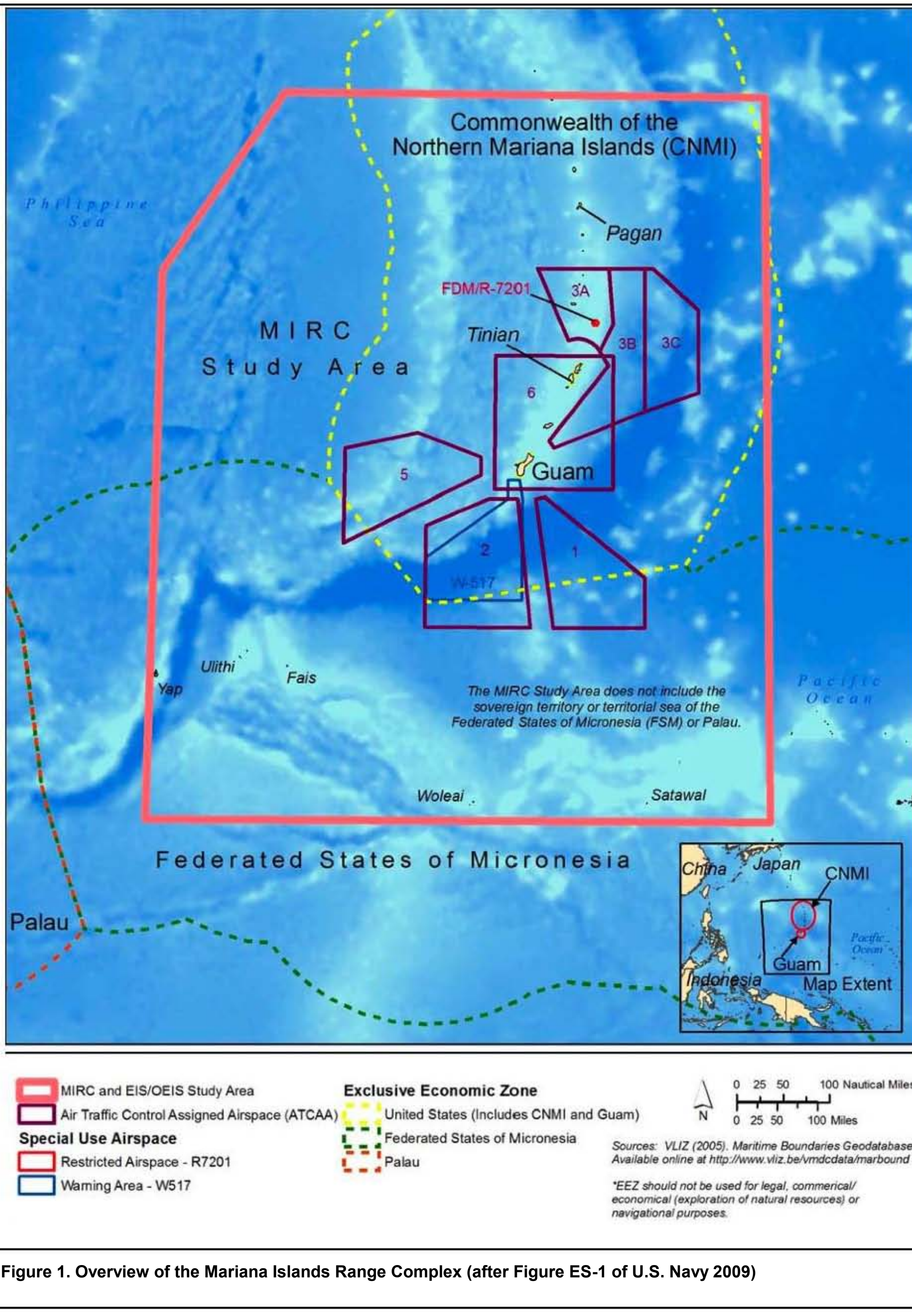

Figure 1. Overview of the Mariana Islands Range Complex (after Figure ES-1 of U.S. Navy 2009)

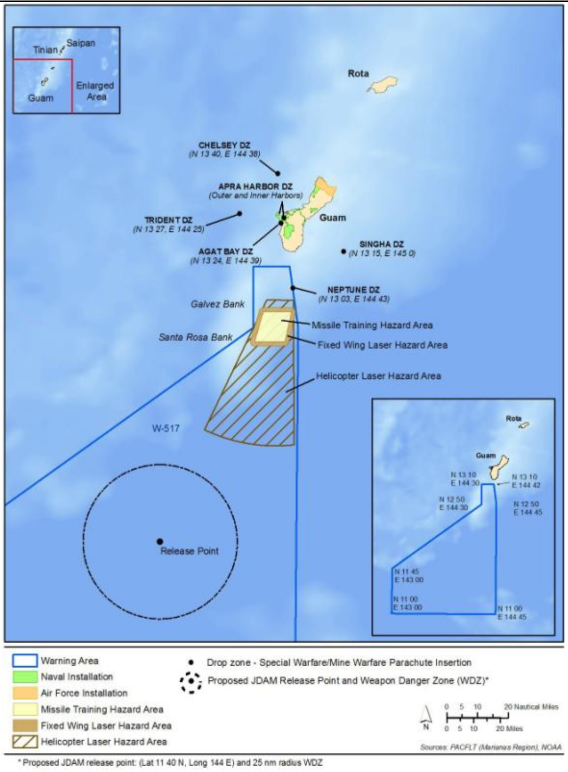

Figure 2. Warning Area W-517 (updated figure provided by U.S. Navy)

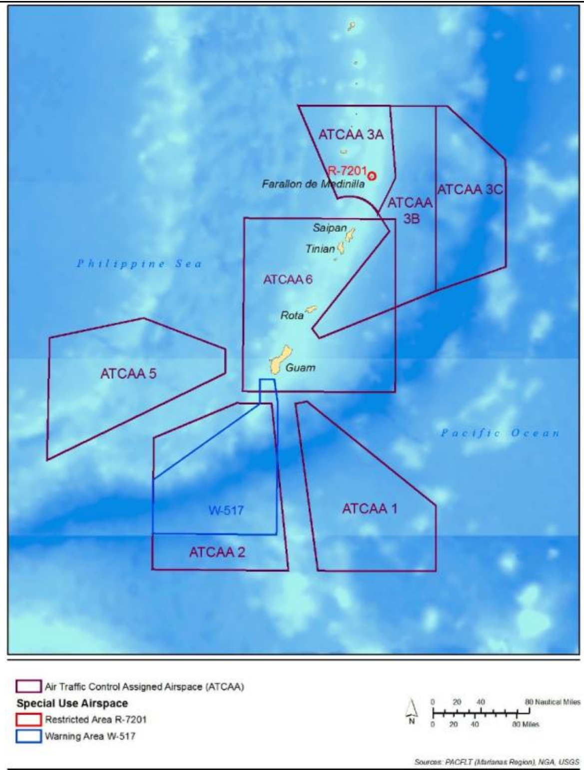

Figure 3. The Air Traffic Control Assigned Airspace or ATCAAS (after Figure ES-11 of U.S. Navy 2009)

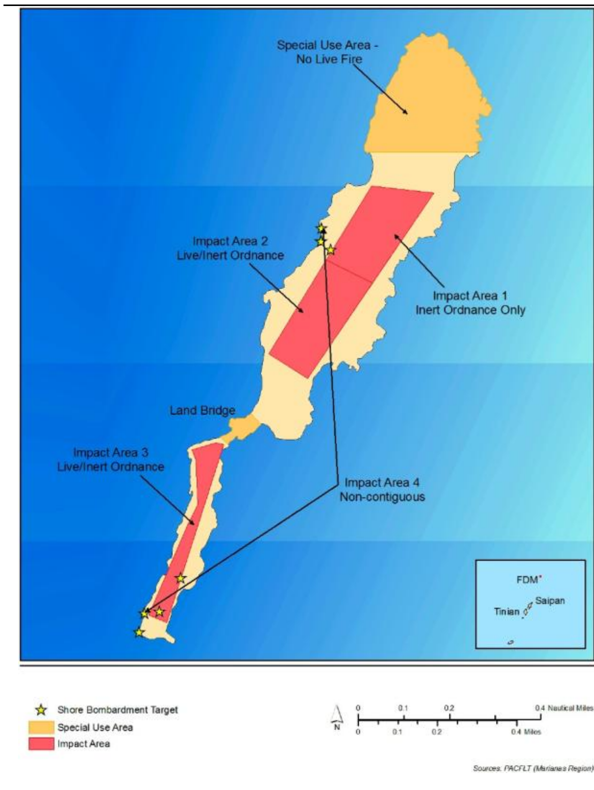

Figure 4. Farallon de Medinilla (after Figure ES-3 of U.S. Navy 2009)

Figure 5. Saipan and Tinian (after Figure ES-9 of U.S. Navy 2009)

1.1.3 Anti-Submarine Warfare

The anti-submarine warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex include Torpedo Exercises (Maritime Patrol Aircraft – Helicopter); Torpedo Exercises (Surface Ship); Torpedo Exercises (Submarine); Tracking Exercise (Helicopters); Tracking Exercise (Maritime Patrol Aircraft); Tracking Exercise (Surface Ship); Tracking Exercise (Submarine). All of these exercises are designed to train U.S. Navy personnel to detect, classify, localize, track, and neutralize submarines (see Table 1).

TORPEDO EXERCISE, MARITIME PATROL AIRCRAFT – HELICOPTER. In these training events, helicopters or maritime patrol aircraft deliver torpedoes against target submarines. These training exercises follow the sequence of an anti-submarine warfare tracking exercise (these are described in greater detail in narratives that follow in this sub-section), but advance to the actual launch of exercise torpedoes (expendable or recoverable) against MK-30 mobile anti-submarine targets or MK-39 expendable mobile anti-submarine warfare training targets (EMATT) targets. The kinds of active and passive sonar systems the U.S. Navy employs during these training exercises are described in greater detail in the next sub-section.

The U.S. Navy plans to conduct 4 of these exercises each year in the Mariana Islands Range Complex, which would represent new exercises for the range complex (these exercises do not currently occur on the range complex). Each exercise would involve 16 dips of the AQS-22 dipping sonar, 20 DICASS sonobuoys, and 4 recoverable exercise torpedoes (see narratives in the following sub-section describe these sonar systems and exercise torpedoes in more detail). These training exercises would primarily occur in maritime areas off Guam more than 3 nm from land with Warning Area W-517 as a secondary site.

TORPEDO EXERCISE, SURFACE SHIP. In these training events, surface ships deliver torpedoes against target submarines. These training exercises follow the sequence of an anti-submarine warfare tracking exercise (see narratives that follow in this sub-section), but advance to the actual launch of exercise torpedoes (expendable or recoverable) against MK-30 mobile anti-submarine targets or MK-39 expendable mobile anti-submarine warfare training targets (EMATT) targets. The kinds of active and passive sonar systems the U.S. Navy employs during these training exercises are described in greater detail in the next sub-section.

The U.S. Navy plans to conduct 3 of these exercises each year in the Mariana Islands Range Complex, which would represent new exercises for the range complex (these exercises do not currently occur on the range complex). Each exercise would involve 8 hours of AN/SQS 53 sonar, 4 hours of AN/SQS 56 sonar, and 3 recoverable exercise torpedoes (see narratives in the following sub-section describe these sonar systems and exercise torpedoes in more detail). These training exercises would primarily occur in maritime areas off Guam more than 3 nm from land with Warning Area W-517 as a secondary site.

TORPEDO EXERCISE, SUBMARINE. In these training events, submarines deliver torpedoes against target submarines, which are typically MK-30 mobile anti-submarine targets or MK-39 expendable mobile anti-submarine warfare training targets (EMATT). The kinds of active and passive sonar systems the U.S. Navy employs during these training exercises are described in greater detail in the next sub-section.

The U.S. Navy plans to conduct 10 of these exercises each year in the Mariana Islands Range Complex, which would double the number of these training events that occur on the range complex. Each year, these exercises would involve 12 hours of AN/BQQ sonar and 40 MK-48 exercise torpedoes (see narratives in the following sub-section describe these sonar systems and exercise torpedoes in more detail). These training exercises would primarily occur in maritime areas off Guam more than 3 nm from land with Warning Area W-517 as a secondary site.

ANTI-SUBMARINE WARFARE TRACKING EXERCISE, HELICOPTER. In these training events, helicopters using sonobuoys and dipping sonar to search for, detect, classify, localize, and track a simulated target submarine. Sonobuoys are typically employed by a helicopter operating at altitudes below 3,000 ft. and are deployed in specific patterns cover many different size areas, depending on submarine threat and water conditions. Both passive and active sonobuoys are employed.

The dipping sonar is employed from an altitude of about 50 ft after the search area has been narrowed based on the an sonobuoy search. Both passive and active sonar are employed. As the location of the submarine is further narrowed, a Magnetic Anomaly Device (MAD) is used by the MH-60R/SH-60B to further confirm and localize the target. Targets for these exercises are either an MK-39 Expendable Mobile ASW Training Target (EMATT), MK-30 targets, or live submarine and may be either non-evading and assigned to a specified track, or fully evasive depending on the state of training of the helicopter. These exercises usually take one to two hours and may involve a single aircraft, or be undertaken in the context of a coordinated larger exercise involving multiple aircraft or ships, including a major range event. No ordnance is expended during the training events the U.S. Navy proposes to conduct on the range complex.

The U.S. Navy plans to conduct 18 of these exercises each year in the Mariana Islands Range Complex, which would double the number of these training events that occur on the range complex. Each exercise would involve 16 dips of the AQS-22 dipping sonar and 72 DICASS sonobuoys (see narratives in the following sub-section describe these sonar systems in more detail). These training exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 3 nm from land as secondary sites.

ANTI-SUBMARINE WARFARE TRACKING EXERCISE, MARITIME PATROL AIRCRAFT. During these training activities, a typical scenario would involve a single maritime patrol aircraft (usually P-3s Orion or P-8 Poseidon aircraft; the U.S. Navy refers to the latters as multi-mission maritime aircraft) dropping sono-buoys, from an altitude below 3,000 ft (sometimes as low as 400 ft), into specific patterns designed to respond to the movement of a target submarine and specific water conditions. These patterns vary in size and coverage area based on anticipated threat and water conditions. Typically, maritime patrol aircraft will use passive sonobuoys first to avoid alerting the target submarine. They then use active sonobuoys as necessary either to locate extremely quiet submarines, or to further localize and track submarines previously detected by passive sonobuoys.

The U.S. Navy proposes to employ a suite of sonobuoys during these training exercises, including DICASS, Extended Echo Ranging, Improved Extended Echo Ranging, and Acoustic Extended Echo Ranging sonobuoy systems (the U.S. Navy expects the AEER sonobuoy system to be employed by fleets in 2011). The Extended Echo Ranging sonobuoy system uses an AN/SSQ-110A sonobuoy to produce a signal source and the passive AN/SSQ-77 receiver sonobuoy “listen” for the return echo of the sonar ping that has been bounced off the surface of a submarine. 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.

These training events usually last for two to four hours and do not involve firing torpedoes. The U.S. Navy plans to conduct 8 of these exercises each year in the Mariana Islands Range Complex, which is an increase from the five training events that currently occur on the range complex. Each exercise would involve 10 DICASS sonobuoy and 1 AEER sonobuoy (see narratives in the following sub-section describe these sonar systems in more detail). These training exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 3 nm from land as secondary sites.

ANTI-SUBMARINE WARFARE TRACKING EXERCISE, SURFACE SHIP: Surface ships occasionally employ mid-frequency active sonar during ship transits through the operating area (usage last for one to one and a half hours).

These training events usually last for four hours and do not involve firing torpedoes. The U.S. Navy plans to conduct 30 of these exercises each year in the Mariana Islands Range Complex. These training exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 3 nm from land as secondary sites.

ANTI-SUBMARINE WARFARE TRACKING EXERCISE, SUBMARINE: During these training events, submarines rely on passive sonar sensors almost exclusively to search, detect, classify, localize and track target submarines with the goal of developing a firing solution that could be used to launch a torpedo and destroy the threat submarine (active sonar use is tactically proscribed because it would reveal the tracking submarine's presence to the target submarine). No torpedoes are fired during this training activity.

These training events usually last for four hours and do not involve firing torpedoes. The U.S. Navy plans to conduct 10 of these exercises each year in the Mariana Islands Range Complex. These training exercises would primarily occur on maritime areas off Guam more than 3 nm from land with Warning Area W-517 as a secondary site.

1.1.3.1 Acoustic Systems Associated with Anti-Submarine Warfare Training

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 in the RIMPAC exercise 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 which is a large, active-passive, bow-mounted sonar that has been operational since 1975. AN/SQS-53 is the U.S. Navy's most powerful surface ship sonar and is installed on *Ticonderoga* (22 units) and *Arleigh Burke* I/II/IIIa (51 units) class vessels in the U.S. Navy (Polmar 2001, D`Spain *et al.* 2006). This sonar transmits at a center frequency of 3.5 kHz at sources levels of 235 dB_{rms} re: 1 μPa at 1 meter[1]. The sonar has pulse durations between 1 and 2 seconds, with about 24-second intervals between pulses. AN/SQS-53 operates at depths of about 7 meters.

   The AN/SQS-53 is a computer-controlled, hull-mounted surface-ship sonar that has both active and passive operating capabilities, providing precise information for anti-submarine warfare weapons control and guidance. The system is designed to perform direct-path anti-submarine warfare search, detection, localization, and tracking from a hull-mounted transducer array. The AN/SQS-53 sonar is installed on *Arleigh Burke* Class guided missile destroyers and *Ticonderoga* Class guided missile cruisers. The AN/SQS-53 Kingfisher is a modification that provides a surface ship with the ability to detect mine-like objects.

2. The AN/SQS-56 system is a lighter active-passive bow-mounted sonar that has been operational since 1977. AN/SQS-56 is installed on FFG-7 (33 units) class guided missile frigates in the U.S. Navy (Polmar 2001, D`Spain *et al.* 2006). This sonar transmits at a center frequency of 7.5 kHz and a source level of 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 duration, rise times, and wave form of sounds sonar transmitted from these sonar systems classified; however, the characteristics of the transmissions that were used during the Bahamas exercises might help illustrate attributes of the transmissions from these two sonar sources. During the Bahamas exercises, these two sonars transmitted 1 – 2 second pulses once every 24 seconds (D'Spain *et al*. 2006). Pulses had rise times of 0.1 – 0.4 seconds and typically consisted of three waveforms with nominal bandwidths up to 100 Hz (D'Spain *et al*. 2006). Both sonar create acoustic fields that are omnidirectional in azimuth, although AN/SQS-53 also can create beams covering 120˚ azimuthal sectors that can be swept from side to side during transits (D'Spain *et al*. 2006). Waveforms of both sonar systems are frequency modulated with continuous waves (D'Spain *et al*. 2006).

SONAR SYSTEMS ASSOCIATED WITH SUBMARINES. Tactical military submarines (i.e. 29 attack submarines as

1 Throughout this document, decidels for sound sources refer to dBrms re: 1 μPa at 1 meter unless noted otherwise.

of 2008) 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 submarine 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. AN/BQQ-10 (also known as Advanced Rapid Commercial-Off-the-Shelf Insertion– a four-phase program for transforming existing submarine sonar systems (i.e., AN/BQQ -5) from legacy systems to more capable and flexible active and passive systems with enhanced processing using commercial-off-the-shelf components. The system is characterized as mid-frequency active sonar, although the exact frequency range is classified. The AN/BQQ-10 is installed on Seawolf Class SSNs, Virginia Class SSNs, Los Angeles Class SSNs, and Ohio Class SSBN/nuclear guided missile submarines (SSGNs). The BQQ-10 systems installed on Ohio Class SSBNs do not have an active sonar capability.

2. 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 (Figure C-4) sonar system is installed on Los Angeles Class nuclear attack submarines (SSNs) and Ohio Class ballistic missile nuclear submarines (SSBNs), although the AN/BQQ-5 systems installed on Ohio Class SSBNs 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.

SONAR SYSTEMS ASSOCIATED WITH AIRCRAFT. Aircraft sonar systems that typically operate during Navy training exercises include sonobuoys and dipping sonar. Current dipping sonar systems used by the Navy are either AN/SQS-22 or AN/AQS -13. AN/AQS -13 is an older and less powerful dipping sonar system (maximum source level 215 dB re µPa-s^2 at 1m) than the AN/AQS -22 (maximum source level 217 dB re µPa-s^2 at 1m). In its modeling, the Navy assumed that all dipping sonar were AN/AQS -22. P-3 aircraft may deploy sonobuoys while helicopters may deploy sonobuoys or dipping sonars (the latter are used by carrier-based helicopters). Sonobuoys are expendable devices used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets. In addition, the U.S. Navy employs tonal sonobuoys (DICASS, AN/SSQ-62) and the Improved Extended Echo Ranging (IEER) System discussed earlier.

1. The AN/SSQ-62C Directional Command Activated Sonobuoy System (DICASS) sonar system is part of a sonobuoy that operates under direct command of fixed-wing aircraft or helicopters. The system can determine the range and bearing of the target relative to the sonobuoys position and can deploy to various depths within the water column. After it enters the water, the sonobuoy transmits sonar pulses (continuous waveform or linear frequency modulation) upon command from the aircraft. The echoes from the active sonar signal are processed in the buoy and transmitted to the receiving station onboard the launching aircraft.

2. AN/SSQ-110A Explosive Source Sonobuoy is 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 maritime patrol aircraft.

3. 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.

In addition to these torpedoes, the U.S. Navy can employ Acoustic Device Countermeasures in their training exercises, which include 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.

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.

Training targets include MK-30 anti-submarine warfare training targets, and MK-39 Expendable Mobile anti-submarine warfare training targets. Targets may be non-evading while operating on specified tracks or they may be fully evasive, depending on the training requirements of the training operation.

1.1.3.2 Portable Underwater Tracking Range.

Portable underwater tracking ranges are self-contained, portable, undersea tracking capability that employs modern technologies to support coordinated undersea warfare training for forward deployed naval forces. These tracking ranges would be capable of tracking submarines, surface ships, weapons, targets, and unmanned underwater vehicles and distribute the data to a data processing and display system, either aboard ship, or at a shore site.

These systems temporarily instrument 100-square-mile or smaller areas on the seafloor with a baseline configuration of seven electronics packages, each approximately 3 ft long by 2 ft in diameter, on the seafloor by a range boat, in water depths from 400 to 3,500 meters. The anchors used to keep the electronics packages on the seafloor would be either concrete or sand bags, which would be approximately 1.5 ft-by-1.5 ft and would weigh approximately 300 pounds. When training is complete, the U.S. Navy recovers the equipment that is used to install the range, although the anchors would remain on the seafloor. No on-shore construction would take place.

Operation of this range requires exercise participants transmit their locations via pingers (see "Range Tracking Pingers" below). Each package consists of a hydrophone that receives pinger signals and a transducer that sends an acoustic "uplink" of locating data to a range boat. The uplink signal is transmitted at 8.8 kilohertz (kHz) or 40 kHz, at source levels of 186 or 190 decibels. The Portable Undersea Tracking Range system also incorporate underwater voice capability that transmits at 8-11 kHz and a source level of 190 dB. Each of these packages is powered by a D-cell alkaline battery. After the end of the battery life, the electronic packages would be recovered and the anchors would remain on the seafloor.

Range tracking pingers would be used on ships, submarines, and anti-submarine warfare targets when anti-submarine warfare tracking exercise is conducted on the portable undersea tracking range. A typical range pinger generates a 12.93 (or 37) kHz sine wave at source levels of 194 dB re 1 micro-Pascal at 1 meter in pulses with a maximum duty cycle of 30 milliseconds (3% duty cycle). Although the specific exercise, and number and type of participants will determine the number of pingers in use at any time, a maximum of four pingers and a minimum of one pinger would be used for each anti-submarine warfare training activity. A maximum of four pingers would be used for a portable undersea tracking range torpedo exercise or tracking exercise with event durations of aout 8 hours.

1.1.4 Electronic Combat Operations

The electronic combat training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex consist of chaff exercises and flare exercises (see Table 1).

CHAFF EXERCISES. Chaff exercises train aircraft crews to counter "enemy" threats. Chaff is a radar reflector material made of thin, narrow, metallic strips cut in various lengths to elicit frequency responses, which deceive enemy radars. The U.S. Navy employs various types of chaff; including (1) AN/ALQ-190(V)1 and -181/AL, which are used by SH-60B/F and maritime patrol aircraft; and (2) RR-129A/AL and RR-144A/AL, which are used by all naval airframes. Chaff deployed from ships is typically MK-214 (seduction chaff) or MK-216 (distraction chaff) from the MK-36 SRBOC launcher. The specific type and amount of chaff deployed during a training exercise will vary with the specific training situation. The chaff disperses with the winds over a wide area and will eventually settle in limited concentrations over the surrounding sea areas where it was dispensed.

The U.S. Navy typically conducts chaff exercises with flare exercises or other exercises rather than as a stand alone exercise. Each year, the U.S. Navy proposes to conduct 14 electronic combat sorties with 420 rounds of RR-144A/AL chaff deployed by rotary airframes, 32 sorties with 320 rounds of RR-144A/AL chaff deployed by fixed-wing airframes; 500 sorties with 5,000 rounds of RR-188 chaff deployed by fixed-wing airframes; and 16 sorties with 90 canisters of MK-214 or MK-216 chaff deployed by surface vessels.

These training activities would primarily occur off the Island of Guam in W-517. Secondary locations are off the Mariana Islands more than 12nm from land.

FLARE EXERCISES. A flare exercise is defensive operation employed by aircraft in which an aircraft's crew uses an infrared or radar energy source to disrupt attempts to lock onto them. Each year, the U.S. Navy proposes to conduct 14 electronic combat sorties with 420 rounds of MK 46 MOD 1C; MJU-8A/B; MJU-27A/B; MJU-32B; MJU-53B; or SM- 875/ALE flares deployed by rotary airframes, 32 sorties with 320 rounds of the same flares deployed by fixed-wing airframes; and 500 sorties of 5,000 rounds of MJU-7; MJU-10; MJU-206 flares deployed by fixed-wing airframes. These training activities would primarily occur off the Island of Guam in W-517. Secondary locations are off the Mariana Islands more than 12nm from land (see Figure 2).

1.1.5 Expeditionary Warfare

The expeditionary warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex consist of Military Operations In Theater Training, specifically military operations in urban terrain or MOUT training (see Table 1). As part of these training operations, U.S. Marine Corps, U.S. Army, U.S. Air Force, Special Warfare, and Naval Expeditionary Combat Command (abbreviated as NECC in Table 1) personnel use combat tactics that are designated for operations in small city environments that are inhabited by noncombatants while being occupied by a hostile forces.

Each year, the U.S. Navy proposes to conduct 17 of these training events involving different force structures and equipment (see Table 1); twelve of these training, training events would last between 3 and 5 days and the remaining seven training events would last between 7 and 21 days. These training events would primarily occur on Guam; Andersen Airforce Base South; Finegayan Communication Annex; Barrigada Housing; Northwest Field with Tinian; Rota; Saipan as secondary sites (see Figures 7, 8, and 9).

1.1.6 Force Protection and Anti-Terrorism

The anti-terrorism training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex include collecting and disseminating threat information, conducting information awareness programs, coordinated security plans, and personal training. The embassy reinforcement exercises involve U.S. Marine Corps units operating in conjuction with Navy ships and aircraft to training in the process of rapidly introducing forces, preparation non-combatants for evacuation, followed by a planned withdrawal. The force protection training exercises involve moving forces and building barriers, detection, and assessment of threats, delay, or denying potential adversaries access to an intended target, appropriate response to threats and attack, and mitigation of effects of attack.

Each year, the U.S. proposes to conduct 80 anti-terrorism training events on the Mariana Islands Range Complex with each event lasting one day. Each year, the U.S. proposes to conduct 50 embassy reinforcement events with each event lasting two to three days. Each year, the U.S. Navy proposes to conduct 75 force protection training events, with each event lasting between one and two days. The embassy reinforcement training events would primarily occur at Orote Point Airfield, Inner Apra Harbor, and Northern and Southern Land Navigation Areas with Orote Point Triple Spot, Orote Point CQC, Kilo Wharf, and Rota Muncipality as secondary sites. The force protection training events would primarily occur on

Northwest Field (Guam), Northern Land Navigation Area; and Barrigada Annex with Orote Point Airfield, Polaris Point airfield, and Tinian North Field as secondary sites (see Figures 5, 6, and 9).

1.1.7 Major Training Exercises

The U.S. Navy proposes to continue conducting Joint Expeditionary Exercises, Joint Multi-Strike Group Exercises, Marine Air Ground Task Force Exercises, and Urban Warfare Exercises on the Mariana Islands Range Complex and proposes to add Special Purpose Marine Air Ground Task Force Exercises to the training activities it conducts in the Mariana Islands Range Complex.

JOINT EXPEDITIONARY EXERCISE. Joint Expeditionary Exercises are major range events that are the culminating exercises in Integrated Phase training for Carrier and Expeditionary Strike Groups. Each year, the U.S. proposes to conduct 1 of these training events on the Mariana Islands Range Complex with each event lasting about 10 days. The primary training site for these training events is Tinian with Guam, Rota, Saipan, and Farallon de Medinilla as secondary sites (see Figures 4 and 5).

JOINT MULTI-STRIKE GROUP EXERCISE. The Joint Multi-Strike Group Exercises up to three Carrier Strike Groups working with other Services while engaging in battle scenarios that pit United States forces against a opposition force. These exercises include components of command and control; air warfare (missile exercises that involve firing live missiles at air targets; ships and aircraft fire missiles against air targets; and non-firing events such as defensive counter air exercises in which ship and aircrews detect and react to incoming airborne threats); anti-surface warfare; and anti-submarine warfare.

During anti-surface warfare, naval forces train to control sea lanes by engaging in maritime interdiction and air interdiction of maritime targets. During Maritime Interdiction, Navy ships counter surface threats, while air interdiction of marine targets employ U.S. aircraft for the same purpose. This component of joint multi-strike group exercises might involve two sinking exercises.

During anti-submarine warfare, naval air, surface and submarine units would employ acoustic active and passive sonar, visual, and electronic detection to locate and track submarines that represent an opposing force. This component of joint multi-strike group exercises would include the U.S. Navy's Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar platform.

Each year, the U.S. Navy proposes to conduct 1 of these training events on the Mariana Islands Range Complex with each event lasting about 10 days. These training events would primarily occur in areas of the Mariana Islands Range Complex that are greater than 12 miles offshore with Farallon de Medinilla as a secondary site.

MARINE AIR GROUND TASK FORCE EXERCISE - SHIP TO OBJECTIVE MANEUVER/NONCOMBATANT EVACUATION OPERATION (STOM/NEO). These training exercises involve expeditionary strike groups and Marine Air Ground Task Force to secure a battlespace (air, land, and sea), maneuver to and seize training objectives, conduct self-sustaining operations ashore logistic support from the Expeditionary Strike Group.

Each year, the U.S. Navy proposes to conduct 4 these training events on the Mariana Islands Range Complex with each event lasting about 10 days. The primary training site for these training events is Tinian with some elements of the exercise rehearsed in nearshore areas of Guam.

MARINE AIR GROUND TASK FORCE EXERCISE – HUMANITARIAN ASSISTANCE – DISASTER RELIEF/ NONCOMBATANT EVACUATION OPERATION (HADR/NEO). These training events involve U.S. Marine Corps units that train to bring relief to or evacuate noncombatants from an area where the lives of the people being are endangered by war, civil unrest, or natural disaster.

Each year, the U.S. Navy proposes to conduct 2 these training events on the Mariana Islands Range Complex with each event lasting about 10 days. The primary training site for these training events is Guam with Tinian, Rota, and Saipan as secondary sites (see Figures 4 and 5).

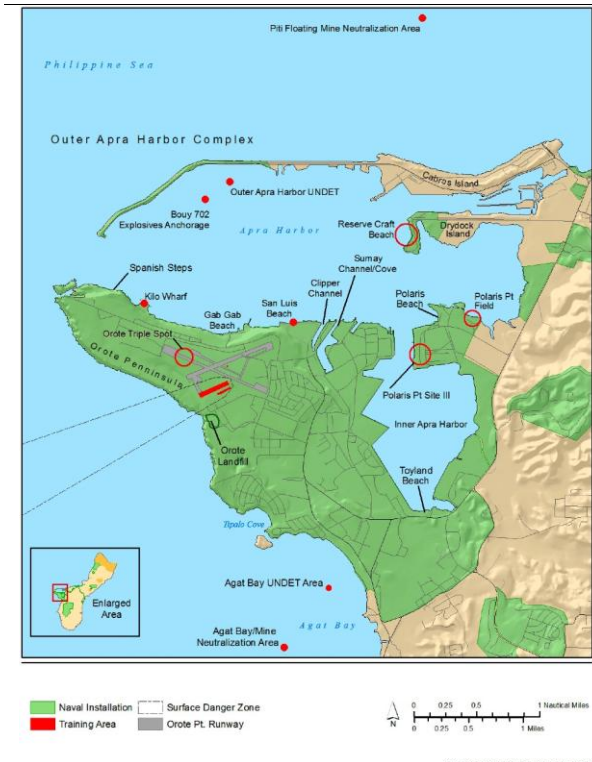

Figure 6. Apra Harbor and nearshore training areas (after Figure ES-5 of U.S. Navy 2009)

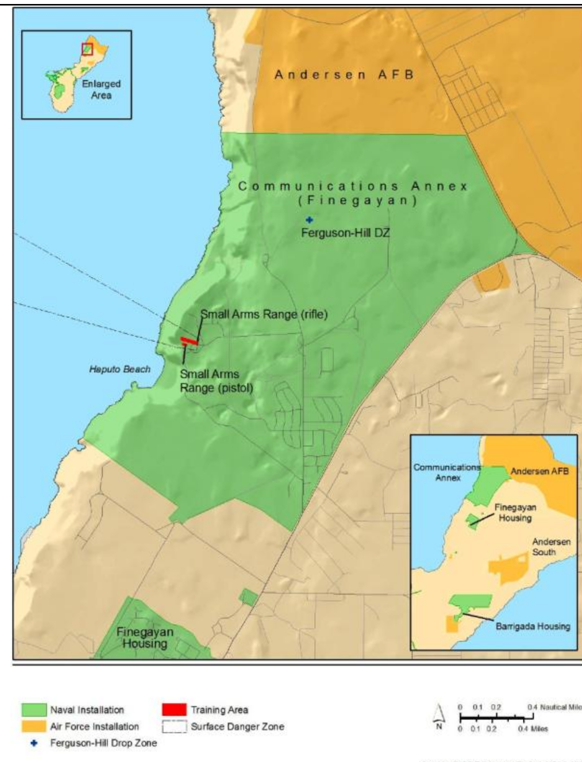

Figure 7. Finegayan communications annex training areas (after Figure ES-7 of U.S. Navy 2009)

Figure 8. Andersen Airforce Base training areas (after Figure ES-10 of U.S. Navy 2009)

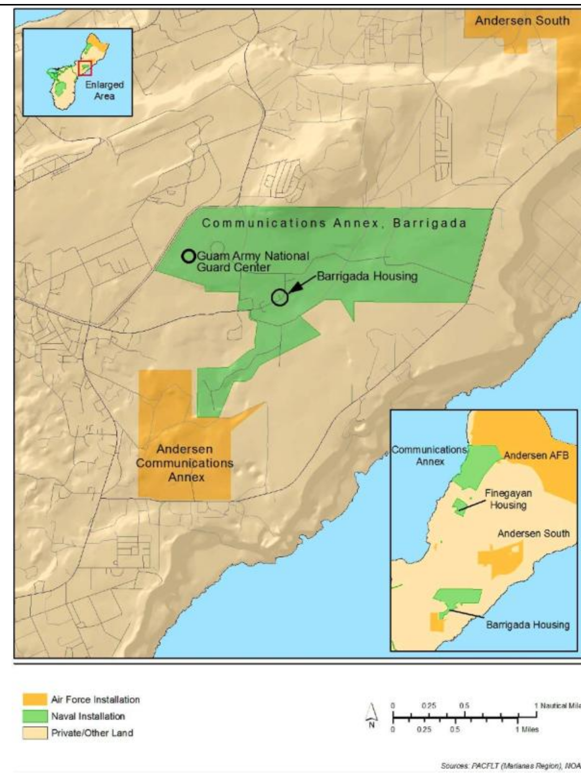

Figure 9. Barrigada communications annex (after Figure ES-8 of U.S. Navy 2009)

URBAN WARFARE EXERCISE. These training exercises involve U.S. Navy surface vessels, amphibious vessels, fixed-wing aircraft. rotary aircraft, and Marine Expeditionary Units in scenarios that train them to engage in combat operations in urban environments.

Each year, the U.S. Navy proposes to conduct 5 these training events on the Mariana Islands Range Complex with each event lasting between 7 and 21 days. Events typically occur on Guam and use Finegayan Housing, Andersen South, Barrigada Housing, and Northwest Field with Tinian, Rota, and Saipan as secondary sites (see Figures 5, 7, 8, and 9).

1.1.8 Mine Warfare

The mine warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex consist of floating mine neutralization and underwater demolition.

FLOATING MINE NEUTRALIZATION. In these training exercises, U.S. Navy Explosive Ordnance Disposal personnel are deployed from surface ships to evaluate mines that had been located by surface vessels or helicopters, then employ explosive charges (up to 10 pounds net explosive weight) to destroy the mine. For safety reasons, these training events normally occur during daylight hours.

Each year, the U.S. Navy proposes to conduct 20 floating mine neutralization training events on the Mariana Islands Range Complex with each event lasting between 2 and 8 hours. These events typically occur at Agat Bay on Guam with Piti Point as a secondary site (see Figure 6).

MINE LAYING EXERCISE. In these training exercises, U.S. Navy maritime patrol aircraft, FA-18, and U.S. Air Force bomber aircraft deploy inert mine shapes such as MK-62 quick strike mines or Mk-56 anti-submarine warfare mines.

Each year, the U.S. Navy proposes to conduct about three mine laying exercises, employing about 480 mine shapes. The primary site for these events is W-517 with the Marianas maritime area (greater then 12 nm from shore) as a secondary site.

UNDERWATER DEMOLITIONS. In these training exercises, U.S. Navy SEALS or Explosive Ordnance Disposal personnel use explosive charges (between 5 and 10 pounds net explosive weight) to destroy obstacles or other structures in an underwater area.

Each year, the U.S. Navy proposes to conduct 30 underwater demolition training events on the Mariana Islands Range Complex with each event lasting between 2 and 8 hours. These events typically occur at Agat Bay on Guam with Apra Harbor as a secondary site (see Figure 6).

1.1.9 Special Warfare

The special warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex involve platoons or squads of U.S. Navy SEALS or Explosive Ordnance Detonation, U.S. Army, U.S. Marine Corps, U.S. Air Force, of U.S. Navy Expeditionary Combat Command personnel engaged in breaching, direct action, hydrographic reconnaissance, insertion/extraction, parachute insertion, or urban warfare training activities.

In breaching exercises, Special Warfare, U.S. Army, and U.S. Marine Corps personnel use explosives to gain access to buildings. These training events occur at Navy munitions site Breacher House on Guam.

In direct action exercises, squads or platoons of Special Forces or Naval Expeditionary Combat Command personnel are inserted into and extracted from simulated hostile areas and, while there, use small unit tactics to to seize, damage, or destroy targets or capture or recover personnel or material. This training occurs on Farallon de Medinilla, the Orote Point Combat Qualification Center and Navy Munitions Site Breacher House; or Tarague Beach CQC and Navy Munitions Site Breacher House.

In hydrographic reconnaissance exercises, squads or platoons of U.S. Navy SEALS or U.S. Marine Corps personnel survey underwater terrain conditions and report their findings. As part of these exercises, military personnel methodically reconnoiter beach and surf conditions during the day and night to find and clear underwater obstacles. These training events occur primarily on Farallon de Medinilla; Tinian; or Tipalao Cove with Haputo Beach; Gab Gab Beach; Dadi Beach as secondary sites (see Figures 4, 5, and 6).

In insertion/extraction exercises, fixed-winged aircraft (such as a C-130) fly to an area from a land based airfield and Special Warfare, Navy Expeditionary Combat Command, or other personnel will parachute (static line or free fall) into a landing zone from either a high (25,000 ft or more), a low (1,000 ft and below) altitude, or an altitude between these heights, or they use SCUBA or small craft. These exercises primarily occur at the Orote Point Airfield; Northwest Field; Orote Pt. Triple Spot; Apra Harbor; Gab Gab

Beach with the Orote Point CQC; Finegayan Drop Zone; Haputo Beach; Munitions Site Breacher House; Polaris Pt. Field; and Orote Point. KD Range as secondary sites (see Figures 5, 6, 7, 8, and 9).

In military operations in theater training exercises, platoons of U.S. Navy SEALS or Explosive Ordnance Detonation personnel train in military operations in urban terrain (see Table 1). These exercises primarily occur at Andersen Airforce Base South; Finegayan Communication Annex; Barrigada Housing; Navy Munitions Site Breaching House with Tinian, Rota, and Saipan as secondary sites.

In parachute insertion exercises, Special Warfare and U.S. Army personnel use fixed-winged and rotary aircraft to insert personnel and equipment by parachute or helicopters. These training exercises primarily occur at the Orote Point Airfield; Northwest Airfield; Orote Point Triple Spot with Finegayan Drop Zone; Apra Harbor; and Navy Munitions Site Breacher House as secondary sites.

1.1.10 Special Warfare-Expeditionary Warfare

The special warfare-expeditionary warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex involve specific training exercises for Airfield Expeditionary, Field Training Exercise, Humanitarian Assistance/Disaster Relief Operation, Intelligence, Surveillance, Reconnaissance, Land Demolitions, Maneuver, Non-Combatant Evacuation Operation, and Airfield Seizure (see Table 1).

In airfield expeditionary exercises, U.S. Airforce Rapid Engineer Deployable Heavy Operational Repair Squadron Engineer squadrons, U.S. Navy Expeditionary Combat Command construction battalion (SEABEES) companies, U.S. Marine Corps Combat Engineer companies, and U.S. Army Reserve Engineers provide airlift support to combat forces; provide air expeditionary operations support to forward deployed forces; and provide force protection exercises. These exercises primarily occur at Northwest Field on Guam with Orote Point Airfield and Tinian North Airfield as secondary sites (see Figures 5 and 6).

In field training exercises, U.S. Army companies and U.S. Navy Expeditionary Combat Command construction battalion (SEABEES) companies or platoons deploy to field locations to conduct operations under simulated combat conditions. These exercises primarily occur at Northwest Field, Northern Land Navigation Area on Guam with the Orote Point Airfield and Polaris Point Field and Tinian North Field as secondary sites (see Figures 5 and 6).

In humanitarian assistance/disaster relief operation exercises, military service personnel train to bring relief to or evacuate noncombatants from an area where the lives of the people being are endangered by war, civil unrest, or natural disaster

In intelligence, surveillance, reconnaissance exercises, platoons or squads of U.S. Navy SEAL, U.S. Army, U.S. Marine Corps, or U.S. Air Force personnel train to evaluate battlefields, enemy forces, and gather intelligence. These exercises primarily occur at Northwest Field, Barrigada Housing, Finegayan Communications Annex, or Orote Point Airfield with Tinian, Rota, and Saipan as secondary sites (see Figures 5, 6, 7, 8, and 9).

In land demolition exercises (IED discovery and disposal), Explosive Ordnance Disposal personnel to locate, excavate, and use explosive charges to destroy land mines, explosive devices, such as improvised explosive devices, bombs, structures, or other items as required. These exercises primarily occur at the Orote Point Airfield, Orote Point CQC; Polaris Point Field; Andersen South; Northwest Field with Northern or Southern Land Navigation Area; Munitions Site Breacher House, and Tinian Military Leased Area as secondary sites (see Figures 5, 6, 7, 8, and 9).

In land demolition exercises (UXO discovery and disposal), Explosive Ordnance Disposal personnel to locate, excavate, relocate (if necessary), and use explosive charges to destroy unexploded ordnance. These exercises primarily occur at the Explosive Ordnance Disposal Site at the Naval Munitions Site on Guam with the Andersen Airforce Base Explosive Ordnance Disposal site and Northwest Airfield disposal site as secondary sites (see Figures 5, 6, 7, 8, and 9).

In maneuver exercises, U.S. Marine Corps units practice maneuvering and deploying their forces. These exercises primarily occur at Northwest Field, Andersen Airforce Base South, Northern and Southern Land Navigation Area, or Tinian Military Leased Area with Finegayan Annex; Barrigada Annex, and Orote Point Airfield as secondary sites (see Figures 5, 6, 7, 8, and 9).

In non-combatant evacuation operation exercises, U.S. Marine Corps units that train to bring relief to or evacuate noncombatants from an area where the lives of the people being are endangered by war, civil unrest, or natural disaster. These exercises would primarily occur at Apra Harbor, Reserve Craft Beach, Polaris Point Beach, Polaris Point Field; Orote Point Airfield; Northwest Field; Sumay Cove or MWR Marina Ramp with Tinian Military Leased Area, Unai Chulu (beach) and Tinian Harbor, and North Field and Rota Airfield/West Harbor as secondary sites (Figures 5 and 6).

In airfield seizure exercises, platoons or companies of Special Warfare, U.S. Army and U.S. Marine Corps personnel train to seize and secure occupied airfields. These exercises primarily occur at the Northwest Field on Guam with the Orote Point Airfield and Tinian North Field as secondary sites (Figures 5 and 6).

1.1.11 Strike Warfare

The strike warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex involve bombing exercises (land-based targets), air-to-ground missile exercises, and combat search and rescue exercises (see Table 1).

BOMBING EXERCISES. In these training exercises, fixed-winged aircraft deliver unguided or precision-guided inert or live bombs and rockets against land targets during the day or night (see Table 1 for a list of the aircraft involved in these exercises). Aircraft involved in these exercises typically approach targets from altitudes between 3,000 and 15,000 feet. The U.S. Navy proposes to conduct 500 of these training events each year with high explosive bombs with weights less than or equal to 500 pounds; 1,650 training events each year with 750-, 1,000- or 2,000-pound high explosive bombs, 2,800 training events each year with inert training bombs (less than or equal to 2,000 pounds); and a total of 1,300 sorties. These exercises would occur on Farallon de Medinilla (area R-7201, Figure 4).

MISSILE EXERCISES (air-to-ground). In these training exercises, fixed-winged aircraft and helicopters deliver bombs and rockets against ground targets and ships in port during the day or night (see Table 1 for a list of the aircraft involved in these exercises). Depending on the ordnance, aircraft involved in these exercises typically approach targets from altitudes between 25,000 and 40,000 feet or 5,000 and 25,000 feet. The U.S. Navy proposes to conduct 60 of these training events each year with TOW, MAVERICK, OR HELLFIRE missiles. These exercises would occur on Farallon de Medinilla (area R-7201; Figure 4).

COMBAT SEARCH AND RESCUE. In these training exercises, fixed-winged aircraft, helicopters and submarines train to rescue military personnel within hostile areas. During these exercises, helicopters fly below 3,000 ft and at speeds between 50 and 100 knots. These exercises would primarily occur at Tinian North Field or Northwest Field with Orote Point Airfield and Rota Airport as secondary sites.

1.1.12 Surface Warfare

The surface warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex involve Gunnery Exercises (Surface-to-Surface – small arms), Gunnery Exercises (Surface-to-Surface Ship), Gunnery Exercises (Air to Surface), Bombing Exercises (Air to Surface), Sinking Exercises, and Visit, Board, Search, and Seizure or Maritime Interception Operations (see Table 1).

BOMBING EXERCISE (Air to Surface – Inert Ordnance). In these training exercises, U.S. Navy fighters and maritime patrol aircraft deliver unguided and precision-guided bombs against surface maritime targets during the day or night. The U.S. Navy proposes to conduct 24 of these training events and would expend about 72 inert rounds during each training event. These training exercises would primarily occur in maritime areas of the Mariana Islands more than 3 nm from land with Warning Area W-517 and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1, 2, and 3).

BOMBING EXERCISE (Air to Surface – Live Ordnance). In these training exercises, U.S. Navy fighters and maritime patrol aircraft deliver unguided and precision-guided bombs against surface maritime targets during the day or night. The U.S. Navy proposes to conduct about four of these training events and would expend about four live bombs each year. These training exercises would primarily occur in maritime areas of the Mariana Islands more than 3 nm from land with Warning Area W-517 and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1, 2, and 3).

GUNNERY EXERCISE (Surface-to-Surface – small arms). In these training exercises, U.S. Navy special warfare tteams and Navy Expeditionary Combat Command units (which include Naval Coastal Warfare, Inshore Boat Units, Mobile Security Detachments, and Explosive Ordnance Disposal units) use small boats equipped with machine guns and small arms to attack and disable or destroy surface targets that simulate other ships, boats, swimmers, floating mines or near shore land targets. The U.S. Navy proposes to conduct 32 of these training events and would expend about 500 rounds during each training event or 16,000 rounds per year. These training exercises would primarily occur in maritime areas of the Mariana Islands more than 3 nm from land with Warning Area W-517 and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1, 2, and 3).

GUNNERY EXERCISE (Surface-to-Surface Ship). In these training exercises, gun crews on U.S. Navy ships engage surface targets at sea with their main battery 5-inch and 76 mm guns as well as smaller surface targets with 25 mm, .50 cal, or 7.62 mm machine guns. The U.S. Navy proposes to conduct 5 of these training events expending 12,000 rounds of .50 caliber ammunition; 5 of these training events with

Amphibious Assault Ships (general purpose), Amphibious Assault Ships (multipurpose), Dock Landing Ships, and Amphibious Transport Docks expending 12,000 rounds of .25 mm ammunition; 5 training events involving Guided Missile Cruisers and Guided Missile Destroyers; and 4 training events involving Guided Missile Frigates. These training exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 12 nm from land as secondary sites (see Figures 1 and 2).

GUNNERY EXERCISE (Air to Surface). In these training exercises, fighter aircraft and helicopter crews (including Naval Special Warfare personnel) use guns to attack surface maritime targets, which include ships, boats, or floating or near-surface mines, during the day or night. The U.S. Navy proposes to conduct 200 of these training events in which 40,000 7.62 mm rounds would be expended; 20 training events in which 4,000 .50 caliber rounds would be expended; 100 training events in which 10,000 .20 mm rounds would be expended; 40 training events in which 4,000 .25 mm rounds would be expended; and 15 training events in which 1,500 .30 mm rounds would be expended. These training exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 12 nm from land and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1, 2, and 3).

MISSILE EXERCISE (Air to Surface). In these training exercises, fighter aircraft and helicopter launch live missiles against surface maritime targets, which include ships, boats, or floating or near-surface mines, during the day or night. The U.S. Navy proposes to conduct two of these training events in which two HELLFIRE missiles each year. These training exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 12 nm from land and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1, 2, and 3).

MISSILE EXERCISE, CAPTURED TRAINING MISSILE (Air to Surface – inert only). In these training exercises, fighter aircraft and helicopter conduct a simulated missile launch against surface maritime targets, which include ships, boats, or floating or near-surface mines, during the day or night. The U.S. Navy proposes to conduct 60 Missile/Captured Training Missile Exercises each year with one HELLFIRE Missile/Captured Training Missile Exercise each year on a designated laser training range in W-517 (see Figures 1, 2, and 3).

SINKING EXERCISE (SINKEX). In a SINKEX, a decommissioned surface ship is towed to a specified deep-water location and there used as a target for a variety of weapons. Although no SINKEXs are ever the same, the *Programmatic SINKEX Overseas Environmental Assessment* (March 2006) for the Western North Atlantic describes a representative case derived from past exercises.

In a SINKEX, weapons are typically fired in order of decreasing range from the source with weapons fired until the target is sunk. A torpedo may be used after all munitions have been expended if the target is still afloat. Since the target may sink at any time during the exercise, the actual number of weapons used can vary widely. In the representative case, however, all of the ordnances are assumed expended; this represents the worst case of maximum exposure.

Sinking exercises typically involve one full-size hulk which serves as the target ship, one to five guided missile cruiser(s), guided missile destroyer(s), or guided missile frigates which fire rounds at the target; one to ten F/A-18, or maritime patrol aircraft which also fire rounds at the target; one or two HH-60H, MH-60R/S, or SH-60B helicopters; one E-2 aircraft for Command and Control; one firing submarine; and one to three range clearance aircraft. Ordnance that is fired at the target can include two to four Harpoon surface-to-surface or air-to-surface missiles; two to eight air-to-surface Maverick missiles; two to 16 MK-82 / MK-84 General Purpose Bombs; two to four Hellfire air-to-surface missiles; one or two SLAM-ER air-to-surface missiles; fifty to 500 rounds 5-inch and 76 mm gun; one MK-48 heavyweight submarine-launched torpedo; and two to 10,000 rounds .50 cal and 7.62 mm.

Sinking exercises would primarily occur on Warning Area W-517 with maritime areas of the Mariana Islands more than 50 nm from land and Air Traffic Control Assigned Airspaces as secondary sites (see Figures 1, 2, and 3).

VISIT, BOARD, SEARCH, AND SEIZURE OR MARITIME INTERCEPTION OPERATIONS. In these training exercises, helicopters and surface ships deliver boarding parties to surface vessels to inspect and examine the vessels' papers or examine it for compliance with applicable resolutions or sanctions. The U.S. Navy proposes to conduct 8 of these training exercises primarily at Apra Harbor with maritime areas of the Mariana Islands as secondary sites.

1.2 Surveillance Towed Array Sensor System – Low Frequency Active

As a separate but related action, the U.S. Navy also proposes to employ the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar system in Joint Multi-Strike Group Exercises it proposes to conduct in the Mariana Islands Range Complex. The SURTASS LFA sonar system is a long-range, low frequency sonar (between 100 and 500 Hertz (Hz)) that has both active and passive components. 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.

Operational LFA systems are currently installed on two SURTASS vessels: the USNS IMPECCABLE (T-AGOS 23) and USNS ABLE (T-AGOS 20). Over the five-year period that is being considered in this biological opinion, the U.S. Navy plans to develop and introduce a compact active system deployable from existing, smaller SURTASS Swath-P ships. This system upgrade is known as Compact LFA (CLFA) and consists of smaller, lighter-weight source elements than the current LFA system, and will be compact enough to be installed on the existing SURTASS platforms, VICTORIOUS Class (T-AGOS Class 19). Three additional platforms equipped with this Compact LFA are planned for the T-AGOS Class 19.

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"). 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 beamwidth that can be steered above or below the horizontal. The source level of an individual projector in the SURTASS LFA sonar array is about 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).

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 earlier LFA operating parameters), the system transmits for about 72 hours per 49-day mission (about 432 hours per year for each of the two SURTASS LFA sonar systems). SURTASS LFA sonar vessels generally travel in straight lines or racetrack patterns depending on the operational scenario. The characteristics and operating features of the active component (LFA) are:

- The source is a vertical line array (VLA) of up to 18 source projectors suspended below the vessel. LFA's transmitted beam is omnidirectional (360 degrees) in the horizontal, with a narrow vertical beamwidth that can be steered above or below the horizontal.
- The source frequency is between 100 and 500 hertz (Hz). A variety of signal types can be used, including continuous wave (CW) and frequency-modulated (FM) signals.
- The source level (SL) of an individual source projector of the SURTASS LFA sonar array is approximately 215 dB or less. The sound field of the array can never be higher than the SL of an individual source projector.
- The typical LFA signal is not a constant tone, but rather a transmission of various waveforms that vary in frequency and duration. A complete sequence of sound transmissions is referred to as a wavetrain (also known as a "ping"). These wavetrains last between 6 and 100 seconds with an average length of 60 seconds. Within each wavetrain the duration of each continuous frequency sound transmission is never longer than 10 seconds.
- Average duty cycle (ratio of sound "on" time to total time) is less than 20 percent. The typical duty cycle, based on historical LFA operational parameters, is nominally 7.5 percent.
- The time between wavetrain transmissions is typically from 6 to 15 minutes.

HIGH FREQUENCY/MARINE MAMMAL MONITORING SONAR [HF/M3]. The source level required for the HF/M3 sonar to effectively detect marine mammals (and possibly sea turtles) out to the 180-dB LFA mitigation zone under the most adverse oceanographic conditions (low echo return and high ambient noise) is on the order of 220 dB.

1.3 Scope of the Proposed MMPA Regulations

The regulations the Permits Division proposes to promulgate would establish a framework whereby the U.S. Navy may obtain authorization to "take" marine mammals only if (a) the "take" occurs within the Mariana Islands Range Complex Study Area (as depicted in Figure 1-1 in the Navy's application for MIRC), which is bounded by a pentagon with the following five corners: 16°46'29.3376" N. lat., 138°00'59.835" E. long.; 20°02'24.8094" N. lat., 140°10'13.8642" E. long.; 20° 3' 27.5538" N. lat., 149° 17' 41.0388" E. long.; 7° 0' 30.0702" N. lat., 149° 16' 14.8542"E. long; and 6° 59' 24.633" N. lat, 138° 1' 29.7228" E. long. and (b) the "take" occurs incidental to the following activities within the designated amounts of use:

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

i AN/SQS-53 (hull-mounted active sonar) – up to 10865 hours over the course of 5 years (an average of 2173 hours per year), with no more than approximately 10% of this use in the winter;

ii AN/SQS-56 (hull-mounted active sonar) – up to 705 hours over the course of 5 years (an average of 141 hours per year);

iii AN/SSQ-62 (Directional Command Activated Sonobuoy System (DICASS) sonobuoys) – up to 8270 sonobuoys over the course of 5 years (an average of 1654 sonobuoys per year)

iv AN/AQS-22 (helicopter dipping sonar) - up to 2960 dips over the course of 5 years (an average of 592 dips per year);

v AN/BQQ-10 (submarine hull-mounted sonar) - up to 60 hours over the course of 5 years (an average of 12 hours per year);

vi MK-48, MK-46, or MK-54 (torpedoes) – up to 200 torpedoes over the course of 5 years (an average of 40 torpedoes per year);

vii AN/SSQ-110 (IEER) – up to 530 buoys deployed over the course of 5 years (an average of 106 per year);

viii AN/SSQ-125 (AEER) – up to 530 buoys deployed over the course of 5 years (an average of 106 per year);

ix Range Pingers - up to 1400 hours over the course of 5 years (an average of 280 hours per year); and

x PUTR Transponder - up to 1400 hours over the course of 5 years (an average of 280 hours per year).

2 The detonation of the underwater explosives indicated in this paragraph (c)(2)(i) conducted as part of the training events indicated in this paragraph (c)(2)(ii):

i Underwater Explosives:

(A) 5” Naval Gunfire (9.5 lbs);

(B) 76 mm rounds (1.6 lbs);

(C) Maverick (78.5 lbs);

(D) Harpoon (448 lbs);

(E) MK-82 (238 lbs);

(F) MK-83 (574 lbs);

(G) MK-84 (945 lbs);

(H) MK-48 (851 lbs);

(I) Demolition Charges (10 lbs);

(J) AN/SSQ-110A (IEER explosive sonobuoy - 5 lbs);

(K) HELLFIRE (16.5lbs);

(L) GBU 38/32/31.

ii Training Events:

(A) Gunnery Exercises (S-S GUNEX) - up to 60 exercises over the course of 5 years (an average of 12 per year);

(B) Bombing Exercises (BOMBEX) - up to 20 exercises over the course of 5 years (an average of 4 per year);

(C) Sinking Exercises (SINKEX) – up to 10 exercises over the course of 5 years (an average of 2 per year);

(D) Extended Echo Ranging and Improved Extended Echo Ranging (EER/IEER) Systems - up to 530 deployments over the course of 5 years (an average of 106 per year);

(E) Demolitions – up to 50 over the course of 5 years (an average of 10 per year); and

(F) Missile exercises (A-S MISSILEX) – up to 10 exercises over the course of 5 years (an average of 2 per year).

No person in connection with the activities described in the proposed regulations may:

1. "Take" any marine mammals that are not specifically identified in the regulations;
2. "Take" any of the marine mammals identified in the regulations other than by incidental take;
3. "Take" a marine mammal identified in the regulations if such taking results in more than a negligible impact on the species or stocks of such marine mammal; or
4. Violate, or fail to comply with, the terms, conditions, and requirements of the proposed regulations or future Letters of Authorization issued under the proposed regulations.

1.4 Mitigation Measures the U.S. Navy Proposes to Employ on the Mariana Islands Range Complex

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

1.4.1 General Maritime Measures

1.4.1.1 Personnel Training – Watchstanders and Lookouts

All Commanding Officers (COs), Executive Officers (XOs), lookouts, OODs, junior OODs (JOODs), maritime patrol aircraft aircrews, and Anti-submarine Warfare (ASW)/Mine Warfare (MIW) helicopter crews will complete the NMFS-approved Marine Species Awareness Training (MSAT) by viewing the U.S. Navy MSAT digital versatile disk (DVD). MSAT may also be viewed on-line at https://portal.navfac.navy.mil/go/msat. All bridge watchstanders/lookouts will complete both parts one and two of the MSAT; part two is options for other personnel. Part 1 of this training addresses the lookout's role in environmental protection, laws governing the protection of marine species, Navy stewardship commitments and general observation information to aid in avoiding interactions with marine species. Part 2 focuses on identification of specific species.

- Navy lookouts will undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (Naval Education and Training Command [NAVEDTRA] 12968-D).
- Lookout training will include on-the-job instruction under the supervision of a qualified, experienced lookout. Following successful completion of this supervised training period, Lookouts will complete the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects). This does not preclude personnel being trained as lookouts from being counted as those listed in previous measures so long as supervisors monitor their progress and performance.
- Lookouts will be trained in the most effective means to ensure quick and effective communication within the command structure in order to facilitate implementation of protective measures if marine species are spotted.

1.4.1.2 Operating Procedures & Collision Avoidance

- Prior to major exercises, 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.

- While underway, surface vessels will have at least two lookouts with binoculars; surfaced submarines will have at least one lookout with binoculars. Lookouts already posted for safety of navigation and man-overboard precautions may be used to fill this requirement. As part of their regular duties, lookouts will watch for and report to the OOD the presence of marine mammals and sea turtles.

- On surface vessels equipped with a mid-frequency active sonar, pedestal mounted "Big Eye" (20x110) binoculars will be properly installed and in good working order to assist in the detection of marine mammals and sea turtles 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).

- While in transit, naval vessels will 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.

- When marine mammals have been sighted in the area, Navy vessels will 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).

- Naval vessels will maneuver to keep a safe distance from any observed marine mammal and avoid approaching them head-on. This requirement does not apply if a vessel's safety is threatened, such as when change of course will create an imminent and serious threat to a person, vessel, or aircraft, and to the extent vessels are restricted in their ability to maneuver. Restricted maneuverability includes, but is not limited to, situations when vessels are engaged in dredging, submerged operations, launching and recovering aircraft or landing craft, minesweeping operations, replenishment while underway and towing operations that severely restrict a vessel's ability to deviate course. Vessels will take reasonable steps to alert other vessels in the vicinity of the marine mammal.

- 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. 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 mammals.

- All vessels will maintain logs and records documenting training activities should they be required for event reconstruction purposes. Logs and records will be kept for a period of 30 days following completion of a major training exercise.

1.4.2 Measures for Specific Training Events

1.4.2.1 Mid-Frequency Active Sonar Operations

1.4.2.1.1 General Maritime Mitigation Measures: Personnel Training

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

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

- Navy personnel will undertake extensive training in order to qualify as a lookout in accordance with the Lookout Training Handbook (Naval Education and Training [NAVEDTRA] 12968-D).

- Lookout training will include on-the-job instruction under the supervision of a qualified, experienced lookout. Following successful completion of this supervised training period, Lookouts will complete the Personal Qualification Standard program, certifying that they have demonstrated the necessary skills (such as detection and reporting of partially submerged objects). This does not preclude personnel being trained as lookouts from being counted as those listed in previous measures so long as supervisors monitor their progress and performance.

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

1.4.2.1.2 General Maritime Mitigation Measures: 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.

- All surface ships participating in ASW training events will, 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 marine mammal lookouts.

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

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

- After sunset and prior to sunrise, lookouts will employ Night Lookouts Techniques in accordance with the Lookout Training Handbook. Application of these techniques, which include the use of night vision goggles, allow lookouts to effectively monitor a 1,100 yard (yd) (1,000 meter [m]) safety zone at night.

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

1.4.2.1.4 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 MFA sonar 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 yd (183 m) 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) within 1,000 yds (914 m) of the sonar dome (the bow), the ship or submarine will limit active transmission levels to at least 6 decibels (dB) below normal operating levels. (A 6 dB reduction equates to a 75 percent power reduction. The reason is that decibel levels are on a logarithmic scale. Thus, a 6 dB reduction results in a power level only 25 percent of the original power.)

  — 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 200-yard safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (1,829 m) beyond the location of the last detection.

  — Should a marine mammal be detected within or closing to inside 500 yds (457 m) of the sonar dome, active transmissions will be limited to at least 10 dB below the equipment's normal operating level. Ships and submarines will continue to limit maximum ping levels by this 10-dB factor until the marine mammal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (457 m) beyond the location of the last detection.

  — Should the marine mammal be detected within 200 yards of the sonar dome, active sonar transmissions will cease. Sonar will not resume until the animal 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 yds (457 m) beyond the location of the last detection.

  — 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.

— If the need for power-down should arise as detailed in “Safety Zones” above, the 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 the 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.
- ACTIVE 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 yds (183 m) of a marine mammal and shall cease pinging if a marine mammal closes within 200 yds (183 m) 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:

- Areas of at least 1,094 yards (1,000 m depth) near a shoreline where there is a rapid change in bathymetry on the order of 1,000 to 6,000 yards (914 -5,486 meters) occurring across a relatively short horizontal distance (e.g., 5 nautical miles [nm]).
- Cases for which multiple ships or submarines (≥ 3) operating MFA sonar in the same area over extended periods of time (≥ 6 hours) in close proximity (≤ 10 nm apart).
- 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.

- Though not as dominant a condition as bathymetric features, the historical presence of a strong surface duct (i.e., a mixed layer of constant water temperature extending from the sea surface to 100 or more feet).

If the Major Exercise must occur in an area where the above conditions exist in their aggregate, these conditions must be fully analyzed in environmental planning documentation. The Navy will increase vigilance by undertaking the following additional protective measure:

- A dedicated aircraft (Navy asset or contracted aircraft) will undertake reconnaissance of the embayment or channel ahead of the exercise participants to detect marine mammals that may be in the area exposed to active sonar. Where practical, advance survey should occur within about 2 hours prior to MFA sonar use and periodic surveillance should continue for the duration of the exercise. Any unusual conditions (e.g., presence of sensitive species, groups of species milling out of habitat, and any stranded animals) shall be reported to the Officer in Tactical Command, who should give consideration to delaying, suspending, or altering the exercise.

- All safety zone power-down requirements described in this measure apply.

- The post-exercise report must include specific reference to any event conducted in areas where the above conditions exist, with exact location and time/duration of the event, and noting results of surveys conducted.

1.4.2.2 Surface-to-Surface Gunnery (up to 5-inch explosive rounds)

- For exercises using targets towed by a vessel, target-towing vessels shall maintain a trained lookout for marine mammals and sea turtles when feasible. If a marine mammal or sea turtle is sighted in the vicinity, the tow vessel will immediately notify the firing vessel, which will suspend the exercise until the area is clear.
- A 600 yard (585 m) radius buffer zone will be established around the intended target.
- From the intended firing position, trained lookouts will survey the buffer zone for marine mammals and sea turtles prior to commencement and during the exercise as long as practicable. Due to the distance between the firing position and the buffer zone, lookouts are only expected to visually detect breaching whales, whale blows, and large pods of dolphins and porpoises.
- The exercise will be conducted only when the buffer zone is visible and marine mammals and sea turtles are not detected within it.

1.4.2.3 Surface-to-Surface Gunnery (non-explosive rounds)

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

1.4.2.4 Surface-to-Air Gunnery (explosive and non-explosive rounds)

- Vessels will orient the geometry of gunnery exercises in order to prevent debris from falling in the area of sighted marine mammals.
- Vessels will attempt to recover any parachute deploying aerial targets to the extent practicable (and their parachutes if feasible) to reduce the potential for entanglement of marine mammals.
- Target towing vessel shall maintain a lookout if feasible. If a marine mammal or sea turtle is sighted in the vicinity of the exercise, the tow vessel will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.

1.4.2.5 Air-to-Surface Gunnery (explosive and non-explosive rounds)

- A 200 yard (183 m) radius buffer zone will be established around the intended target.
- If surface vessels are involved, lookout(s) will visually survey the buffer zone for marine mammals and sea turtles prior to and during the exercise.
- Aerial surveillance of the buffer zone for marine mammals and sea turtles will be conducted prior to commencement of the exercise. Aerial surveillance altitude of 500 feet to 1,500 feet (152 – 456 m) is optimum. Aircraft crew/pilot will maintain visual watch during exercises. Release of ordnance through cloud cover is prohibited; aircraft must be able to actually see ordnance impact areas.
- The exercise will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

1.4.2.6 Small Arms Training (grenades, explosive and non-explosive rounds)

Lookouts will visually survey for marine mammals and sea turtles. Weapons will not be fired in the direction of known or observed marine mammals or sea turtles.

1.4.2.7 Air-to-Surface At-Sea Bombing Exercises (explosive bombs and rockets)

- Ordnance shall not be targeted to impact within 1,000 yards (914 m) of known or observed sea turtles or marine mammals.

- A buffer zone of 1,000 yards (914 m) radius will be established around the intended target.
- Aircraft will visually survey the target and buffer zone for marine mammals prior to and during the exercise. The survey of the impact area shall be made by flying at 1,500 ft (152 m) or lower, if safe to do so, and at the slowest safe speed. When safety or other considerations require the release of weapons without the releasing pilot having visual sight of the target area, a second aircraft, the "wingman," will clear the target area and perform the clearance and observation functions required before the dropping plane may release its weapons. Both planes must have direct communication to assure immediate notification to the dropping plane that the target area may have been fouled by encroaching animals or people. The clearing aircraft will assure it has visual site of the target area at a maximum height of 1500 ft. The clearing plane will remain within visual sight of the target until required to clear the area for safety reasons. Survey aircraft should employ most effective search tactics and capabilities.
- The exercises will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

1.4.2.8 Air-to-Surface At-Sea Bombing Exercises (non-explosive bombs and rockets)

- If surface vessels are involved, trained lookouts will survey for sea turtles and marine mammals. Ordnance shall not be targeted to impact within 1,000 yds (914 m) of known or observed sea turtles or marine mammals.
- A 1,000 yd (914 m) radius buffer zone will be established around the intended target.
- Aircraft will visually survey the target and buffer zone for marine mammals prior to and during the exercise. The survey of the impact area shall be made by flying at 1,500 ft (152 m) or lower, if safe to do so, and at the slowest safe speed. When safety or other considerations require the release of weapons without the releasing pilot having visual sight of the target area, a second aircraft, the "wingman," will clear the target area and perform the clearance and observation functions required before the dropping plane may release its weapons. Both planes must have direct communication to assure immediate notification to the dropping plane that the target area may have been fouled by encroaching animals or people. The clearing aircraft will assure it has visual site of the target area at a maximum height of 1500 ft. The clearing plane will remain within visual sight of the target until required to clear the area for safety reasons. Survey aircraft should employ most effective search tactics and capabilities.
- The exercise will be conducted only if marine mammals and sea turtles are not visible within the buffer zone.

1.4.2.9 Underwater Detonations (up to 10 lb charges)

To ensure protection of marine mammals and sea turtles during underwater detonation training and mining activities, the surveillance area must be determined to be clear of marine mammals and sea turtles prior to detonation. Implementation of the following mitigation measures continue to ensure that marine mammals would not be exposed to temporary threshold shift (TTS), permanent threshold shift (PTS), or injury from physical contact with training mine shapes during Major Exercises.

1.4.2.9.1 Exclusion Zones

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

1.4.2.9.2 Pre-exercise Surveillance

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

1.4.2.9.3 Post-Exercise Surveys and Reporting

Surveillance within the same radius shall also be conducted within 30 minutes after the completion of the explosive event. If there is evidence that a marine mammal or sea turtle may have been stranded, injured or killed by the action, Navy training activities will be immediately suspended and the situation immediately reported by the participating unit to the Officer in Charge of the Exercise (OCE), who will follow Navy procedures for reporting the incident to the Commander, Navy Marianas who will contact Commander, Pacific Fleet.

1.4.2.10 Sinking Exercise

The selection of sites suitable for Sinking Exercises (SINKEXs) involves a balance of operational suitability, requirements established under the Marine Protection, Research and Sanctuaries Act (MPRSA) permit granted to the Navy (40 Code of Federal Regulations §229.2), and the identification of areas with a low likelihood of encountering ESA listed species. To meet operational suitability criteria, locations must be within a reasonable distance of the target vessels' originating location. The locations should also be close to active military bases to allow participating assets access to shore facilities. For safety purposes, these locations should also be in areas that are not generally used by non-military air or watercraft. The MPRSA permit requires vessels to be sunk in waters which are at least 2,000 yds (1,839 m) deep and at least 50 nm from land.

In general, most listed species prefer areas with strong bathymetric gradients and oceanographic fronts for significant biological activity such as feeding and reproduction. Typical locations include the shelf-edge.

1.4.2.10.1 SINKEX Mitigation Plan

The Navy has developed range clearance procedures to maximize the probability of sighting any ships or protected species in the vicinity of an exercise, which are as follows:

- All weapons firing would be conducted during the period 1 hour after official sunrise to 30 minutes before official sunset.
- Extensive range clearance 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 (μPa2-s) threshold established for the *WINSTON S. CHURCHILL* (DDG 81) shock trials (DoN, 2001). 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:
  - Overflights within the exclusion zone would be conducted in a manner that optimizes the surface area of the water observed. This may be accomplished through the use of the Navy's Search and Rescue Tactical Aid, which provides the best search altitude, ground speed, and track spacing for the discovery of small, possibly dark objects in the water based on the environmental conditions of the day. These environmental conditions include the angle of sun inclination, amount of daylight, cloud cover, visibility, and sea state.
  - All visual surveillance activities would be conducted by Navy personnel trained in visual surveillance. At least one member of the mitigation team would have completed the Navy's marine mammal training program for lookouts.
  - In addition to the overflights, the exclusion zone would be monitored by passive acoustic means, when assets are available. This passive acoustic monitoring would be maintained throughout the exercise. Potential assets include sonobuoys, which can be utilized to detect 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.

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

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

- 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.

- 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.

- 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.

• Every attempt would be made to conduct the exercise in sea states that are ideal for marine mammal sighting, Beaufort Sea State 3 or less. In the event of a 4 or above, survey efforts would be increased within the zones. This would be accomplished through the use of an additional aircraft, if available, and conducting tight search patterns.

- The exercise would not be conducted unless the exclusion zone could be adequately monitored visually.
- In the unlikely event that any listed species are observed to be harmed in the area, a detailed description of the animal would be taken, the location noted, and if possible, photos taken. This information would be provided to National Oceanic and Atmospheric Administration (NOAA) Fisheries per the stranding communication plan.
- 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.

1.4.2.11 Mitigation Measures Related to Explosive Source Sonobuoys (AN/SSQ-110A)

1.4.2.11.1 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 500 yards (457 m) at a slow speed, if operationally feasible and weather conditions permit. In dual aircraft operations, crews are allowed to 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 detonation. This 30-minute observation period may include pattern deployment time.
- For any part of the briefed pattern where a post (source/receiver sonobuoy pair) will be deployed within 1,000 yards (914 m) of observed marine mammal activity, crews will deploy the receiver ONLY and monitor while conducting a visual search. When marine mammals are no longer detected within 1,000 yards (914 m) of the intended post position, crews will co-locate the explosive source sonobuoy (AN/SSQ-110A) (source) with the receiver.
- When operationally feasible, crews will conduct continuous visual and aural monitoring of marine mammal activity. This is to include monitoring of own-aircraft sensors from first sensor placement to checking off station and out of radio frequency (RF) of these sensors.

1.4.2.11.2 AN/SSQ-110A Pattern Employment

- 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.

- Visual Detection:

  - If marine mammals are visually detected within 1,000 yards (914 m) of the explosive source sonobuoy (AN/SSQ-110A) intended for use, then that payload shall not be detonated. Aircrews may utilize this post once the marine mammals have not been re-sighted for 10 minutes, or are observed to have moved outside the 1,000 yards (914 m) safety buffer.

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

1.4.2.11.3 AN/SSQ-110A Scuttling Sonobuoys

- Aircrews shall make every attempt to manually detonate the unexploded charges at each post in the pattern prior to departing the operations area by using the "Payload 1 Release" command followed by the "Payload 2 Release" command. Aircrews shall refrain from using the "Scuttle" command when two payloads remain at a given post. Aircrews will ensure that a 1,000 yard (914 m) safety buffer, visually clear of marine mammals, is maintained around each post as is done during active search operations.

- Aircrews shall only leave posts with unexploded charges in the event of a sonobuoy malfunction, an aircraft system malfunction, or when an aircraft must immediately depart the area due to issues such as fuel constraints, inclement weather, and in-flight emergencies. In these cases, the sonobuoy will self-scuttle using the secondary or tertiary method.

- Aircrews shall ensure all payloads are accounted for. Explosive source sonobuoys (AN/SSQ-110A) that cannot be scuttled shall be reported as unexploded ordnance via voice communications while airborne, then upon landing via naval message.

- Mammal monitoring shall continue until out of own-aircraft sensor range

1.4.3 Measures Associated with the Surveillance Towed Array Sensor System – Low Frequency Active

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 will (a) commence at least 30 minutes before the first SURTASS LFA sonar transmission; (b) continue between pings; and (c) continue for at least 15 minutes after completion of a SURTASS LFA sonar transmission exercise or, if marine mammals are showing abnormal behavior patterns, for a period of time until those behavior patterns return to normal or until conditions prevent continued observations.

The Navy proposes to use 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 [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 will include daytime observations from the SURTASS LFA sonar vessel for potentially affected species. This monitoring will begin 30 minutes before sunrise, for ongoing transmissions, or 30 minutes before SURTASS LFA sonar is deployed and continue until 30 minutes after sunset or until SURTASS LFA sonar array is recovered. Personnel trained in detecting and identifying marine animals will make observations from the vessel. At least one observer, qualified by NMFS, will train, test and evaluate 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 will be immediately suspended. Transmissions will 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. Passive acoustic monitoring for low frequency sounds generated by marine mammals will be conducted when SURTASS is deployed. The following actions will be taken:

- 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 will conduct 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 HF/M3 source will be ramped-up slowly to operating levels over a period of no less than 5 minutes:

- No later than 30 minutes before the first SURTASS LFA sonar transmission;

- Prior to any SURTASS LFA sonar calibrations or tests that are not part of regular SURTASS LFA sonar transmissions; and
- Anytime after the HF/M3 source has been powered down for a period of time greater than 2 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.

1.4.3.1 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 (1 micropascal) 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 will operate continuously while the SURTASS LFA sonar is deployed. A remote display from the PC control station will be situated at the Watch Supervisor console, which will be manned 24 hours a day during all SURTASS or SURTASS LFA sonar operations at sea.

When a marine animal is detected by the HF/M3 sonar, it automatically triggers an alert to the Watch Supervisor, who will notify the Officer in Charge. The Officer in Charge will then order the immediate delay/suspension of SURTASS LFA sonar transmissions until the animal is determined to have moved beyond the mitigation zone. All contacts will be 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, as documented in the SURTASS LFA Sonar Final EIS Subchapter 2.3.2.2, has demonstrated a probability of single-ping detection above 95 percent within the LFA mitigation zone for most marine mammals.

When the SURTASS LFA sonar is deployed, all marine mammal and sea turtle sightings/ detections would be recorded and provided to NMFS as part of the Long Term Monitoring Program associated with the proposed action.

1.4.3.2 Geographic Restrictions

The SURTASS LFA sonar system would be operated in a manner that would not cause sonar sound fields to exceed 180 dB (re 1 μPa_{rms}) within "coastal exclusion zones" or within 1 kilometer of designated offshore areas that are designated as biologically important. For any annual Letter of Authorization NMFS issues for

SURTASS LFA sonar missions, NMFS' regulations establish a minimum coastal exclusion zone of 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular area. When in the vicinity of known recreational and commercial dive sites, SURTASS LFA sonar will be operated to ensure that the sound field at these sites would not exceed 145 dB.

1.5 Mitigation Requirements Proposed by NMFS' Permits Division

When the U.S. Navy conducts the training activities identified in the relevant regulations, the regulations that NMFS' Permits Division proposes to finalize requires the U.S. Navy to implement the following mitigation measures:

1 Personnel Training:

(i) All commanding officers (COs), executive officers (XOs), lookouts, Officers of the Deck (OODs), junior OODs (JOODs), maritime patrol aircraft aircrews, and Anti-submarine Warfare (ASW)/Mine Warfare (MIW) helicopter crews shall complete the NMFS-approved Marine Species Awareness Training (MSAT) by viewing the U.S. Navy MSAT digital versatile disk (DVD). All bridge lookouts shall complete both parts one and two of the MSAT; part two is optional for other personnel.

(ii) Navy lookouts shall undertake extensive training in order to qualify as a watchstander in accordance with the Lookout Training Handbook (Naval Education and Training Command [NAVEDTRA] 12968-D).

(iii) Lookout training shall include on-the-job instruction under the supervision of a qualified, experienced lookout. 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). Personnel being trained as lookouts can be counted among required lookouts as long as supervisors monitor their progress and performance.

(iv) 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 protective measures if marine species are spotted.

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

(vi) All COs, XOs, and officers standing watch on the bridge will have reviewed the Marine Species Awareness Training material prior to a training event employing the use of MFAS/HFAS.

(2) General Operating Procedures (for all training types):

(i) Prior to major exercises, a Letter of Instruction, Mitigation Measures Message or Environmental Annex to the Operational Order shall be issued to further disseminate the personnel training requirement and general marine species protective measures.

(ii) COs shall make use of marine species detection cues and information to limit interaction with marine mammals to the maximum extent possible consistent with safety of the ship.

(iii) While underway, surface vessels shall have at least two lookouts with binoculars; surfaced submarines shall have at least one lookout with binoculars. Lookouts already posted for safety of navigation and man-overboard precautions may be used to fill this requirement. As part of their regular duties, lookouts will watch for and report to the OOD the presence of marine mammals.

(iv) On surface vessels equipped with a multi-function active sensor, pedestal mounted "Big Eye" (20x110) binoculars shall be properly installed and in good working order to assist in the detection of marine mammals in the vicinity of the vessel.

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

(vi) After sunset and prior to sunrise, lookouts shall employ Night Lookouts Techniques in accordance with the Lookout Training Handbook (NAVEDTRA 12968-D).

(vii) While in transit, naval vessels shall be alert at all times, use extreme caution, and proceed at a "safe speed", which means the speed at which the CO can maintain crew safety and effectiveness of current operational directives, so that the vessel can take action to avoid a collision with any marine mammal.

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

(ix) Navy aircraft participating in exercises at-sea shall conduct and maintain surveillance for marine mammals as long as it does not violate safety constraints or interfere with the accomplishment of primary operational duties.

(x) All marine mammal detections shall be immediately reported to assigned Aircraft Control Unit for further dissemination to ships in the vicinity of the marine species as appropriate when 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.

3 Operating Procedures (for Anti-submarine Warfare Operations):

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

(ii) All surface ships participating in ASW training events shall have, in addition to the three personnel on watch noted in (i), at least two additional personnel on watch as lookouts at all times during the exercise.

(iii) 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.

(iv) 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, 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 mammal that may need to be avoided.

(v) 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.

(vi) During mid-frequency active sonar operations, personnel shall utilize all available sensor and optical systems (such as night vision goggles) to aid in the detection of marine mammals.

(vii) Aircraft with deployed sonobuoys shall use only the passive capability of sonobuoys when marine mammals are detected within 200 yds (183 m) of the sonobuoy.

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

(ix) 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.

(x) Safety Zones—When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) within or closing to inside 1,000 yds (914 m) of the sonar dome (the bow), the ship or submarine shall limit active transmission levels to at least 6 decibels (dB) below normal operating levels for that source (i.e., limit to at most 229 dB for AN/SQS-53 and 219 for AN/SQS-56, etc.).

(A) Ships and submarines shall continue to limit maximum transmission levels by this 6-dB factor until the animal has been seen to leave the 1000-yd safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (1829 m) beyond the location of the last detection.

(B) When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) the Navy shall ensure that sonar transmission levels are limited to at least 10 dB below normal operating levels if any detected marine mammals are within 500 yards (914 m) of the sonar dome (the bow). Ships and submarines shall continue to limit maximum ping levels by this 10-dB factor until the animal has been seen to leave the 500-yd safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (457 m) beyond the location of the last detection.

(C) When marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) the Navy shall ensure that sonar transmission ceases if any detected marine mammals are within 200 yards (about 61 m) of the sonar dome (the bow). Sonar shall not resume until the animal has been seen to leave the

200-yd safety zone, has not been detected for 30 minutes, or the vessel has transited more than 2,000 yds (457 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 OOD 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.

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

(xii) Active sonar levels (generally)—Navy shall operate active sonar at the lowest practicable level, not to exceed 235 dB, except as required to meet tactical training objectives.

(xiii) Submarine sonar operators will review detection indicators of close-aboard marine mammals prior to the commencement of ASW training events involving MFAS.

(E) If the need for power-down should arise (as detailed in 218.114(a)(3)(x)) when the Navy was operating a hull-mounted or sub-mounted source above 235 db (infrequent), the 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 active sonar was being operated).

3 Operating Procedures for Underwater Detonations (up to 10-lb charges):

(i) Exclusion Zones - All demolitions and ship mine countermeasures training exercises involving the use of explosive charges must include exclusion zones for marine mammals to prevent physical and/or acoustic effects to those species. These exclusion zones shall extend in a 700-yard arc radius around the detonation site. Should a marine mammal be present within the the surveillance area, the explosive event shall not be started until the animal leaves the area.

(ii) Pre-Exercise Surveys - For Demolition and Ship Mine Countermeasures Operations, pre-exercise surveys shall be conducted 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, and personnel shall be alert to the presence of any marine mammal. Should such an animal be present within the survey area, the explosive event shall not be started until the animal voluntarily leaves the area. The Navy will ensure the area is clear of marine mammals for a full 30 minutes prior to initiating the explosive event. Personnel will record any marine mammal observations during the exercise as well as measures taken if species are detected within the exclusion zone.

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

(iv) Reporting - If there is evidence that a marine mammal may have been stranded, injured or killed by the action, Navy training activities shall be immediately suspended and the situation immediately reported by the participating unit to the Officer in Charge of the Exercise (OCE), who will follow Navy procedures for reporting the incident to Commander, Pacific Fleet, Commander, Navy Region Northwest, Environmental Director, and the chain-of-command. The situation shall also be reported to NMFS (see Stranding Plan for details).

4 Sinking Exercise:

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

(ii) An exclusion zone with a radius of 1.0 nm (1.9 km) will be established around each target. An additional buffer of 0.5 nm (0.9 km) will be added to account for errors, target drift, and animal movements. Additionally, a safety zone, which will extend beyond the buffer zone by an additional 0.5 nm (0.9 km), would be surveyed. Together, the zones extend out 2 nm (3.7 km) from the target.

(iii) 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 shall 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 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 shall be conducted by Navy personnel trained in visual surveillance. At least one member of the mitigation team will 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 would be maintained throughout the exercise. Additionally, passive sonar onboard submarines may be utilized to detect any vocalizing marine mammals in the area. The OCE will be informed of any aural detection of marine mammals and will 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 2 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 may commence until the OCE declares the safety and exclusion zones free of marine mammals.

(F) If a marine mammal is observed within the exclusion zone, firing will 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 can be assumed to have left the exclusion zone. The OCE will determine if the marine mammal 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 shall again be surveyed for any marine mammal. If marine mammals are sighted within the exclusion zone or buffer zone, the OCE shall be notified, and the procedure described above shall be followed.

(H) Upon sinking of the vessel, a final surveillance of the exclusion zone shall be monitored for 2 hours, or until sunset, to verify that no marine mammals were harmed.

(iv) Aerial surveillance shall 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 shall be used. These aircraft shall 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.

(v) Every attempt shall be made to conduct the exercise in sea states that are ideal for marine mammal sighting, Beaufort Sea State 3 or less. In the event of a 4 or above, survey efforts shall be increased within the zones. This shall be accomplished through the use of an additional aircraft, if available, and conducting tight search patterns.

(vi) The exercise shall not be conducted unless the exclusion zone and the buffer zone could be adequately monitored visually. Should low cloud cover or surface visibility prevent adequate visual monitoring as described previously, the exercise would be delayed until conditions improved, and all of the above monitoring criteria could be met.

(vii) In the event that any marine mammals are observed to be harmed in the area, a detailed description of the animal shall be taken, the location noted, and if possible, photos taken of the marine mammal. This information shall be provided to NMFS via the Navy's regional environmental coordinator for purposes of identification (see the draft Stranding Plan for detail).

(viii) 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 shall be submitted to NMFS.

5 Surface-to-Surface Gunnery (up to 5-inch Explosive Rounds)

(i) For exercises using targets towed by a vessel, target-towing vessels shall maintain a trained lookout for marine mammals when feasible. If a marine mammal is sighted in the vicinity, the tow vessel will immediately notify the firing vessel, which will suspend the exercise until the area is clear.

(ii) A 600 yard (585 m) radius buffer zone will be established around the intended target.

(iii) From the intended firing position, trained lookouts will survey the buffer zone for marine mammals prior to commencement and during the exercise as long as practicable. Due to the distance between the firing position and the buffer zone, lookouts are only expected to visually detect breaching whales, whale blows, and large pods of dolphins and porpoises.

(iv) The exercise will be conducted only when the buffer zone is visible and marine mammals are not detected within it.

6 Surface-to-Surface Gunnery (non-explosive rounds)

(i) A 200-yd (183 m) radius buffer zone shall be established around the intended target.

(ii) From the intended firing position, trained lookouts shall survey the buffer zone for marine mammals prior to commencement and during the exercise as long as practicable.

(iii) If available, target towing vessels shall maintain a lookout (unmanned towing vessels will not have a lookout available). If a marine mammal is sighted in the vicinity of the exercise, the tow vessel shall immediately notify the firing vessel in order to secure gunnery firing until the area is clear.

(iv) The exercise shall be conducted only when the buffer zone is visible and marine mammals are not detected within the target area and the buffer zone.

7 Surface-to-Air Gunnery (Explosive and Non-explosive Rounds)

(i) Vessels will orient the geometry of gunnery exercises in order to prevent debris from falling in the area of sighted marine mammals.

(ii) Vessels will attempt to recover any parachute deploying aerial targets to the extent practicable (and their parachutes if feasible) to reduce the potential for entanglement of marine mammals.

(iii) Target towing aircraft shall maintain a lookout if feasible. If a marine mammal is sighted in the vicinity of the exercise, the tow aircraft will immediately notify the firing vessel in order to secure gunnery firing until the area is clear.

8 Air-to-Surface Gunnery (Explosive and Non-explosive Rounds)

(i) A 200 yard (183 m) radius buffer zone will be established around the intended target.

(ii) If surface vessels are involved, lookout(s) will visually survey the buffer zone for marine mammals to and during the exercise.

(iii) Aerial surveillance of the buffer zone for marine mammals will be conducted prior to commencement of the exercise. Aerial surveillance altitude of 500 feet to 1,500 feet (152 – 456 m) is optimum. Aircraft crew/pilot will maintain visual watch during exercises. Release of ordnance through cloud cover is prohibited; aircraft must be able to actually see ordnance impact areas.

(iv) The exercise will be conducted only if marine mammals are not visible within the buffer zone.

9 Small Arms Training (Grenades, Explosive and Non-explosive Rounds) - Lookouts will visually survey for marine mammals. Weapons will not be fired in the direction of known or observed marine mammals.

10 Air-to-Surface At-sea Bombing Exercises (explosive bombs and rockets):

(i) If surface vessels are involved, trained lookouts shall survey for marine mammals. Ordnance shall not be targeted to impact within 1,000 yds (914 m) of known or observed marine mammals.

(ii) A 1,000 yd (914 m) radius buffer zone shall be established around the intended target.

(iii) Aircraft shall visually survey the target and buffer zone for marine mammals prior to and during the exercise. The survey of the impact area shall be made by flying at 1,500 ft (152 m) or lower, if safe to do so, and at the slowest safe speed. When safety or other considerations require the release of weapons without the releasing pilot having visual sight of the target area, a second aircraft, the "wingman," will clear the target area and perform the clearance and observation functions required before the dropping plane may release its weapons. Both planes must have direct communication to assure immediate notification to the dropping plane that the target area may have been fouled by encroaching animals or people. The clearing aircraft will assure it has visual site of the target area at a maximum height of 1500 ft. The clearing plane will remain within visual sight of the target until required to clear the area for safety reasons. Survey aircraft shall employ most effective search tactics and capabilities. Survey aircraft should employ most effective search tactics and capabilities.

(iv) The exercise will be conducted only if marine mammals are not visible within the buffer zone.

11 Air-to-Surface At-Sea Bombing Exercises (Non-explosive Bombs and Rockets)

(i) If surface vessels are involved, trained lookouts will survey for marine mammals. Ordnance shall not be targeted to impact within 1,000 yards (914 m) of known or observed or marine mammals.

(ii) A 1,000 yard (914 m) radius buffer zone will be established around the intended target.

(iii) Aircraft will visually survey the target and buffer zone for marine mammals prior to and during the exercise. The survey of the impact area will be made by flying at 1,500 feet

(152 m) or lower, if safe to do so, and at the slowest safe speed. When safety or other considerations require the release of weapons without the releasing pilot having visual sight of the target area, a second aircraft, the "wingman," will clear the target area and perform the clearance and observation functions required before the dropping plane may release its weapons. Both planes must have direct communication to assure immediate notification to the dropping plane that the target area may have been fouled by encroaching animals or people. The clearing aircraft will assure it has visual site of the target area at a maximum height of 1500 ft. The clearing plane will remain within visual sight of the target until required to clear the area for safety reasons. Survey aircraft shall employ most effective search tactics and capabilities.

(iv) The exercise will be conducted only if marine mammals and are not visible within the buffer zone.

12 Air-to-Surface Missile Exercises (explosive and non-explosive):

(i) Aircraft will visually survey the target area for marine mammals. Visual inspection of the target area will be made by flying at 1,500 (457 m) feet or lower, if safe to do so, and at slowest safe speed. Firing or range clearance aircraft must be able to actually see ordnance impact areas.

(ii) Explosive ordnance shall not be targeted to impact within 1,800 yds (1646 m) of sighted marine mammals.

13 Aircraft Training Activities Involving Non-Explosive Devices:

Non-explosive devices such as some sonobuoys, inert bombs, and Mining Training Activities involve aerial drops of devices that have the potential to hit marine mammals if they are in the immediate vicinity of a floating target. The exclusion zone (200 yd), therefore, shall be clear of marine mammals and around the target location. Pre- and post-surveillance and reporting requirements outlined for underwater detonations shall be implemented during Mining Training Activities.

14 Extended Echo Ranging/Improved Extended Echo Ranging and Advanced Extended Echo-ranging (EER/IEER/AEER) - The following mitigation measures shall be used with the employment of IEER/AEER sonobuoys:

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

(ii) For IEER (AN/SSQ-110A), crews shall conduct a minimum of 30 minutes of visual and aural monitoring of the search area prior to commanding the first post detonation. This 30-minute observation period may include pattern deployment time.

(iii) For any part of the intended sonobuoy pattern where a post (source/receiver sonobuoy pair) will be deployed within 1,000 yd (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 yd (914 m) of the intended post position, the source sonobuoy (AN/SSQ-110A/SSQ-125) will be co-located with the receiver.

(iv) When operationally feasible, Navy crews shall conduct continuous visual and aural monitoring of marine mammal activity. This shall include monitoring of own-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, then that shall cue the Navy aircrew to increase the diligence of their visual surveillance. Subsequently, if no marine mammals are visually detected, then the crew may continue multi-static active search.

(vi) Visual Detection - If marine mammals are visually detected within 1,000 yd (914 m) of the explosive source sonobuoy (AN/SSQ-110A/SSQ-125) intended for use, then that payload shall not be activated. 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 yd (914 m) safety buffer. Aircrews may shift their multi-static active search to another post, where marine mammals are outside the 914 m (1,000 yd) safety buffer.

(vii) For IEER (AN/SSQ-110A), 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 shall ensure that a 1,000 yd (914 m) safety buffer, visually clear of marine mammals, is maintained around each post as is done during active search operations.

(viii) Aircrews shall only leave posts with unexploded charges in the event of a sonobuoy malfunction, an aircraft system malfunction, or when an aircraft must immediately depart the area due to issues such as fuel constraints, inclement weather, and in-flight emergencies. In these cases, the sonobuoy will self-scuttle using the secondary or tertiary method.

(ix) The Navy shall ensure all payloads are accounted for. Explosive source sonobuoys (AN/SSQ-110A) that can not 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.

15 The Navy shall abide by the letter of the “Stranding Response Plan for Major Navy Training Exercises in the MIRC” (available at: http://www.nmfs.noaa.gov/pr/permits/incidental.htm), which is incorporated herein by reference, to include the following measures:

(i) Shutdown Procedures – When an Uncommon Stranding Event (USE – defined in § 218.271) occurs during a Major Training Exercise (MTE) (as defined in the Stranding Plan, meaning including Multi-strike group exercises, Joint Expeditionary exercises, and

Marine Air Ground Task Force exercises in the MIRC), the Navy shall implement the procedures described below.

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

(B) 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).

(C) If the Navy finds an injured or dead marine mammal 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 behaviors (if alive), and photo or video of the animals (if available). Based on the information provided, NMFS shall determine if, and advise the Navy whether a modified shutdown is appropriate on a case-by-case basis.

(D) 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/HFAS activities or explosive detonations, though farther than 14 nm from the distressed animal(s), is likely decreasing the likelihood that the animals return to the open water. If so, NMFS and the Navy shall further coordinate to determine what measures are necessary to further minimize that likelihood and implement those measures as appropriate.

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

16. Requirements for monitoring and reporting.

(a) General Notification of Injured or Dead Marine Mammals - Navy personnel shall ensure that NMFS is notified immediately ((see Communication Plan) or as soon as clearance procedures allow) if an injured, stranded, 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 will provide NMFS with the name of 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). In the event that an injured, stranded, or dead marine mammal is found by the Navy that is not in the vicinity of, or during or shortly after, MFAS, HFAS, or underwater explosive detonations, the Navy will report the same information as listed above as soon as operationally feasible and clearance procedures allow.

(b) General Notification of Ship Strike - In the event of a ship strike by any Navy vessel, at any time or place, the Navy shall do the following:

(1) Immediately report to NMFS the species identification (if known), location (lat/long) of the animal (or the strike if the animal has disappeared), and whether the animal is alive or dead, or whether its status is unknown.

(2) Report to NMFS as soon as operationally feasible the size and length of animal, an estimate of the injury status (ex., dead, injured but alive, injured and moving, unknown, etc.), vessel class/type and operational status.

(3) Report to NMFS the vessel length, speed, and heading as soon as feasible.

(4) Provide NMFS a photo or video, if equipment is available

(c) The Navy must conduct all monitoring and/or research required under the Letter of Authorization, including abiding by the annual MIRC Monitoring Plan. (http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications)

(d) Report on Monitoring required in paragraph (e) of this section – The Navy shall submit a report annually describing the implementation and results of the monitoring required in paragraph (d) of this section. Required submission date will be identified each year in the LOA. Navy will standardize data collection methods across ranges to allow for comparison in different geographic locations.

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

(1) Location of the exercise;

(2) Beginning and end dates of the exercise; and

(3) Type of exercise.

(f) Annual MIRC Report - The Navy will submit an Annual Exercise MIRC Report every year. This report shall contain the subsections and information indicated below.

(1) MFAS/HFAS Major Training Exercises - This section shall contain the following information for the following Coordinated and Strike Group exercises, which for simplicity will be referred to as major training exercises for reporting (MTERs): Joint Multi-strike Group Exercises; Joint Expeditionary Exercises; and Marine Air Ground Task Force MIRC:

(i) Exercise Information (for each MTER):

(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.)); and

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

(ii) Individual marine mammal sighting info (for each sighting in each MTER):

(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(s);

(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 (x) 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); and

(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 MTERs) of the effectiveness of mitigation measures designed to avoid exposing marine mammals to MFAS. 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 non-major training exercises (unit-level exercises, such as TRACKEXs):

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

(ii) Cumulative Impacts - To the extent practicable, the Navy, in coordination with NMFS, shall develop and implement a method of annually reporting non-major training (i.e., ULT) utilizing hull-mounted sonar. The report shall present an annual (and seasonal, where practicable) depiction of non-major training exercises geographically across MIRC. The Navy shall include (in the MIRC annual report) a brief annual progress update on the status of the development of an effective and unclassified method to report this information until an agreed-upon (with NMFS) method has been developed and implemented.

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

(i) Exercise Info:

(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); and

(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 during SINKEX (by Navy lookouts) information:

(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) 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 (TBD m for SINKEX in MIRC);

(2) the required exclusion zone (1 nm for SINKEX in MIRC);

(3) the required observation distance (if different than the exclusion zone (2 nm for SINKEX in MIRC); and

(4) greater than the required observed distance. For example, in this case, the observer shall indicate if < TBD m, from 426 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 animals (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 munitions type in use at time of marine mammal detection.

(4) Improved Extended Echo-Ranging System (IEER)/Advanced Extended Echo-Ranging (AEER) Summary:

(i) Total number of IEER and AEER events conducted in MIRC;

(ii) Total expended/detonated rounds (buoys); and

(iii) Total number of self-scuttled IEER rounds.

(5) Explosives Summary - The Navy is in the process of improving the methods used to track explosive use to provide increased granularity. To the extent

practicable, the Navy shall 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 exercise (of those identified as part of the "specified activity" in this final rule) conducted in MIRC; and

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

(g) MIRC 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 MIRC Exercise Reports and MIRC Monitoring Plan Reports). This report will be submitted at the end of the fourth year of the rule (November 2014), covering activities that have occurred through July 15, 2014.

(h) Comprehensive National ASW Report - By June, 2014, the Navy shall submit a draft National Report that analyzes, compares, and summarizes the active sonar data gathered (through January 1, 2014) from the watchstanders and pursuant to the implementation of the Monitoring Plans for the Northwest Training Range Complex, the Southern California Range Complex, the Atlantic Fleet Active Sonar Training, the Hawaii Range Complex, the Marianas Islands Range Complex, and the Gulf of Alaska.

(i) The Navy shall comply with the 2009 Integrated Comprehensive Monitoring Program (ICMP) Plan and continue to improve the program in consultation with NMFS. Changes and improvements to the program made during 2010 (as prescribed in the 2009 ICMP and otherwise deemed appropriate by the Navy and NMFS) will be described in an updated 2010 ICMP and submitted to NMFS by October 31, 2010 for review. An updated 2010 ICMP will be finalized by December 31, 2010.

2.0 Approach to the Assessment

2.1 Overview of NMFS' Assessment Framework

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

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

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

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

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

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 current or expected future reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual's probable response to stressors produced by an Action would reasonably be expected to reduce the individual's current or expected future reproductive success by increasing the individual's likelihood of dying prematurely, having reduced longevity, increasing the age at which individuals become reproductively mature, reducing the age at which individuals stop reproducing, reducing the number of live births individual produce during any reproductive bout, reducing the number of times an individual is likely to reproduce over its reproductive lifespan (in animals that reproduce multiple times), or causing an individual's progeny to experience any of these phenomena (Brommer *et al*. 1998, 2000, 2002; Clutton-Brock 1988, Coulson *et al*. 2006, Crowe *et al*. 2004, Fox and Gurevitch 2000, Kotiaho *et al*. 2005, McGraw and Caswell 1996, Newton 1989, Oli and Dobson 2003, Reed 2005, Roff 2002, Stearns 1992, Turchin 2003).

When individual, listed plants or animals are expected to experience reductions in their current or expected future reproductive success, 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. On the other hand, when listed plants or animals exposed to an Action's effects are *not* expected 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 (for example, see Anderson 2000, Mills and Beatty 1979, Stearns 1992). If we conclude that listed plants or animals are *not* likely to experience reductions in their fitness, we would conclude our assessment.

If, however, we conclude that listed plants or animals are likely to experience reductions in their current or expected future reproductive success, our assessment tries to determine if those 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. The primary advantage of this approach is that it considers the consequences of the response of endangered and threatened species in terms of fitness costs, which allows us to assess how particular behavioral decisions are likely to influence individual reproductive success (Bejder et al. 2009). Individual-level effects can then be translated into changes in demographic parameters of populations, thus allowing for an assessment of the biological significance of particular human disturbances.

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

RISK ANALYSES FOR DESIGNATED CRITICAL HABITAT. Our "destruction or adverse modification" determinations must be based on an action's effects on the conservation value of habitat that has been designated as critical to threatened or endangered species3. If an area encompassed in a critical habitat designation is

3 We are aware that several courts have ruled that the definition of destruction or adverse modification that appears in the section 7 regulations at 50 CFR 402.02 is invalid and do not rely on that definition for the determinations we make in this Opinion. Instead, as we explain in the text, we use the "conservation value" of critical habitat for our determinations which focuses on the designated area's ability to contribute to the conservation or the species for which the area was designated.

likely to be exposed to the *direct or indirect consequences of the proposed action on the natural environment*, we ask if primary or secondary constituent elements included in the designation (if there are any) or physical, chemical, or biotic phenomena that give the designated area value for the conservation are likely to respond to that exposure.

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

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

In this step of our assessment, we must identify or make assumptions about (a) the habitat's probable condition before any exposure as our point of reference (that is part of the impact of the *Environmental Baseline* on the conservation value of the designated critical habitat); (b) the ecology of the habitat at the time of exposure; (c) where the exposure is likely to occur; and (d) when the exposure is likely to occur; (e) the intensity of exposure; (f) the duration of exposure; and (g) the frequency of exposure.

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

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

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

2.2 Application of this Approach in this Consultation

The primary stressors associated with the military readiness activities the U.S. Navy proposes to conduct in waters on and adjacent to the Mariana Islands Range Complex consist of:

1. surface vessels and submarines involved in training activities and the associated risk of collisions;
2. pressure waves produced by the underwater detonations;
3. projectiles associated with firing operations;
4. sound fields produced by the low-, mid-, and high-frequency active sonar systems the U.S. Navy would employ during the training activities it proposes;
5. sound fields produced by the underwater detonations the U.S. Navy would employ during the training activities it proposes;
6. disturbance produced by surface vessels and aircraft involved in training activities;
7. the chemical constituents of explosives, ordnance, chaff, and flares; and
8. parachutes associated with flares and sonobuoys.

The first step of our analysis evaluates the available evidence to determine the likelihood of listed species or critical habitat being exposed to these potential stressors. Our analysis assumed that these stressors pose no risk to listed species or critical habitat if these potential stressors do not co-occur, in space or time, with (1) individuals of endangered or threatened species or units of critical habitat that has been designated for endangered or threatened species; (2) species that are food for endangered or threatened species; (3) species that prey on or compete with endangered or threatened species; (4) pathogens for endangered or threatened species. During our analyses, we did not identify situations where species the proposed training activities are likely to indirectly affect endangered or threatened species by disrupting marine food chains, or by adverse affecting the predators, competitors, or forage base of endangered or threatened species.

2.2.1 Exposure Analyses

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

For our exposure analyses, NMFS generally relies on an action agency's estimates of the number of marine mammals that might be "taken" (as that term is defined for the purposes of the MMPA).In a small number of consultations, however, NMFS has conducted separate analyses to estimate the number of endangered or threatened marine animals that might be exposed to stressors produced by a proposed action to assess the effect of assumptions in an action agency's model on model estimates. For example, NMFS used a model based on components of Hollings' disc equation (1959) to independently estimate the number of marine mammals that might be exposed to U.S. Navy training activities in a few recent consultations that satisfied the following conditions:

1 the sole or primary stressor was hull-mounted mid-frequency active sonar and

2 data were available on (2a) the density of endangered or threatened animals in an action area, (2b) the ship's speed, (2c) the radial distance at which different received levels would be detected from a source given sound speed profiles, and (2d) the duration of specific training exercises.

These conditions have been met in five of the 23 consultations NMFS has completed on U.S. Navy training since 2002 (for example, opinions on anti-submarine warfare training on the U.S. Navy's Hawai'i Range Complex and Southern California Range Complex) so NMFS conducted independent exposure analyses and included the results of those analyses in biological opinions on those actions. In the remaining opinions, hull-mounted mid-frequency active sonar was not the primary stressor associated with proposed training or the data for one of the model's variables were not available.

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 Mariana Islands Range Complex:

1. the method the U.S. Navy and the Permits Division develop to produce 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 Mariana Islands Range Complex. The incidental "take" the Permits Division proposes to authorize in the proposed 5-year regulations reflect these "take" estimates; and

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

The first approach cited in this list was designed to estimate the number of times marine mammals might be "taken" (as that term is defined pursuant to the MMPA) as a result of being exposure to active sonar or underwater detonations during U.S. Navy training, which is a subset of the number of animals that might be exposed to those training activities or respond given exposure. Although the U.S. Navy's modeling efforts and the results of NMFS' exposure models may produce similar numerical results, the U.S. Navy and Permits

Division estimated the number of times marine mammals might be 'taken' given that they have been exposed and respond to that exposure while we estimated the number of times marine mammals might be exposed to those activities. As a result, the "take" estimates produced by the U.S. Navy and the Permits Division are not comparable to the exposure estimates we produce in this Opinion.

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

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

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

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

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

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

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

We relied on published sources of information and information contained in the U.S. Navy's Environmental Impact Statement on the Mariana Islands Range Complex (which itself relies on published sources) to estimate the density of endangered and threatened marine mammals in waters off Mariana Islands., then we relied on a component of an established ecological model developed by Holling (1959) to estimate D or the ensonified area. Holling (1959) studied predation of small mammals on pine sawflies and found that predation rates increased with increasing densities of prey populations. In that paper, Holling proposed a model that is commonly called the "disc equation" because it describes the path of foraging predators as a moving disc that represents the predator's sensory field (normally with two-dimensions) as it searches for prey (see Figure 10). Although, Holling developed what is commonly called "the disc equation" to describe a predator's functional response to prey densities, a component of his equation estimates the number or prey a predator is likely to encounter during a foraging bout. This component of the disc equation combines the diameter of the predator's speed (s; units are distance/time), the predator's sensory field ($2r$; units are distance; here we use nautical miles), the time the predator spends searching for prey (T_s; units are distance) to estimate the area searched by a predator (the units (distance/time)(distance)(time) = $(\text{distance})^2$ = area). Because a predator is not likely to detect all prey within an area, a "detectability" variable (denoted *k;*

which ranges from 0.0 to 1.0) expresses this limitation. This produces the equation

No. prey encountered = [k(s • 2r • T_s)] • "prey" per unit area

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

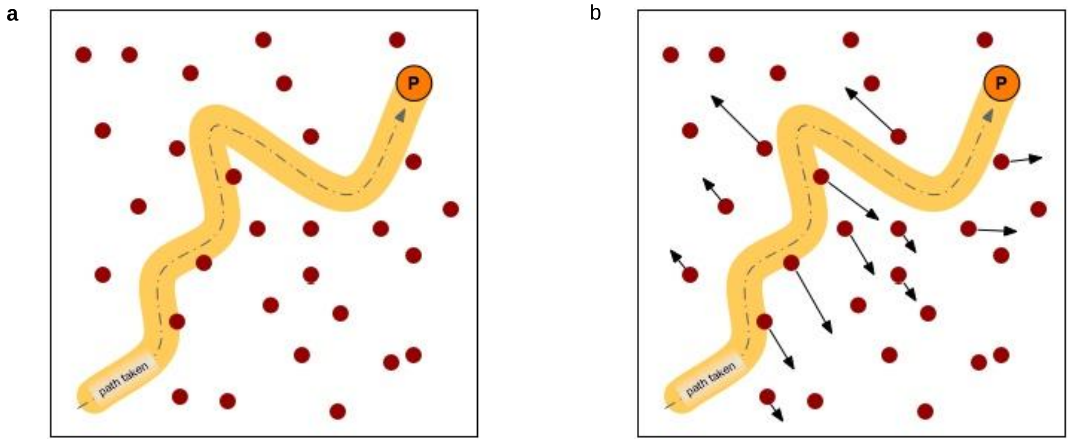

Figure 10. A representation of Hollings disc equation with a predator (denoted P) moving on a path (dashed line) through a field of potential prey (smaller circles). The thick orange line surrounding the predator's path represents the predator's sensory radius; increasing the size of this sensory radius increases the width of the area search per unit time. Similarly, assuming that everything else is equal, increasing a predator's speed would also increase the area the predator searches in a unit of time. The number of prey a predator encounters on a path = (the area searched)(prey density) = (search velocity)(sensory diameter)(time spent searching)(prey density). **Figure 10a** illustrates a situation in which prey do not try to avoid a predator. **Figure 10b** illustrates a situation in which prey actively try to avoid a predator. The exposure models NMFS developed simulated prey avoidance by reducing prey density along a predator's path over time. See text for further explanation.

NMFS adapted this component of the Holling's disc equation by treating Navy vessels to "predators," whose sensory field (2*r*, in square kilometers) represented the sound field of an active sonar system and speed (*s*) represented 10 knots, and whose search time represented the duration of an exercise (in hours). We treated the different species of endangered or threatened marine mammals as "prey." We assumed the "detect-ability" 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, Guadalupe fur seals). This left us with the equation

No. individuals encountered = [k(s • 2r • T_s)] • density of marine mammal species

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

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

The exposure model we developed assumed ship speeds of 10 knots (or 18.25 kilometers per hour), which is the same assumption contained in the Navy's models. The "sensory field" (2r) in the model represented the U.S. Navy's estimates of the area that would be ensonified at different received levels presented in the U.S. Navy's Environmental Impact Statements for the Mariana Islands Range Complex, adjusted to eliminate overlap (U.S. Navy 2009). Our exposure model was also based on the Navy's estimates of the number of hours of the different kinds of active sonar that would be employed in the different exercises.

2.2.2 Response Analyses

As discussed in the introduction to this section of this Opinion, once we identified which listed resources were likely to be exposed to active sonar, underwater detonations, and disturbance associated with the proposed training activities and the nature of that exposure, we examined the scientific and commercial data available to determine whether and how those listed resources are likely to respond given their exposure (Figure 2). Prior to this consultation, we made several major changes to the conceptual model that forms the foundation for our response analyses. First, we constructed our revised model on a model of animal behavior and behavioral decision-making, which incorporates the cognitive processes involved in behavioral decisions; earlier versions of this model ignored critical components of animal behavior and behavioral decision-making. As a result, our revised model assumes that Navy training activities primarily affect endangered and threatened species by changing their behavior, although we continue to recognize the risks of physical trauma and noise-induced losses in hearing sensitivity (threshold shift). Second, we expanded our conception of "hearing" that includes cognitive processing of auditory cues, rather than a focus solely on the mechanical processes of the ear and auditory nerve. Third, our revised model incorporates the primary mechanisms by which behavioral responses affect the longevity and reproductive success of animals: changing an animal's energy budget, changing an animal's time budget (which is related to changes in an animal's energy budget), forcing animal's to make life history trade-offs (for example, engaging in evasive behavior such a deep dives that involve short-term risks while promoting long-term survival), or changes in social interactions among groups of animals (for example, interactions between a cow and her calf).

Like our earlier conceptual models (presented in Southall *et al* 2008), this conceptual model begins with acoustic stimuli we focus on in an assessment (Box 1 in Figure 11). In this case, we treat the active sonar and any pressure waves or sound fields associated with underwater detonations as separate focal stimuli. The preceding section of our *Approach* described how we estimated the number of animals that are likely to be exposed to those acoustic stimuli associated with the proposed training activities and the nature of that exposure.

The stressors that would be associated with the training activities the U.S. Navy proposes to conduct at the Mariana Islands Range Complex consist of two classes: *processive stressors*, which require high-level cognitive processing of sensory information, and *systemic stressors*, which usually elicit direct physical or physiological responses and, therefore, do not require high-level cognitive processing of sensory information (Anisman and Merali 1999, de Kloet 2003, Herman and Cullinan 1997). Disturbance from surface vessels and active sonar would be examples of processive stressors while ship strikes and pressure waves associated with underwater detonations would be examples of systemic stressors (the sound field produced by an underwater detonation would be a systemic stressor close to the explosion and a processive stressor further away). As a result, exposures resulting from the proposed training exercises are likely to result in 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 11: Behavioral Response).
2. responses that are not influenced by the animal's assessment of whether a potential stressor poses a threat or risk (see Figure 11: Physical Damage).

Unlike our earlier conceptual model, our revised model explicitly acknowledges the existence of other acoustic and non-acoustic stimuli in an animal's environment that might diminish the focal stimulus' salience (the line connecting Box 2b. to Box 2) or that might compete for the animal's finite attentional resources, which would affect the salience of the focal stimulus as perceived by the animal (the line connecting Box 2b to Box B4). Absent information to the contrary, our assessment assume the focal stimulus remains salient regardless of competing stimuli and the limited attentional resources of animals. By extension, we assume that any behavioral change we might observe in an animal would have been caused by the focal stimulus rather than competing stimuli.

If we conclude (or if we assume) that an acoustic stimulus, such as mid-frequency active sonar, was salient, we would then ask how an animal might classify the stimulus as a cue about its environment (Box B2) because an animal's response to a stimulus in its environment will depend upon whether and how the animal converts the stimulus into some information about its environment (Blumstein and Bouskila 1996, Yost

---

4 see Blumstein and Bouskila (1996) for more extensive reviews of the literature on how animals process and filter sensory information, which affects the subjective salience of sensory stimuli. See Crick (1984), Dukas (2002), Dukas and Real (19993), and Roitblat (1987) for more extensitve reviews of the literature on attentional processes and the consequences of limited attentional resources.

2007). For example, if an animal classifies a stimulus as a "predatory cue," that classification will invoke a suite of candidate physical, physiological, or behavioral responses that are appropriate to being confronted by a predator (this would occur regardless of whether a predator is, in fact, present).

Our revised conceptual model departs from our earlier model and models advanced by the U.S. Navy and others by adopting a more expansive concept of "hearing." Other conceptions of the sensory modality that we call "hearing" have focused on the the mechanical processes associated with structures in the ear that transduce sound pressure waves into vibrations and vibrations to electro-chemical impulses. That concept-tion of hearing resulted in assessments that focus exclusively on active sonar while discounting other acoustic stimuli associated with U.S. Navy training activities that marine animals might also perceive as relevant. That conception of hearing also led to an almost singular focus on the intensity of the sound ─ its received level (in decibels) ─ as an assessment metric and noise-induced hearing loss as an assessment endpoint. Among other considerations, that focus fails to recognize that animals will tend to treat sounds as environmental cues (a stimulus that provides information about an animal's environment); that animals have to decide which environmental cues they will focus on given that their ability to process those cues is limited; that animals can distinguish not only perceive received levels, they also perceive their distance from a sound source; that both received levels and the spectral qualities of sounds degrade over distance so an animal that receives the signal at some distance from the source would not receive the same signal as an animal that is close to the sound's source; that animals are more likely to devote attentional resources to those environmental cues that are proximate than cues that are distant.

Our revised conceptual model expands the conception of "hearing" to include a mechanical-cognitive-perceptual processes. That is, it includes the mental processes an animal employs when it analyzes acoustic impulses (see Aikin 1990, Bregman 1990, Blumstein and Bouskila 1996, Hudspeth 1997, Pickles 1982, Yost 2007), which includes the processes animals employ to integrate and segregate sounds and auditory streams and the circumstances under which they are likely to devote attentional resources to an acoustic stimulus. As a result of this shift in focus, we have to consider more than the received level of a particular low- or mid-frequency wave form and its effects on the sensitivity of an animal's ear structure, we also have to distinguish between different auditory scenes; for example, animals will distinguish between sounds from a source that is moving away versus a sound produced by a source that is approaching them, sounds from multiple sources that are all approaching, and sounds from multiple sources that appear to be moving at random, etc

Animals would then combine their perception of the acoustic stimulus with their assessment of the auditory scene (which include other acoustic stimuli), their awareness of their behavioral state, physiological state, reproductive condition, and social circumstances to assess whether the acoustic stimulus poses a risk and the degree of risk it might pose, whether it is impairing their ability to communicate with conspecifics, whether it is impairing their ability to detect predators or prey, etc. We assume that animals would classify an acoustic source differently if the source is moving towards the animal's current position (or projected position), moving away from the animal's position, moving tangential to the animal's position, if the source is stationary, or if there are multiple acoustic sources in the animal's auditory field.

This process of "classifying a stimulus" (Box B2) lends meaning to a stimulus and places the animal in a position to decide whether and how to respond to the stimulus (Blumstein and Bouskila 1996, Bottledooren *et al*. 2008). How an animal classifies a stimulus will determine the set of candidate responses that are appropriate. That is, we assume that animals that classified a stimulus as a "predatory cue" would invoke candidate responses that consisted of anti-predator behavior rather than foraging behavior (Bejder *et al*. 2009, Blumstein and Bouskila 1996). We then assume that animals apply one or more behavioral decision rules to the set of candidate responses that are appropriate to the acoustic stimulus as it has been classified (Box B3). Our use of the term "behavioral decision rule" follows Blumstein and Bouskila (1996), Dill (1987), McFarland (1987), and Lima and Dill (1990) and is synonymous with the term "behavioral policy" of McNamara and Houston (1986): the process an animal applies to determine which specific behavior it will select from the set of behaviors that are appropriate to the auditory scene, given its physiological and behavioral state when exposed and its experience. Because we would never know the behavioral policy of an individual, free- ranging animal, we treat this policy as a probability distribution function that matches the vector of candidate behavioral responses.

Once an animal selects a behavioral response from a set of candidate behaviors, we would assume that any change in behavior would represent a shift from an optimal behavioral state (or behavioral act) to a sub-optimal behavioral state (or behavioral act) and that the selection of the sub-optimal behavioral state or act would be accompanied by *canonical costs*, which are reductions in the animal's expected future reproductive success that would occur when an animal engages in suboptimal behavioral acts (McNamara and Houston 1986). Specifically, canonical costs represent a reduction in current and expected future reproductive success (which integrates survival and longevity with current and future reproductive success) that would occur when an animal engages in a sub-optimal rather than an optimal sequence of behavioral acts; given the pre-existing physiological state of the animal in a finite time interval (Barnard and Hurst 1996, Houston 1993, McFarland and Sibly 1975, McNamara 1993, McNamara and Houston 1982, 1986, 1996; Nonacs 2001). Canonical costs would generally result from changes in animals' energy budgets (McEwen and Wingfield 2003, Moberg 2000; Romero 2004, Sapolsky 1990, 1997), time budgets (Frid and Dill 2002, Sutherland 1996), life history trade-offs (Cole 1954, Stearns 1992), changes in social interactions (Sutherland 1996), or combinations of these phenomena (see Box B4 of Figure 11). We assume that an animal would not incur a canonical cost if they adopted an optimal behavioral sequence (see McNamara and Houston 1986 for further treatment and discussion).

This conceptual model does not require us to assume that animals exist in pristine environments; in those circumstances in which animals are regularly or chronically confronted with stress regimes that animals would adopt to by engaging in sub-optimal behavior, we would assume that a change in behavior that resulted from exposure to a particular stressor or stress regime would either contribute to their sub-optimal behavior or would force them to engage in behavior that is even further from optimal.

We used Bayesian analysis to estimate the probability of one or more of the proximate responses identified in Figure 11 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

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

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

To apply this procedure to our response analyses, we formed the set of candidate responses identified in Figure 11 (see Table 2). Then we identified the number of instances in which animals were reported to have exhibited one or more of those proximate responses based on published studies or studies available as gray literature. For example, Nowacek *et al* (2004) reported one instance in which North Atlantic right whales exposed to alarm stimuli did not respond to the stimulus and several instances in which right whales exhibited “disturbance” responses. We coded these two responses (no response and disturbance response) separately. We used the resulting posterior probabilities to identify the kind of responses that would be represented by the “take” estimates that were produced by the models the U.S. Navy and the Permits Division used.

2.2.3 Risk Analyses

As discussed in the Introduction to this section, the final steps of our analyses — establishing the risks those responses pose to endangered and threatened species or designated critical habitat — normally 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 concept of current or expected future reproductive success which, as we described in the preceding sub-section, .integrates survival and longevity with current and future reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual’s probable response to stressors produced by an Action would reasonably be expected to reduce the individual’s current or expected future reproductive success by increasing the individual’s likelihood of dying prematurely, having reduced longevity, increasing the age at which individuals become reproductively mature, reducing the age at which individuals stop reproducing, reducing the number of live births individual produce during any reproductive bout, increasing the number of times an individual is likely to reproduce over the reproductive lifespan (in animals that reproduce multiple times), or causing an individual’s progeny to experience any of these phenomena.

When individual plants or animals would be expected to experience reductions in their current or expected future reproductive success, we would also 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 current or expected future reproductive success, we would conclude our assessment.

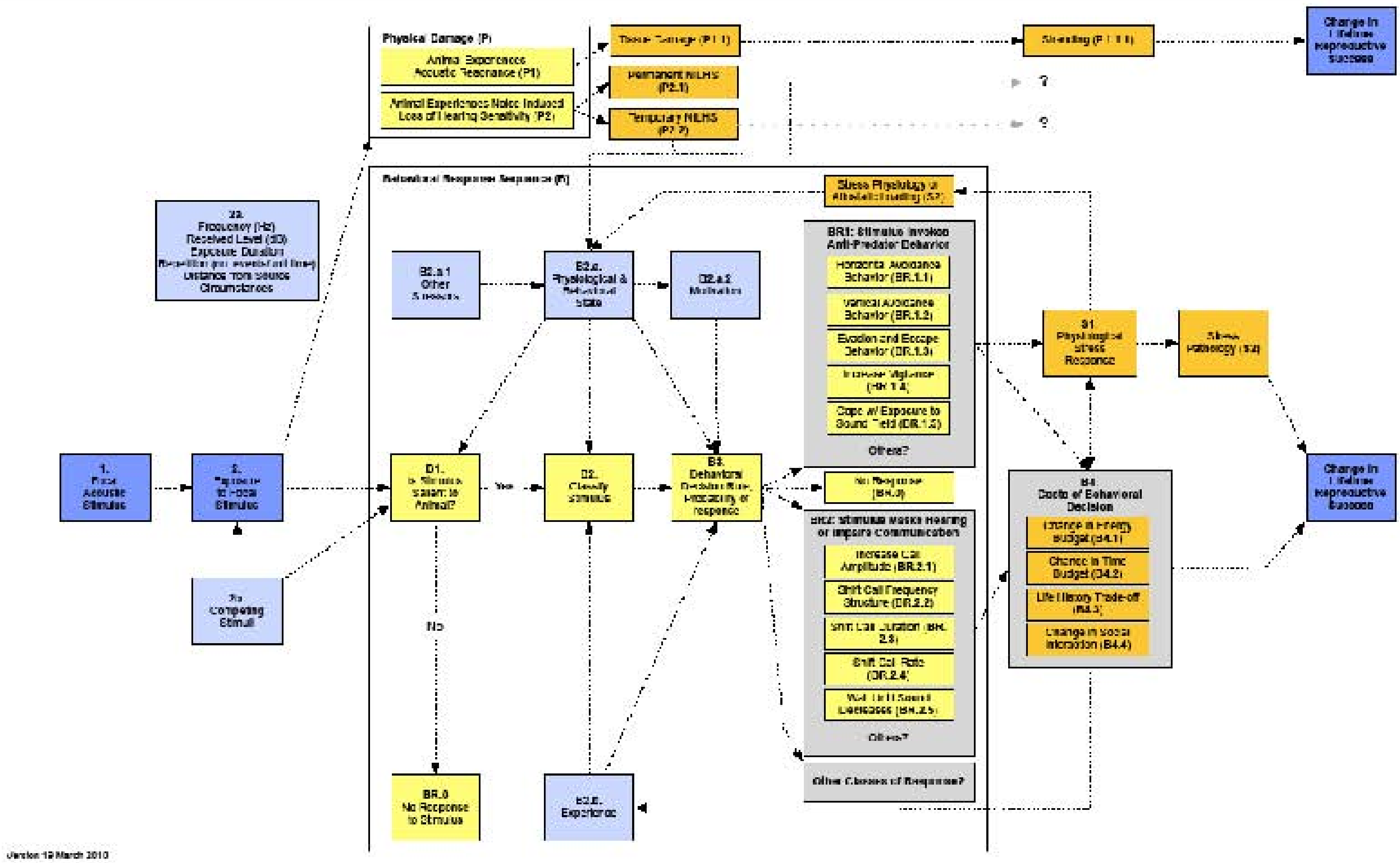

Figure 11. Conceptual model that illustrates the processes that determine whether endangered and threatened species are likely to respond upon being exposed to active sonar and sounds produced by underwater detonations and how particular responses might affect the fitness of individual animals that exhibit different responses. See text in "Application of this Approach" and "Response Analyses" for an explanation of the model and supporting literature

If we conclude that listed plants or animals are likely to experience reductions in their current or expected future reproductive success, we would integrate those individuals risks to determine if the number of individuals that

Table 2. Grouping of proximate responses (identified in Figure 11) into categories for response analyses

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

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 a population's probability of becoming demographically, ecologically, or genetically extinct in 10, 25, 50, or 100 years). For this step of our analyses, we would rely on 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 normally 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.

If and 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 to occur; we do not conduct these analyses to establish that such an outcome is likely to occur. For this step of our analyses, we would also use the species' status (established in the *Status of the Species* section of this Opinion) as our point of reference.

2.3 Evidence Available for the Consultation

To conduct these analyses, we considered all lines of evidence available through published and unpublished sources that represent evidence of adverse consequences or the absence of such consequences. Over the past decade, a considerable body of scientific information on anthropogenic and its effects on marine mammals and other marine life has become available. Many investigators have studied the potential responses of marine mammals and other marine organisms to human-generated sounds in marine environments or have integrated and synthesized the results of these studies (for example, Abgrail *et al.* 2008, Bowles *et al.* 1994; Cox *et al*. 2006, Croll *et al.* 1999, 2001; Frankel and Clark 1998; Gisiner 1998, McCauley and Cato 2001; NRC 1994 1996, 2000, 2003, 2005; Norris 1994; Reeves 1992, Richardson *et al.* 1995, Southall *et al*. 2007, Tyack 2000, 2007; Wright *et al.* 2007).

To supplement that body of knowledge, we conducted electronic literature searches using the Library of Congress' *First Search* and *Dissertation Abstracts* databases, SCOPUS, *Web of Science*, and Cambridge Abstract's *Aquatic Sciences and Fisheries Abstracts* (ASFA) database services. The *First Search* databases provide access to general biological literature, master's theses, and doctoral dissertations back to 1980; ASFA provides access to journal articles, magazine articles, and conference proceedings back to 1964. Our searches specifically focus on the *ArticleFirst*, *BasicBiosis*, *Dissertation Abstracts*, *Proceedings* and *ECO* databases, which index the major journals dealing with issues of ecological risk (for example, the journals *Environmental Toxicology and Chemistry*, *Human and Ecological Risk Assessment*), marine mammals (*Journal of Mammalogy*, *Canadian Journal of Zoology*, *Journal of Zoology*, *Marine Mammal Science*), sea turtles (*Copeia*, *Herpetologia*, *Journal of Herpetology*), ecology (*Ambio, Bioscience, Journal of Animal Ecology*, *Journal of Applied Ecology*, *Journal of the Marine Biological Association of the UK*, *Marine Pollution Bulletin, Oikos*), bioacoustics (*Bioacoustics*, *Journal of the Acoustical Society of America*), and animal behavior (*Advances in the Study of Behavior, Animal Behavior, Behavior, Behavioral Ecology and Sociobiology*, *Ethology*). We manually searched issues of the *Journal of Cetacean Research and Management* and *Reports of the International Whaling Commission*.

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

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

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

From each document, we extracted the following: when the information for the study or report was collected, the study design, which species the study gathered information on, the sample size, acoustic source(s) associated with the study (noting whether it was part of the study design or was correlated with an observation), other stressors associated with the study, study objectives, and study results, by species. We estimated the probability of responses from the following information: the known or putative stimulus; exposure profiles (intensity, frequency, duration of exposure, and nature) where information is available; and the entire distribution of responses exhibited by the individuals that have been exposed. Because the response of individual animals to stressors will often vary with time (for example, no responses may be apparent for minutes or hours followed by sudden responses and vice versa) we also noted any temporal differences in responses to an exposure.

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

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

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

Over the past few years, several organizations have argued that several of our previous biological opinions on the U.S. Navy's use of active sonar failed to consider the "cumulative impact" (in the NEPA sense of the term) of active sonar on the ocean environment and its organisms, particularly endangered and threatened species and critical habitat that has been designated for them (for example, see NRDC 2007 and Ocean Mammal Institute 2007). In each instance, we have had to explain how section 7 consultations and biological opinions consider "cumulative impacts" (in the NEPA sense of the term). We reiterate that explanation in this sub-section.

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).

By regulation, the Services assess the effects of a proposed action by adding its direct and indirect effects to the *impacts* of the activities we identify in an *Environmental Baseline* (50 CFR 402.02). Although our regulations use the term "adding" the effects of actions to an environmental baseline, we do not assume that the effects of actions are all additive; our assessments consider synergistic effects, multiplicative effects, and antagonistic effects of stressors on endangered species, threatened species, and any critical habitat that has been designated for those species.

A critical question that is rarely asked during cumulative impact analyses is: what effects are being accumulated? When native vegetative communities in terrestrial ecosystems are being coverted to multiple housing projects, it would be a relatively simple matter to accumulate the acreage disturbed or destroyed. When chemical pollutants are discharged into a river or stream from non-point sources, it becomes much harder to identify which chemicals are likely to accumulate and how plants or animals are likely to respond to that accumulation. With ephemeral stimuli such as active sonar or underwater detonations, the stressor (the sound or pressure wave) disappears moments after it is introduced into the environment; as a result, it is not likely to accumulate in any meaningful way. What might accumulate, however, are physical, physiological, behavioral, or social consequences of animals that are exposed to those sounds or pressure waves multiple times.

In practice we address "cumulative impacts" by focusing on individual organisms, which integrate the environments they occupy or interact with indirectly over the course of their lives. In our assessments, we think in terms of the biotic or ecological "costs" of exposing endangered and threatened individuals to a single stressor, a sequence of single stressors, or a suite of stressors (or "stress regime"). At the level of individual organisms, these "costs" consist of incremental reductions in the current or expected future reproductive success of the individuals that result from exposing those individuals to one or more stressors. The "costs" of those exposures might be immediately significant for an organism's reproductive success (for example, when an individual dies or loses one of its young) or the "costs" might become significant only over time. The costs of syneristic interactions between two stressors or a sequence of stressors would be expected to be higher than the "costs" incurred without the synergism; the "costs" of antagonistic interactions would be expected to be lower than the "costs" incurred without the antagonism.

We being our assessments by either qualitatively or quantitatively accumulate the biotic "costs" of exposing endangered or threatened individuals to the threats we identify in the *Status of the Species* and *Environmental Baseline* sections of our biological opinions. Then we estimate the probable additional "costs" associated with the proposed action on those individuals and ask whether or to what degree those "costs" would be expected to translate into reductions in the current and expected future reproductive success of those individuals. If those "costs" would be expected to reduce the current and expected future reproductive success of individuals or an endangered or threatened species, we assess the probable effects of those reductions on the population or populations those individuals represent, then continue to assess effects on the endangered or threatened species.

2.5 Action Area

The action area for this biological opinion consists of the Mariana Islands Range Complex and marine areas immediately adjacent to the range complex (see Figures 1 through 9). This area encompasses a 501,873-square-nautical mile area around the islands of Guam, Tinian, Saipan, Rota, Fallaron de Medenillia, and others and includes ocean areas in both the Pacific Ocean and the Philippine Sea. This action area is limited to those marine, coastal, and estuarine waters that are sea-ward of the mean higher high water line within this geographic area. Any of the proposed activities that are likely to occur on the open ocean, seaward of the territorial seas off Guam and the Mariana Islands.

3.0 Status of Listed Resources

NMFS has determined that the following species and critical habitat designations may occur in this action area for the readiness activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex:

Blue whale	*Balaenoptera musculus*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
North Pacific right whale	*Eubalaena japonica*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Green sea turtle	*Chelonia mydas*	Threatened
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Olive ridley sea turtle	*Lepidochelys olivacea*	Threatened

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

3.1 Species Not Considered Further in this Opinion

As described in the Approach to the Assessment, NMFS uses two criteria to identify those endangered or threatened species or critical habitat that are not likely to be adversely affected by the various activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex from June 2010 to June 2015. The first criterion was *exposure* or some reasonable expectation of a co-occurrence betweeon one or more potential stressor associated with the U.S. Navy's activities and a particular listed species or designated critical habitat: if we conclude that a listed species or designated critical habitat is not likely to be exposed to U.S. Navy's activities, we must also conclude that the critical habitat is not likely to be adversely affected by those activities. The second criterion is the probability of a *response* given exposure, which considers *susceptibility*: species that may be exposed to sound transmissions from active sonar, for example, but are likely to be unaffected by the sonar (at sound pressure levels they are likely to be exposed to) are also not likely to be adversely affected by the sonar. We applied these criteria to the species listed at the beginning of this section; this subsection summarizes the results of those evaluations.

NORTH PACIFIC RIGHT WHALES. Very little is known of the population size and distribution of right whales in the North Pacific because very few of these animals have been seen over the past 20 years. Nevertheless, Brownell *et al*. (2001) identified the waters within about 200 miles of the coast of Japan, including outlying islands as accounting for 37.4 percent of right whale sightings since 1900 in the Pacific. Best *et al*. (2001) suggested the Ryuku Islands, Yellow Sea, and Sea of Japan as important breeding and calving areas for Pacific right whales. The winter distribution of right whales in the Pacific remains unknown, although some right whales have been sighted as far south as 27ºN in the eastern North Pacific (Best *et al*. 2001).

Historically, North Pacific right whales occurred in waters off Guam and the Mariana Islands (Clapham *et al.* 2004; Scarff 1986). Despite many years of systematic aerial and ship-based surveys for marine mammals off the western coast of the U.S., only seven documented sightings of right whales were made from 1990 through 2000 (Waite *et al*. 2003). The relative rarity of reports of this species and the extremely low population numbers of this species suggests that these right whales have a very low probability of being exposed to ship and aircraft traffic and sonar transmissions associated with the activities considered in this Opinion. Consequently, we conclude that the proposed activities may affect, but are not likely to adversely affect endangered northern right whales so this species will not be considered in greater detail in the remainder of this opinion.

LEATHERBACK, LOGGERHEAD, AND OLIVE RIDLEY SEA TURTLE. Leatherback, loggerhead, and olive ridley sea turtles have all been reported in waters offshore of the Mariana Islands, but they are reported as transients in the region (Wiles *et al*. 1995) or they are reported as not occurring in those waters. Sea turtle surveys that have been conducted in waters on or adjacent to the Mariana Islands Range Complex have not reported observations of these sea turtles (Belt Collins 2001, Dollar and Stefansson 2000, Grimm and Farley 2008, Kolinski 2001, Kolinski *et al*. 1999, Pultz *et al*. 1999, Randall 1975, Stojkovich 1977, U.S. Navy 2007b, Vogt 2009). As a result, we assume that the probability of exposing these sea turtles to one or more of the stressors associated with the proposed action is sufficiently small to be discountable. Therefore, we assume that leatherback, loggerhead, and olive ridley sea turtles are not likely to be adversely affected by the activities the U.S. Navy plans to conduct on the Mariana Islands Range Complex. Consequently, we conclude that the proposed activities may affect, but are not likely to adversely affect these three sea turtles so they will not be considered in greater detail in the remainder of this opinion.

3.1 Climate Change

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

The IPCC estimated that average global land and sea surface temperature has increased by 0.6°C (±0.2) since the mid-1800s, with most of the change occurring since 1976. This temperature increase is greater than what would be expected given the range of natural climatic variability recorded over the past 1,000 years (Crowley 2000). The IPCC reviewed computer simulations of the effect of greenhouse gas emissions on observed climate variations that have been recorded in the past and evaluated the influence of natural phenomena such as solar and volcanic activity. Based on their review, the IPCC concluded that natural phenomena are insufficient to explain the increasing trend in land and sea surface temperature, and that most of the warming observed over the last 50 years is likely to be attributable to human activities (IPCC 2001). Climatic models estimate that global temperatures would increase between 1.4 to 5.8°C from 1990 to 2100 if humans do nothing to reduce greenhouse gas emissions (IPCC 2001). These projections identify a suite of changes in global climate conditions that are relevant to the future status and trend of endangered and threatened species (Table 3).

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

Table 1. Phenomena associated with projections of global climate change including levels of confidence associated with projections (adapted from IPCC 2001 and Campbell-Lendrum Woodruff 2007)

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

The indirect effects of climate change would result from changes in the distribution of temperatures suitable for calving and rearing calves, the distribution and abundance of prey, and the distribution and abundance of competitors or predators. For example, variations in the recruitment of krill (*Euphausia superba*) and the reproductive success of krill predators have been linked to variations in sea-surface temperatures and the extent of sea-ice cover during the winter months. Although the IPCC (2001) did not detect significant changes in the extent of Antarctic sea-ice using satellite measurements, Curran (2003) analyzed ice-core samples from 1841 to 1995 and concluded Antarctic sea ice cover had declined by about 20% since the 1950s.

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

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

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

Climate-mediated changes in the distribution and abundance of keystone prey species like krill and climate-mediated changes in the distribution of cephalopod populations worldwide is likely to affect marine mammal populations as they re-distribute throughout the world's oceans in search of prey. Blue whales, as predators that specialize in eating krill, seem likely to change their distribution in response to changes in the distribution of krill (for example, see

Payne *et al.* 1986, 1990 and Weinrich 2001); if they did not change their distribution or could not find the biomass of krill necessary to sustain their population numbers, their populations seem likely to experience declines similar to those observed in other krill predators, which would cause dramatic declines in their population sizes or would increase the year-to-year variation in population size; either of these outcomes would dramatically increase the extinction probabilities of these whales.

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

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

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

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

Changes in global climatic patterns are also projected to have profound effect on the coastlines of every continent by increasing sea levels and increasing the intensity, if not the frequency, of hurricanes and tropical storms. Based on computer models, these phenomena would inundate nesting beaches of sea turtles, change patterns of coastal erosion and sand accretion that are necessary to maintain those beaches, and would increase the number of turtle nests that are destroyed by tropical storms and hurricanes. Further, the combination of increasing sea levels, changes in patterns of coastal erosion and accretion, and changes in rainfall patterns are likely to affect coastal estuaries, submerged aquatic vegetation, and reef ecosystems that provide foraging and rearing habitat for several species of sea turtles. Finally, changes in ocean currents associated with climate change projections would affect the migratory patterns of sea turtles. The loss of nesting beaches, by itself, would have catastrophic effect on sea turtles populations globally if they are unable to colonize any new beaches that form of if the beaches that form do not provide the sand depths, grain patterns, elevations above high tides, or temperature regimes necessary to allow turtle eggs to survive. When combined with changes in coastal habitats and oceans currents, the future climates that are forecast place sea turtles at substantially greater risk of extinction than they already face.

3.2 Introduction to this Status of Listed Species

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

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

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

3.2.1 Blue whale

Distribution

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

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

In 1992, the U.S. Navy conducted an extensive acoustic survey of the North Atlantic using the Integrated 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).

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

In the eastern 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 edge of Antarctic ice (south of 58° S) with concentrations between 60°-80° E and 66°-

70° S (Kasamatsu *et al*. 1996).

Population Structure

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

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

In addition to these subspecies, the International Whaling Commission's Scientific Committee has formally recognized one blue whale population in the North Pacific (Donovan 1991), although there is increasing evidence that more than there may be more than one blue whale population in the Pacific Ocean (Gilpatrick *et al*. 1997, Barlow *et al*. 1995, Mizroch *et al*. 1984a, Ohsumi and Wada 1974). For example, studies of the blue whales that winter off Baja California and in the Gulf of California suggest that these whales are morphologically distinct from blue whales of the western and central North Pacific (Gilpatrick *et al*. 1997), although these differences might result from differences in the productivity of their foraging areas more than genetic differences (the southern whales forage off California; Sears *et al*.1987; Barlow *et al*.1997; Calambokidis *et al*. 1990). In addition, a population of blue whales that has distinct vocalizations inhabits the northeast Pacific from the Gulf of Alaska to waters off Central America (Calambokidis *et al*. 1999, Mate *et al*. 1999, Gregr *et al*. 2000; Stafford *et al*. 1999, 2001). We assume that this latter population is the one affected by the activities considered in this Opinion.

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 Hawai'ian waters. The only reliable report of this species in the central North Pacific was a sighting made from a scientific research vessel about 400 km northeast of Hawaii in January 1964 (NMFS 1998). However, acoustic monitoring has recorded blue whales off Oahu and the Midway Islands much more recently (Barlow *et al*. 1994, McDonald and Fox 1999, Northrop *et al.* 1971; Thompson and Friedl 1982).

The recordings made off Oahu showed bimodal peaks throughout the year, suggesting that the animals were migrating into the area during summer and winter (Thompson and Friedl 1982; McDonald and Fox 1999). Twelve aerial surveys were flown within 25 nm^2 of the main 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 whales 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 *Carricauda boopis* (Baylis 1920), which are believed to have caused fin whales to die as a result of renal failure (Lambertsen 1986; see additional discussion under *Fin whales*). Killer whales and sharks are also known to attack, injure, and kill very young or sick fin and humpback whale and probably hunt blue whales as well (Perry *et al*. 1999).

ANTHROPOGENIC THREATS. Two human activities are known to threaten blue whales: whaling and shipping. Historically, whaling represented the greatest threat to every population of fin whales and was ultimately responsible for listing fin whales as an endangered species. As early as the mid-seventeenth century, the Japanese were capturing blue, fin, and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen 1982, Cherfas 1989). In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. Before fin whales became the focus of whaling operations, populations of blue whales had already become commercially extinct (IWC 1995).

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

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

In 1980, 1986, 1987, and 1993, ship strikes have been implicated in the deaths of blue whales off California (Barlow *et al.* 1997). In addition, several photo-identified blue whales from California waters were observed with large scars on their dorsal areas that may have been caused by ship strikes. Studies have shown that blue whales respond to approaching ships in a variety of ways, depending on the behavior of the animals at the time of approach, and speed and direction of the approaching vessel. While feeding, blue whales react less rapidly and with less obvious avoidance behavior than whales that are not feeding (Sears *et al.* 1983). Within the St. Lawrence Estuary, blue whales are believed to be affected by large amounts of recreational and commercial vessel traffic. Blue whales in the St. Lawrence appeared more likely to react to these vessels when boats made fast, erratic approaches or sudden changes in direction or speed (Edds and Macfarlane 1987, Macfarlane 1981). The number of blue whales struck and killed by ships is unknown because the whales do not always strand or examinations of blue whales that have stranded did not identify the traumas that could have been caused by ship collisions. In the California/Mexico stock, annual incidental mortality due to ship strikes averaged 0.2 whales during 1991B1995 (Barlow *et al.* 1997), but we cannot determine if this reflects the actual number of blue whales struck and killed by ships.

Status

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

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

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

The size of the blue whale population in the north Atlantic is also uncertain. The population has been estimated to number from a few hundred individuals (Allen 1970; Mitchell 1974) to 1,000 to 2,000 individuals (Sigurjónsson 1995). Gambell (1976) estimated there were between 1,100 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 (review by Yochem and Leatherwood 1985) with an average rate of increase that has been estimated at between 4 and 5 percent per year. Butterworth *et al.* (1993), however, estimated the Antarctic population at 710 individuals. More recently, Stern (2001) estimated the blue whale population in the Southern Ocean at between 400 and 1,400 animals (c.v. 0.4). The pygmy blue whale population has been estimated at 6,000 individuals (Yochem and Leatherwood 1985)

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

Diving and Social Behavior

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

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

Vocalizations and Hearing

The vocalizations that have been identified for blue whales include a variety of sounds described as low frequency moans or long pulses (Cummings and Thompson 1971, 1977; Edds 1982, Thompson and Friedl 1982; Edds-Walton 1997). Blue whales produce a variety of low frequency sounds in the 10-100 Hz band (Cummings and Thompson 1971, Edds 1982, Thompson and Friedl 1982, McDonald *et al.* 1995, Clark and Fristrup 1997, Rivers 1997). The most typical signals are very long, patterned sequences of tonal infrasonic sounds in the 15-40 Hz range. The sounds last several tens of seconds. Estimated source levels are as high as 180-190 dB (Cummings and Thompson 1971). Ketten (1997) reports the frequencies of maximum energy between 12 and 18 Hz. In temperate waters, intense bouts of long patterned sounds are very common from fall through spring, but these also occur to a lesser extent during the summer in high latitude feeding areas. Short sequences of rapid calls in the 30-90 Hz band are associated with animals in social groups. The seasonality and structure of long patterned sounds suggest that these sounds are male displays for attracting females, competing with other males, or both. The context for the 30-90 Hz calls suggests that they are communicative but not related to a reproductive function. Vocalizations attributed to blue whales have been recorded in presumed foraging areas, along migration routes, and during the presumed breeding season (Beamish and Mitchell 1971; Cummings and Thompson 1971, 1977, 1994; Cummings and Fish 1972; Thompson *et al.* 1996; Rivers 1997; Tyack and Clark 1997; Clark *et al.* 1998).

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

As with other vocalizations produced by baleen whales, the function of blue whale vocalizations is unknown, although there are numerous hypotheses (which include include: maintenance of inter-individual distance, species and individual recognition, contextual information transmission, maintenance of social organization, location of topographic features, and location of prey resources; see the review by Thompson *et al.* 1992 for more information on these hypotheses). Responses to conspecific sounds have been demonstrated in a number of mysticetes, and there is no reason to believe that fin whales do not communicate similarly (Edds-Walton 1997). The low-frequency sounds produced by blue whales can, in theory, travel long distances, and it is possible that such long-distance communication occurs (Payne and Webb 1971, Edds-Walton 1997). The long-range sounds may also be used for echolocation in orientation or navigation (Tyack 1999).

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

3.2.2 Fin whale

Distribution

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

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

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

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

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

Population Structure

Fin whales have two recognized subspecies: *Balaoptera physalus physalus* (Linnaeus 1758) occurs in the North Atlantic Ocean while *B. p. quoyi* (Fischer 1829) occurs in the Southern Ocean. These subspecies and the North Pacifc fin whales appear to be organized into separate populations, although the published literature on the population structure of fin whales does not demonstrates a lack of concensus on the population structure of fin whales.

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

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

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

The recovery plan that has been drafted for fin whales treats the fin whales that occur off the Atlantic Coast of the U.S. as a single population that overlaps with the population the International Whaling Commission's Nova Scotia management unit (NMFS 2007). Individuals from this "population" of fin whales occur in the action area for this consultation.

Threats to the Species

NATURAL THREATS. Natural sources and rates of mortality are largely unknown, but Aguilar and Lockyer (1987) suggest annual natural mortality rates may range from 0.04 to 0.06 (based on studies of northeast Atlantic fin whales). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in fin whales and may be preventing some fin whale stocks from recovering from whaling (Lambertsen 1992, as cited in Perry *et al*. 1999). Killer whale or shark attacks may injure or kill very young or sick whales (Perry *et al*. 1999).

ANTHROPOGENIC THREATS. Three human activities are known to threaten fin whales: whaling, commercial fishing, and shipping. Historically, whaling represented the greatest threat to every population of fin whales and was ultimately responsible for listing fin whales as an endangered species. As early as the mid-seventeenth century, the Japanese were capturing fin, blue (*Balaenoptera musculus*), and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen 1982, Cherfas 1989). In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. After blue whales were depleted in most areas, fin whales became the focus of whaling operations and more than 700,000 fin whales were landed in the Southern Hemisphere alone between 1904 and 1979 (IWC 1995).

As its legacy, whaling has reduced fin whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push fin whales closer to extinction. Otherwise, whaling currently does not threaten every fin whale population, although it may threaten specific populations. In the Antarctic Ocean, fin whales are hunted by Japanese whalers who have been allowed to kill up to 10 fin whales each year for the 2005-2006 and 2006-2007 seasons under an Antarctic Special Permit. The Japanese whalers plan to kill 50 fin whales per year starting in the 2007-2008 season and continuing for the next 12 years.

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

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

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

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

Status

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

It is difficult to assess the current status of fin whales because (1) there is no general agreement on the size of the fin whale population prior to whaling and (2) estimates of the current size of the different fin whale populations vary widely. We may never know the size of the fin whale population prior to whaling. Chapman (1976) estimated the "original" population size of fin whales off Nova Scotia as 1,200 and 2,400 off Newfoundland, although he offered no explanation or reasoning to support that estimate. Sergeant (1977) suggested that between 30,000 and 50,000 fin whales once populated the North Atlantic Ocean based on assumptions about catch levels during the whaling period. Sigurjónsson (1995) estimated that between 50,000 and 100,000 fin whales once populated the North Atlantic, although he provided no data or evidence to support that estimate. More recently, Palumbi and Roman (2006) estimated that about 360,000 fin whales (95% confidence interval = 249,000 - 481,000) populated the North Atlantic Ocean before whaling based on mutation rates and estimates of genetic diversity.

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

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

Forcada *et al*. (1996) estimated the fin whale population in the western Mediterranean numbered 3,583 individuals (standard error = 967; 95% confidence interval = 2,130-6,027). This is similar to a more recent estimate published by Notarbartolo-di-Sciara *et al*. (2003). Within the Ligurian Sea, which includes the Pelagos Sanctuary for Marine Mammals and the Gulf of Lions, the fin whale population was estimated to number 901 (standard error = 196.1) whales. (Forcada *et al*. 1995).

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

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

Diving and Social Behavior

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

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

Vocalizations and Hearing

The sounds fin whales produce underwater are one of the most studied *Balaenoptera* sounds. Fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981; Watkins *et al.* 1987a; Edds 1988; Thompson *et al.* 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (Patterson and Hamilton 1964; Watkins *et al.* 1987a; Thompson *et al.* 1992; McDonald *et al.* 1995). In temperate waters intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald *et al.* 1995, Clark personal communication, McDonald personal communication). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999).

During the breeding season, fin whales produce a series of pulses in a regularly repeating pattern. These bouts of pulsing may last for longer than one day (Tyack 1999). The seasonality and stereotype of the bouts of patterned sounds suggest that these sounds are male reproductive displays (Watkins *et al.* 1987a), while the individual counter-calling data of McDonald *et al.* (1995) suggest that the more variable calls are contact calls. Some authors feel there 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 include: maintenance of inter-individual distance, species and individual recognition, contextual information transmission, maintenance of social organization, location of topographic features, and location of prey resources; see the review by Thompson *et al.* 1992 for more information on these hypotheses). Responses to conspecific sounds have been demonstrated in a number of mysticetes, and there is no reason to believe that fin whales do not communicate similarly (Edds-Walton 1997). The low-frequency sounds produced by fin whales have the potential to travel over long distances, and it is possible that long-distance communication occurs in fin whales (Payne and Webb 1971; Edds-Walton 1997). Also, there is speculation that the sounds may function for long-range echolocation of large-scale geographic targets such as seamounts, which might be used for orientation and navigation (Tyack 1999).

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

3.2.3 Humpback Whale

Distribution

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

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

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

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

Population Structure

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

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

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

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

Alaska, and British Columbia to feed (Angliss and Outlaw 2007, Calambokidis 1997, 2001).

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. Based on the data collected during that study, Calambokidis *et al*. (2008) estimated rates of exchange among humpback whales in different areas in the Hawai'ian Islands that are presented in Table 3.

Table 3. Rates of exchange among humpback whales in different sub-areas in the Hawai'ian Islands based on data presented in Calambokidis *et al*. (2008). Numbers along the diagonal represent the total number of individuals that were identified in a sub-area (highlighted in bold), number in the sub-diagonals represent the number of individuals from one sub-area that were identified in other areas (for example, of the 203 humpback whales that were identified off Kaua'i, one of those individuals was also identified off O'ahu). Numbers in parentheses represent percentages; percentages in bold represent percentage of the total number of individuals identified in the Hawai'ian Islands, non-bold percentages represent the percentage of humpback whales from one sub-area that were also counted in other sub-areas.

Sub-Area	Kaua'i	Oahu	Penguin Bank[1]	Moloka'i	Maui	Hawai'i
Kaua'i	**203 (0.0793)**	1 (0.0049)	0 (0.0000)	4 (0.0197)	29 (0.1429)	2 (0.0099)
O'ahu		**89 (0.0348)**	0 (0.0000)	5 (0.0562)	20 (0.2247)	9 (0.1011)
Penguin Bank			**34 (0.0133)**	3 (0.0882)	4 (0.1176)	3 (0.0882)
Moloka'i				**201 (0.0785)**	61 (0.3035)	12 (0.0597)
Maui					**1526 (0.596`)**	99 (0.0649)
Hawai'i						**507 (0.1980)**

1. Penguin Bank is located off the southwest tip of the island of Molokai and is an important shallow, marine habitat that is part of the Hawai'ian Islands Humpback Whale National Marine Sanctuary

NORTH ATLANTIC OCEAN. In the Atlantic Ocean, humpback whales aggregate in four feeding areas in the summer months: (1) Gulf of Maine, eastern Canada, (2) west Greenland, (3) Iceland and (4) Norway (Katona and Beard 1990, Smith *et al.* 1999). The principal breeding range for these whales lies from the Antilles and northern Venezuela to Cuba (Winn *et al.* 1975, Balcomb and Nichols 1982, Whitehead and Moore 1982). The largest contemporary breeding aggregations occur off the Greater Antilles where humpback whales from all of the North Atlantic feeding areas have been identified from photographs (Katona and Beard 1990, Clapham *et al.* 1993b, Mattila *et al.* 1994, Palsbøll *et al.* 1997, Smith *et al.* 1999, Stevick *et al.* 2003a). Historically, an important breeding aggregation was located in the eastern Caribbean based on the important humpback whale fisheries this region supported (Mitchell and Reeves 1983, Reeves *et al.* 2001, Smith and Reeves 2003). Although sightings persist in those areas, modern humpback

whale abundance appears to be low (Winn *et al.* 1975, Levenson and Leapley 1978, Swartz *et al.* 2003). Winter aggregations also occur at the Cape Verde Islands in the Eastern North Atlantic (Reiner *et al.* 1996, Reeves *et al.* 2002, Moore *et al.* 2003). In another example of the "open" structure of humpback whale populations, an individual humpback whale migrated from the Indian Ocean to the South Atlantic Ocean and demonstrated that individual whales may migrate from one ocean basin to another (Pomilla and Rosenbaum 2005).

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

Threats to the Species

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

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

ANTHROPOGENIC THREATS. Three human activities are known to threaten humpback whales: whaling, commercial fishing, and shipping. Historically, whaling represented the greatest threat to every population of humpback whales and was ultimately responsible for listing humpback whales as an endangered species. From 1900 to 1965, nearly 30,000 whales were taken in modern whaling operations of the Pacific Ocean. Prior to that, an unknown number of humpback whales were taken (Perry *et al.* 1999). In 1965, the International Whaling Commission banned commercial hunting of humpback whales in the Pacific Ocean. As its legacy, whaling has reduced humpback whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push these whales closer to extinction.

Humpback whales are also killed or injured during interactions with commercial fishing gear, although the evidence available suggests that these interactions on humpback whale populations may not have significant, adverse consequence for humpback whale populations. 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, fin whales are likely to be entangled and, in some cases, killed by gear used in modern fisheries.

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 Hawaii rescued an entangled humpback, removing two crab pot floats from the whale; the gear was traced to a recreational fisherman in southeast Alaska. The whale was successfully released, but subsequently became entrapped and was attacked and killed by tiger sharks in the surf zone.

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

The number of humpback whales killed by ship strikes is exceeded only by fin whales (Jensen and Silber 2003). On the Pacific coast, a humpback whale is killed about every other year by ship strikes (Barlow *et al*. 1997). The humpback whale calf that was found stranded on Oahu with evidence of vessel collision (propeller cuts) in 1996 suggests that ship collisions might kill adults, juvenile, and calves (NMFS unpublished data). Of 123 humpback whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, 10 (8.1%) showed evidence of collisions with ships (Laist *et al*. 2001). Between 1999 and 2005, there were 18 reports of humpback whales being struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole *et al*. 2005, Nelson *et al*. 2007). Of these reports, 13 were confirmed as ship strikes which were reported as having resulted in the death of 7 humpback whales. Despite several literature searches, we did not identify information on the number of humpback whales killed or seriously injured by ship strikes outside of U.S. waters.

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

Status

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

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

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

Estimates of the number of humpback whales occurring in the different populations that inhabit the Northern Pacific population have risen over time. In the 1980s, estimates ranged from 1,407 to 2,100 (Baker 1985; Darling and Morowitz 1986; Baker and Herman 1987), while recent estimates place the population size at about 6,000 whales (standard error = 474) in the North Pacific (Calambokidis *et al.* 1997; Cerchio 1998; Mobley *et al.* 1999). Based on data collected between 1980 and 1983, Baker and Herman (1987) used a capture-recapture methodology to produce a population estimate of 1,407 whales (95% confidence interval = 1,113 - 1,701). More recently, (Calambokidis *et al.* 1997) relied on resightings estimated from photographic records of individuals to produce an estimate of 6,010 humpback whales occurred in the North Pacific Ocean. Because the estimates produced by the different methodologies are not directly comparable, it is not clear which of these estimates is more accurate or if the change from 1,407 to 6,000 individuals results from a real increase in the size of the humpback whale population, sampling bias in one or both studies, or assumptions in the methods used to produce estimates from the individuals that were sampled. Since the last of these estimates was published almost 12 years ago, we do not know if the estimates represent current population sizes.

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

As discussed previously, between 2004 and 2006, an international group of whale researchers coordinated their surveys to conduct a comprehensive assessment of the population structure, levels of abundance, and status of humpback whales in the North Pacific (Calambokidis *et al*. 2008). That effort identified a total of 7,971 unique individuals from photographs taken during close approaches. Of this total,, 4,516 individuals were identified at wintering regions in at least one of the three seasons in which the study surveyed wintering area and 4,328 individuals were identified at least once at feeding areas in one of the two years in which the study surveyed feeding areas. Based on the results of that effort, Calambokidis *et al*. (2008) estimated that the current population of humpback whales in the North Pacific Ocean consisted of about 18,300 whales, not counting calves. Almost half of the humpback whales that were estimated to occur in wintering areas, or about 8,000 humpback whales, occupy the Hawai’ian Islands during the winter months.

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

Diving and Social Behavior

The maximum diving depths of humpback whales are about 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). Humpback whales may remain submerged for up to 21 min (Dolphin 1987). Dives on feeding grounds ranged from 2.1-5.1 min in the north Atlantic (Goodyear unpublished manuscript). In southeast Alaska average dive times were 2.8 min for feeding whales, 3.0min for non-feeding whales, and 4.3 min for resting whales (Dolphin 1987). In the Gulf of California humpback whale dive times averaged 3.5 min (Strong 1989). Because most humpback prey is likely found above 300 m depths most humpback dives are probably relatively shallow.

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

Vocalizations and Hearing

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

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

1. Complex songs with components ranging from at least 20 Hz–4 kHz with estimated source levels from 144 – 174 dB; these are mostly sung by males on the breeding grounds (Frazer and Mercado 2000; U.S. Navy 2006a; Payne 1970; Winn *et al.* 1970a; Richardson *et al.* 1995)

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

3 Feeding area vocalizations that are less frequent, but tend to be 20 Hz–2 kHz with estimated sources levels in excess of 175 dB re 1 μPa-m (Thompson *et al.* 1986; Richardson *et al.* 1995).

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

3.2.4 Sei Whale

Distribution

Sei whales occur in every ocean except the Arctic Ocean. The migratory pattern of this species is thought to encompass long distances from high-latitude feeding areas in summer to low-latitude breeding areas in winter; however, the location of winter areas remains largely unknown (Perry *et al.* 1999). Sei whales are often associated with deeper waters and areas along the continental shelf edge (Hain *et al*. 1985); however, this general offshore pattern of sei whale distribution is disrupted during occasional incursions into more shallow and inshore waters (Waring *et al.* 2004).

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

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

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

Population Structure

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

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

Threats to the Species

natural threats. Sei whales appear to compete with blue, fin, and right whales for prey and that competition may limit the total abundance of each of the species (Rice 1974, Scarff 1986). As discussed previously in the narratives for fin and right whales, the foraging areas of right and sei whales in the western north Atlantic Ocean overlap and both whales feed preferentially on copepods (Mitchell 1975). In the Southern Ocean, the sei whale population was reported to have increased in size after whalers had reduced the number of blue and fin whales in the region (iwc 1974); as these populations increase, the intensity of competition between these species should increase as well and the larger whales are most likely to prevail in that competition.

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

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

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

Status

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

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

About 50 sei whales are estimated to occur in the North Pacific "stock" with another 77 sei whales in the 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 (1975) analyzed trophic interactions among baleen whales in the western north Atlantic and noted that the foraging grounds of right whales overlapped with the foraging grounds of sei whales and both preferentially feed on copepods.

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

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

Diving and Social Behavior

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

Vocalizations and Hearing

There is a limited amount of information on the vocal behavior of sei whales. McDonald *et al*. (2005) recorded sei whale vocalizations off the Antarctic Peninsula that included broadband sounds in the 100-600 Hz range with 1.5 second duration and tonal and upsweep call in the 200-600 Hz range 1-3 second duration. During visual and acoustic surveys conducted in the Hawai'ian Islands in 2002, Rankin and Barlow (2007) recorded 107 sei whale vocalizations, which they classified as two variations of low-frequency downswept calls. The first variation consisted of sweeps from 100 Hz to 44 Hz, over 1.0 seconds. The second variation, which was more common (105 out of 107) consisted of low frequency calls which swept from 39 Hz to 21 Hz over 1.3 seconds. These vocalization are different from sounds attributed to sei whales in the Atlantic and Southern Oceans but are similar to sounds that had previously been attributed to fin whales in Hawaiian waters.

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

3.2.5 Sperm Whale

Distribution

Sperm whales occur in every ocean except the Arctic Ocean. Sperm whales are found throughout the North Pacific and are distributed broadly from tropical and temperate waters to the Bering Sea as far north as Cape Navarin. Mature, female, and immature sperm whales of both sexes are found in more temperate and tropical waters from the equator to around 45˚ N throughout the year. These groups of adult females and immature sperm whales are rarely found at latitudes higher than 50˚ N and 50˚ S (Reeves and Whitehead 1997). Sexually mature males join these groups throughout the winter. During the summer, mature male sperm whales are thought to move north into the Aleutian Islands, Gulf of Alaska, and the Bering Sea.

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

In the eastern Atlantic Ocean, mature male sperm whales have been recorded as far north as Spitsbergen (Oien, 1990). Recent observations of sperm whales and stranding events involving sperm whales from the eastern North

Atlantic suggest that solitary and paired mature male sperm whales predominantly occur in waters off Iceland, the Faroe Islands, and the Norwegian Sea (Gunnlaugsson and Sigurjonsson 1990, Oien 1990, Christensen *et al.* 1992).

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

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. However, 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 migrate into the Aleutian Islands, Gulf of Alaska, and the Bering Sea.

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

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

Population Structure

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

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

Atlantic Ocean

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

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

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

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

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

Indian Ocean

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

Pacific Ocean

Several authors have proposed population structures that recognize at least three sperm whales populations in the North Pacific for management purposes (Kasuya 1991, Bannister and Mitchell 1980). At the same time, the IWC's

Scientific Committee designated two sperm whale stocks in the North Pacific: a western and eastern stock or population (Donovan 1991). The line separating these populations has been debated since their acceptance by the IWC's Scientific Committee. For stock assessment purposes, NMFS recognizes three discrete population centers of sperm whales in the Pacific: (1) Alaska, (2) California-Oregon-Washington, and (3) Hawai'i.

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

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

Southern Ocean

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

Threats to the Species

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

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

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

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

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

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

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

Although the International Whaling Commission protected sperm whales from commercial harvest in 1981, whaling operations along the Japanese coast continued to hunt sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). More recently, the Japanese Whaling Association began hunting sperm whales for research. In 2000, the Japanese Whaling Association announced that it planned to kill 10 sperm whales in the Pacific Ocean for research, which was the first time sperm whales have been hunted since the international ban on commercial whaling. Despite protests from the U.S. government and members of the IWC, the Japanese government harvested 5 sperm whales and 43 Bryde's whales in the last six months of 2000. According to the Japanese Institute of Cetacean Research (Institute of Cetacean Research undated), another 5 sperm whales were killed for research in 2002 – 2003. The consequences of these deaths on the status and trend of sperm whales remains uncertain, given that they probably have not recovered from the legacy of whaling; however, the renewal of a program that intentionally targets and kills sperm whales before we can be certain they recovered from a history of over-harvest places this species at risk in the foreseeable future.

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

In U.S. waters in the Pacific Ocean, sperm whales are known to have been incidentally captured only in drift gillnet operations, which killed or seriously injured an average of 9 sperm whales per year from 1991 - 1995 (Barlow *et al.* 1997). Interactions between longline fisheries and sperm whales in the Gulf of Alaska have been reported over the past decade (Rice 1989, Hill and DeMaster 1999). Observers aboard Alaskan sablefish and halibut longline vessels have documented sperm whales feeding on fish caught in longline gear in the Gulf of Alaska. During 1997, the first entanglement of a sperm whale in Alaska's longline fishery was recorded, although the animal was not seriously injured (Hill and DeMaster 1998). The available evidence does not indicate sperm whales are being killed or seriously injured as a result of these interactions, although the nature and extent of interactions between sperm whales and long-line gear is not yet clear.

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

Status

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

The status and trend of sperm whales at the time of this summary is largely unknown. Hill and DeMaster (1999) and Angliss and Lodge (2004) reported that estimates for population abundance, status, and trends for sperm whales off the coast of Alaska were not available when they prepared the Stock Assessment Report for marine mammals off

Alaska. Similarly, No information was available to support estimates of sperm whales status and trends in the western North Atlantic Ocean (Waring *et al.* 2004), the Indian Ocean (Perry *et al.* 1999), or the Mediterranean Sea.

Nevertheless, several authors and organizations have published "best estimates" of the global abundance of sperm whales or their abundance in different geographic areas. Based on historic whaling data,190,000 sperm whales were estimated to have been in the entire North Atlantic, but the IWC considers data that produced this estimate unreliable (Perry *et al.* 1999). Whitehead (2002) estimated that prior to whaling sperm whales numbered around 1,110,000 and that the current global abundance of sperm whales is around 360,000 (coefficient of variation = 0.36) whales. Whitehead's current population estimate (2002) is about 20% of past global abundance estimates which were based on historic whaling data.

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

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

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

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

Populations of sperm whales could not have recovered from the overharvests of adult females and immature whales in the 30 to 40 years that have passed since the end of whaling, but the information available does not allow us to determine whether and to what degree those populations might have stabilized or whether they have begun the process of recovering from the effects of whaling. Absent information to the contrary, we assume that sperm whales will have elevated extinction probabilities because of both exogenous threats caused by anthropogenic activities (primarily whaling, entanglement, and ship strikes) and natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate) as well as endogenous threats caused by the legacy of overharvests of adult females and immature whales on their populations (that is, a population with a disproportion of adult males and older animals coupled with a small percentage of juvenile whales that recruit into the adult population).

Diving and Social Behavior

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

Adult, female sperm whales and their young form highly-social groups that have dialects specific to the group (Weilgart and Whitehead 1997), cooperate to defend young (Whitehead 1996) and nurse young calves (Reeves and Whitehead 1997). Adult and sub-adult male sperm whales are commonly solitary, although they will cooperate during feeding.

Vocalizations and Hearing

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

A general description of the anatomy of the ear for cetaceans is provided in the description of the blue whale above. The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1990). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz. Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins and Schevill 1975; Watkins *et al.* 1985). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995). Sperm whales have moved out of areas after the start of air gun seismic testing (Davis *et al.* 1995). Seismic air guns produce loud, broadband, impulsive noise (source levels are on the order of 250 dB) with "shots" every 15 seconds, 240 shots per hour, 24 hours per day during active tests. Because they spend large amounts of time at depth and use low frequency sound sperm whales are likely to be susceptible to low frequency sound in the ocean (Croll *et al* 1999). Furthermore, because of their apparent role as important predators of mesopelagic squid and fish, changing the abundance of sperm whales should affect the distribution and abundance of other marine species.

3.2.6 Green Sea Turtle

Distribution

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

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

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

Population Structure

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

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

Smaller nesting aggregations include: Angola, Bangladesh, Bikar Atoll, Brazil, Chagos Archipelago, China, Costa Rica, Cuba, Cyprus, Democratic Republic of Yemen, Dominican Republic, d'Entrecasteaux Reef, French Guiana, Ghana, Guyana, India, Iran, Japan, Kenya, Madagascar, Maldives Islands, Mayotte Archipelago, Mexico, Micronesia, Pakistan, Palmerston Atoll, Papua New Guinea, Primieras Islands, Sao Tome é Principe, Sierra Leone, Solomon Islands, Somalia, Sri Lanka, Syria, Taiwan, Tanzania, Thailand, Turkey, Scilly Atoll, United States (Hawai'i), Venezuela, and Vietnam (Metcalf *et al*. 2007, Rees *et al*. 2008, Seminoff 2002, Weir *et al*. 2007).

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 western Pacific green sea turtles nesting on Palau, Yap, and the Marshall Islands are distinct from each other and from Guam and Northern Mariana Islands; green sea turtles in the Guam and the Mariana Islands share the same single haplotype which suggests that they are a separate population (P. Dutton, personal communication *fide* Irene Kinan, personal communication, 2010).

In the eastern Pacific, green sea turtles forage coastally from San Diego Bay, California in the north to Mejillones, Chile in the South. Based on mtDNA analyses, green turtles found on foraging grounds along Chile's coast originate from the Galapagos nesting beaches, while those greens foraging in the Gulf of California originate primarily from the Michoacan nesting stock. Green turtles foraging in San Diego Bay and along the Pacific coast of Baja California originate primarily from rookeries of the Islas Revillagigedos (Dutton 2003).

Threats to the Species

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

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

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

Directed harvests of eggs and other life stages of green sea turtles were identified as a "major problem" in American Samoa, Guam, Palau, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Republic of the Marshall Islands, and the Unincorporated Islands (Wake, Johnston, Kingman, Palmyra, Jarvis, Howland, Baker, and Midway). In the Atlantic, green sea turtles are captured and killed in turtle fisheries in Colombia, Grenada, the Lesser Antilles, Nicaragua, St. Vincent and the Grenadines (Bräutigam and Eckert 2006, Grazette *et al*. 2007); the turtle fishery along the Caribbean coast of Nicaragua, by itself, captures more than 11,000 green sea turtles each year for the past 10 years (Bräutigam and Eckert 2006, Lagueux 1998). Grazette *et al*. (2007) estimated that of the 782 sea turtles captured each year between 1996 and 2001 in waters around Grenada and Carriacou , about 62.4 percent were green sea turtles.

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

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

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

Status

Green turtles are listed as threatened under the ESA, except for breeding populations found in Florida and the Pacific coast of Mexico, which are listed as endangered. Using a precautionary approach, Seminoff (2002) estimates that the global green turtle population has declined by 34 to 58 percent over the last three generations (approximately 150 years) although actual declines may be closer to 70 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 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 2002).

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

Diving and Social Behavior

Subadult green sea turtles 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). In nearshore foraging habitat, green sea turtles spent between 89 and 100 percent of their time at depths less than or equal to 5 meters below surface (Hazel *et al*. 2009). Between nesting events, adult green sea turtles have been reported to dive to depths of between 10 and 40 meters, almost most dives were to depths of less than 26 meters (I-Jiunn 2009). While in pelagic water or during migration, however, adult green turtle have been recorded to dive to substantially greater depths (Berkson 1967 *in* Lutcavage and Lutz 1997).

Vocalizations and Hearing

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

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

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

3.2.7 Hawksbill Sea Turtle

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 1995). There are also records of hawksbill sea turtles stranding on the coast of Georgia (Ruckdeschel *et al.* 2000), being captured in pound nets off Savannah, and neing 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 weedlines that accumulate at convergence points. When they growth to about 20-25 cm carapace length, hawksbill sea turtles reenter coastal waters where they inhabit and forage in coral reefs as juveniles, subadults 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 (Hildebrand 1987, Amos 1989).

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. Several human activities are known to threaten hawkbill 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 hawkbill sea turtle populations was overharvest for subsistence and commercial purposes. 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 1998). Over the past 100 years, these threats caused population sizes of hawksbill sea turtles to decline by about 90 percent globally (Mortimer 2008) and contributed to their listing as an endangered species.

Although the volume of trade in products from hawksbill sea turtles has declined in the past 10 to 15 years, that trade still places these sea turtles at substantial risk of extinction. In addition to the demand for the hawksbill's shell, there is a demand for other products including leather, oil, perfume, and cosmetics. In the Pacific, large numbers of nesting and foraging hawksbill sea turtles are captured and killed for trade in Micronesia, the Mexican Pacific coast, southeast Asia, Indonesia, and the Indian Ocean (Mortimer 2008, NMFS and USFWS 1998). 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 (Bräutigam and Eckert 2006).

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. Under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, hawksbill sea turtles are identified as "most endangered."

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 (Groombridge 1982). 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. With the exception of Mexico, and possibly Cuba, nearly all Wider Caribbean countries are estimated to receive <100 nesting females per year (Meylan 1989).

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 (Dam and Diez, 1997a).

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*. 1999, Ridgway *et al*. 1969).

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

4.0 Environmental Baseline

By regulation, environmental baselines for biological opinions include the past and present impacts of all state, Federal or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR 402.02). The environmental baseline for this biological opinion includes the effects of several activities that affect the survival and recovery of endangered whales in the action area.

A number of human activities have contributed to the current status of populations of large whales and sea turtles in the action area. Some of those activities, most notably commercial whaling, occurred extensively in the past, ended, and no longer appear to affect these whale populations, although the effects of these reductions likely persist today. Other human activities are ongoing and appear to continue to affect populations of endangered and threatened whale and sea turtle. The following discussion summarizes the principal phenomena that are known to affect the likelihood that these endangered and threatened species will survive and recover in the wild.

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 (Lambertson *et al*. 1986). A well-documented observation of killer whales attacking a blue whale off Baja, California proves 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.

Human-Induced Mortality

Commercial Whaling and Subsistence Hunting Large whale population numbers in the proposed action areas have historically been impacted by commercial exploitation, mainly in the form of whaling. Prior to current prohibitions on whaling, such as the International Whaling Commission’s 1966 moratorium, most large whale species had been depleted to the extent it was necessary to list them as endangered under the Endangered Species Act of 1966. For example, from 1900 to 1965 nearly 30,000 humpback whales were captured and killed in the Pacific Ocean with an unknown number of additional animals captured and killed before 1900 (Perry *et al.* 1999). Sei whales are estimated to have been reduced to 20% (8,600 out of 42,000) of their pre-whaling abundance in the North Pacific (Tillman

1977). In addition, 9,500 blue whales were reported killed by commercial whalers in the North Pacific between 1910-1965 (Ohsumi and Wada 1972); 46,000 fin whales between 1947-1987 (Rice 1984); and 25,800 sperm whales (Barlow *et al* 1997). North Pacific right whales once numbered 11,000 animals but commercial whaling has now reduced their population to 29-100 animals (Wada 1973).

Whaling in Micronesia reached its peak in the early 1800s and declined in the 1850s with the discovery of petroleum and the beginnings of the Civil War. During the whaling period, Guam was a major port for water and supplies and humpback whales were hunted in the Marianas (Eldredge 2003). Although commercial whaling no longer targets the large, endangered whales in the proposed action areas, historical whaling probably altered the age structure and social cohesion of fin and sperm whales; the degree to which those effects persist in these species is, however, unknown.

Entrapment and Entanglement in Commercial Fishing Gear Entrapment and entanglement in commercial fishing gear is one of the most frequently documented sources of human-caused mortality in large whale species and sea turtles. For example, in 1978, Nishimura and Nakahigashi (1990) estimated that 21,200 turtles, including greens, leatherback turtles, loggerheads, olive ridleys and hawksbills, were captured annually by Japanese tuna longliners in the Western Pacific and South China Sea, with a reported mortality of approximately 12,300 turtles per year. Using commercial tuna longline logbooks, research vessel data and questionnaires, Nishimura and Nakahigashi (1990) estimated that for every 10,000 hooks in the Western Pacific and South China Sea, one turtle is captured, with a mortality rate of 42 percent. Although species-specific information is not available, vessels reported sightings of turtles in locations which overlap with commercial fishing grounds in the following proportions: loggerhead - 36 percent, green turtle - 19 percent, hawksbill - 10.3 percent, olive ridley - 1.7 percent, leatherback - 13.7 percent, and unknown - 19 percent.

aution should be used in interpreting the results of Nishimura and Nakahigashi (1990), including estimates of sea turtle take rate (per thousand hooks) and resultant mortality rate, and estimates of annual take by the fishery, for the following reasons: (1) the data collected was based on observations by training and research vessels, logbooks and a questionnaire (i.e. hypothetical), and do not represent actual, substantiated logged or observed catch of sea turtles by the fishery; (2) the authors assumed that turtles were distributed homogeneously; and (3) the authors used only one year (1978) to estimate total effort and distribution of the Japanese tuna longline fleet. Although the data and analyses provided by Nishimura and Nakahigashi (1990) are conjectural, longliners fishing in the Pacific have had, and (with the current level of effort) probably continue to have significant impacts on sea turtle populations.

NMFS has observed one sperm whale interaction by the Hawaii-based longline fishery. The event occurred in May, 1999 inside the Northwestern Hawaiian Islands EEZ (about 140 nautical miles north of Raita Bank), and the vessel was targeting swordfish (gear was set at night, lightsticks were used, and no line shooter was used). According to the observer report, the sperm whale's pectoral fin was entangled in the mainline. The captain stopped the boat, let out more mainline, and then backed up until he could reach the other end of the mainline. At this point, both ends of the mainline, on each side of the sperm whale, were secured on the vessel. During this time, the whale broke the mainline and swam away without trailing gear.

NMFS has observed 3,251 sets, representing approximately 3,874,635 hooks (data from February 1994 through December 31, 1999). The observed entanglement rate for sperm whales would equal about 0.31 whales per 1,000 sets or 0.0002 per 1,000 hooks. At those rates, we would expect about 200 sperm whales entanglements per 1,000 sets. However, only one sperm whale has been entangled in this gear; as a result, NMFS believes that the estimated entanglement rate substantially overestimates a sperm whale's actual probability of becoming entangled in this gear and the potential hazards longline gear poses to sperm whales.

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 Hawai'ian 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.

Despite these reports, the magnitude of the risks ship traffic poses to large whales on or around the Marianas Range Complex 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 territorial seas and the Exclusive Economic Zone of the continental United States and have virtually no information on interactions between ships and commercial vessels in the western North Pacific Ocean. With the information available, we assume that interactions occur but we cannot estimate the number of interactions or their significance to the endangered whales of the western Pacific Ocean.

Habitat Degradation. Chronic exposure to the neurotoxins associated with paralytic shellfish poisoning (PSP) via zooplankton prey has been shown to have detrimental effects on marine mammals. Estimated ingestion rates are sufficiently high to suggest that the PSP toxins are affecting marine mammals, possibly resulting in lower respiratory function, changes in feeding behavior and a lower reproduction fitness (Durbin *et al.* 2002). Other human activities, including discharges from wastewater systems, dredging, ocean dumping and disposal, aquaculture and additional impacts from coastal development are also known to impact marine mammals and their habitat. In the North Pacific, undersea exploitation and development of mineral deposits, as well as dredging of major shipping channels pose a continued threat to the coastal habitat of right whales. Point-source pollutants from coastal runoff, offshore mineral and gravel mining, at-sea disposal of dredged materials and sewage effluent, potential oil spills, as well as substantial commercial vessel traffic, and the impact of trawling and other fishing gear on the ocean floor are continued threats to marine mammals in the proposed action area.

The impacts from these activities are difficult to measure. However, some researchers have correlated contaminant exposure to possible adverse health effects in marine mammals. Studies of captive harbor seals have demonstrated a link between exposure to organochlorines (*e.g.*, DDT, PCBs, and polyaromatic hydrocarbons) and immuno-suppression (Ross *et al*. 1995, Harder *et al.* 1992, De Swart *et al.* 1996). Organochlorines are chemicals that tend to bioaccumulate through the food chain, thereby increasing the potential of indirect exposure to a marine mammal via its food source. During pregnancy and nursing, some of these contaminants can be passed from the mother to developing offspring. Contaminants like organochlorines do not tend to accumulate in significant amounts in invertebrates, but do accumulate in fish and fish-eating animals. Thus, contaminant levels in planktivorous mysticetes have been reported to be one to two orders of magnitude lower compared to piscivorous odontocetes (Borell, 1993; O'Shea and Brownell, 1994; O'Hara and Rice, 1996; O'Hara *et al.*, 1999).

Anthropogenic Noise. The marine mammals that occur in the action area are regularly exposed to several sources of natural and anthropogenic sounds. Anthropogenic noises that could affect ambient noise arise from the following general types of activities in and near the sea, any combination of which can contribute to the total noise at any one place and time. These noises include transportation, dredging, construction; oil, gas, and mineral exploration in offshore areas; geophysical (seismic) surveys; sonars; explosions; and ocean research activities (Richardson *et al*. 1995).

Noise in the marine environment has received a lot of attention in recent years and is likely to continue to receive attention in the foreseeable future. Several investigators have argued that anthropogenic sources of noise have increased ambient noise levels in the ocean over the last 50 years ((Jasny *et al*. 2005; NRC 1994, 1996, 2000, 2003, 2005; Richardson *et al*. 1995). Much of this increase is due to increased shipping as ships become more numerous and of larger tonnage (NRC 2003). Commercial fishing vessels, cruise ships, transport boats, airplanes, helicopters and recreational boats all contribute sound into the ocean (NRC 2003). The military uses sound to test the construction of new vessels as well as for naval operations. In some areas where oil and gas production takes place, noise originates from the drilling and production platforms, tankers, vessel and aircraft support, seismic surveys, and the explosive removal of platforms (NRC 2003). Many researchers have described behavioral responses of marine mammals to the sounds produced by helicopters and fixed-wing aircraft, boats and ships, as well as dredging, construction, geological explorations, etc. (Richardson *et al*. 1995). Most observations have been limited to short-term behavioral responses, which included cessation of feeding, resting, or social interactions. Several studies have demonstrated short-term effects of disturbance on humpback whale behavior (Baker *et al.* 1983; Bauer and Herman 1986; Hall 1982; Krieger and Wing 1984), but the long-term effects, if any, are unclear or not detectable. Carretta *et al.* (2001) and Jasny *et al*. (2005) identified the increasing levels of anthropogenic noise as a habitat concern for whales and other cetaceans because of its potential effect on their ability to communicate.

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans (Simmonds and Hutchinson 1996). The Navy estimated that the 60,000 vessels of the world's merchant fleet annually emit low frequency sound into the world's oceans for the equivalent of 21.9 million days, assuming that 80 percent of the merchant ships at sea at any one time (U.S. Navy 2001). The radiated noise spectrum of merchant ships ranges from 20 to 500 Hz and peaks at approximately 60 Hz. Ross (1976) has estimated that between 1950 and 1975 shipping had caused a rise in ambient ocean noise levels of 10 dB. He predicted that this would increase by another 5 dB by the beginning of the 21st century. NRC (1997) estimated that the background ocean noise level at 100 Hz has been increasing by about 1.5 dB per decade since the advent of propeller-driven ships.

Michel *et al.* (2001) suggested an association between long-term exposure to low frequency sounds from shipping and an increased incidence of marine mammal mortalities caused by collisions with shipping. At lower frequencies, the dominant source of this noise is the cumulative effect of ships that are too far away to be heard individually, but because of their great number, contribute substantially to the average noise background.

Navy Exercises. From 19 to 23 June 2006, the U.S. Navy conducted a Valiant Shield exercise off Guam in the western Pacific. This exercise entailed 28 Navy vessels, more than 300 aircraft and more than 20,000 service members from the U.S. Navy, Air Force, Marine Corps, and Coast Guard. The 2006 Valiant Shield involved carrier strike groups associated with three aircraft carrier — the *USS Abraham Lincoln*, *USS Kitty Hawk*, and *USS Ronald Reagan* — as well as the *RV Cory Chouest* and *USNS Impeccable*. Several submarines also participated in the exercise. The exercise emphasized undersea warfare, particularly detecting and tracking submarines representing the opposition force of the exercise. We assume that mid-frequency active sonar and low-frequency active sonar were used extensively in the exercise, but cannot assess the number of threatened or endangered species exposed to mid- and low-frequency active sonar during the exercise, the received levels they were exposed to, or their responses to that exposure.

Since 1997, the U.S. Navy has sponsored biennial joint training exercises in the western Pacific Ocean with the Australian military and other participants (which have occurred under the names Tandem Thrust or Talisman Sabre). The exercises have been conducted in and around training areas in Australia (1997, 2001, 2005, 2007, and 2009) or in and around the Guam and the northern Mariana Islands (2000 and 2003). From 14 April to 5 May 2003, these exercises involved 17 ships and submarines, including the aircraft carrier USS CARL VINSON and the USS ESSEX Amphibious Ready Group. Information on active sonar that might have been employed during the exercises conducted off Guam and the northern Marianas is not available.

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 ambient noise frequency spectrum and level 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.

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 the Pacific Islands region, whale watching has grown at an average annual growth rate estimated to be 45% between 1998 and 2005 (Ecolarge and the Government of Australia 2006). By comparison, over a similar period, Australian and New Zealand whale watch annual average growth rates were estimated at 15% and 11% respectively.

The high recent growth of whale watching in the Pacific Islands region demonstrates a strongly emerging industry, beginning at a very low level in 1998 to a point seven years later where it is a well established element of the tourism industry in several countries in the Pacific region. The countries that have experienced the strongest annual average growth rates include the Cook Islands, French Polynesia, and Guam. Between 1998 and 2005, the number of tourists who participated in whale watching in Guam increased by more than 70%, from 4,000 to 84,000. Commercial whale watching is virtually non-existent in the Commonwealth of the Northern Marianas (Ecolarge and the Government of Australia 2006).

Several investigators have studied the effects of whale watch vessels on marine mammals (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães *et al*. 2002, Richter *et al*. 2003, Scheidat *et al*. 2004, Simmonds 2005, Watkins 1986, Williams *et al*. 2002). The whale's behavioral responses to whale watching vessels depended on the distance of the vessel from the whale, vessel speed, vessel direction, vessel noise, and the number of vessels. The whales' responses changed with these different variables and, in some circumstances, the whales did not respond to the vessels, but in other circumstances, whales changed their vocalizations, surface time, swimming speed, swimming angle or direction, respiration rates, dive times, feeding behavior, and social interactions.

The Impact of the Baseline on Listed Resources

Although listed resources are exposed to a wide variety of past and present state, Federal or private actions and other human activities that have already occurred or continue to occur in the action area as well as Federal projects in the action area that have already undergone formal or early section 7 consultation, and State or private actions that are contemporaneous with this consultation, the impact of those activities on the status, trend, or the demographic processes of threatened and endangered species remains largely unknown.

Historically, commercial whaling had occurred in the action area and had caused all of the large whales to decline to the point where the whales faced risks of extinction that were high enough to list them as endangered species. Since the end of commercial whaling, the primary threat to these species has been eliminated. However, all of the whale species have not recovered from those historic declines and scientists cannot determine if those initial declines continue to influence current populations of most large whale species. Species like North 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 an pollutant in the marine environment. Relationships between specific sound sources, or anthropogenic sound generally, and the responses of marine mammals to those sources are still subject to extensive scientific research and public inquiry but no clear patterns have emerged. In contrast the individual and cumulative impacts of human activities in the Mariana Islands 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 remains uncertain.

Few of the anthropogenic phenomena in Guam and the Marianas that represent potential risks to whales in the Action Area 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 the region. The second line of evidence consists of reports that suggest that the response of whales to many of the anthropogenic activities in the Action Area are probably short-lived, which suggests that the responses would not be expected to affect the fitness of individual whales. Most of these reports relate to humpback whales during their winter, breeding season; there are very few reports of the behavioral responses of other whales species to human activity in the action area. For example, annual reports from the North Gulf Oceanic Society and two other investigators reported that most whales did not react to approaches by their vessels or only small numbers of whales reacted. That is, in their 1999 report on their research activities, NGOS reported observing signs that whales were “disturbed” in only 3 out of 51 encounters with whales and that the whales’ behavioral responses consisted of breaching, slapping tail and pectoral fin, and diving away from research vessels.

Gauthier and Sears (1999), Weinrich *et al.* (1991, 1992), Clapham and Mattila (1993), Clapham *et al.* (1993) concluded that close approaches for biopsy samples or tagging did cause humpback whales to respond or caused them to exhibit “minimal” responses when approaches were “slow and careful.” This caveat is important and is based on studies conducted by Clapham and Mattila (1993) of the reactions of humpback whales to biopsy sampling in breeding areas in the Caribbean Sea. These investigators concluded that the way a vessel approaches a group of whales had a major influence on the whale’s response to the approach; particularly cow and calf pairs. Based on their experiments with different approach strategies, they concluded that experienced, trained personnel approaching humpback whales slowly would result in fewer whales exhibiting

At the same time, several lines of evidence suggest that these human activities might be greater consequences for individual whales (if not for whale populations). Several investigators reported behavioral responses to close approaches that suggest that individual whales might experience stress responses. Baker *et al*. (1983) described two responses of whales to vessels, including: (1) “horizontal avoidance” of vessels 2,000 to 4,000 meters away characterized by faster swimming and fewer long dives; and (2) “vertical avoidance” of vessels from 0 to 2,000 meters away during which whales swam more slowly, but spent more time submerged. Watkins *et al.* (1981) found that both fin and humpback whales appeared to react to vessel approach by increasing swim speed, exhibiting a startled reaction, and moving away from the vessel with strong fluke motions.

Bauer (1986) and Bauer and Herman (1986) studied the potential consequences of vessel disturbance on humpback whales wintering off Hawai'i. They noted changes in respiration, diving, swimming speed, social exchanges, and other behavior correlated with the number, speed, direction, and proximity of vessels. Results were different depending on the social status of the whales being observed (single males when compared with cows and calves), but humpback whales generally tried to avoid vessels when the vessels were 0.5 to 1.0 kilometer from the whale. Smaller pods of whales and pods with calves seemed more responsive to approaching vessels.

Baker *et al*. (1983) and Baker and Herman (1987) summarized the response of humpback whales to vessels in their summering areas and reached conclusions similar to those reached by Bauer and Herman (1986): these stimuli are probably stressful to the humpback whales in the action area, but the consequences of this stress on the individual whales remains unknown. Studies of other baleen whales, specifically bowhead and gray whales document similar patterns of short-term, behavioral disturbance in response to a variety of actual and simulated vessel activity and noise (Richardson et. al, 1985; Malme *et al*. 1983). For example, studies of bowhead whales revealed that these whales oriented themselves in relation to a vessel when the engine was on, and exhibited significant avoidance responses when the vessel's engine was turned on even at distance of approximately 3,000 ft (900 m). Weinrich *et al*. (1992) associated "moderate" and "strong" behavioral responses with alarm reactions and stress responses, respectively.

Jahoda *et al*. (2003) studied the response of 25 fin whales in feeding areas in the Ligurian Sea to close approaches by inflatable vessels and to biopsy samples. They concluded that close vessel approaches caused these whales to stop feeding and swim away from the approaching vessel. The whales also tended to reduce the time they spent at surface and increase their blow rates, suggesting an increase in metabolic rates that might indicate a stress response to the approach. In their study, whales that had been disturbed while feeding remained disturbed for hours after the exposure ended. They recommended keeping vessels more than 200 meters from whales and having approaching vessels move a low speeds to reduce visible reactions in these whales.

Beale and Monaghan (2004) concluded that the significance of disturbance was a function of the distance of humans to the animals, the number of humans making the close approach, and the frequency of the approaches. These results would suggest that the cumulative effects of the various human activities in the action area would be greater than the effects of the individual activity. None of the existing studies examined the potential effects of numerous close approaches on whales or gathered information of levels of stress-related hormones in blood samples that are more definitive indicators of stress (or its absence) in animals.

There is mounting evidence that wild animals respond to human disturbance in the same way that they respond to predators (Beale and Monaghan 2004, Frid 2003, Frid and Dill 2002, Gill *et al*. 2000, Gill and Sutherland 2001, Romero 2004). These responses manifest themselves as stress responses (in which an animal perceives human activity as a potential threat and undergoes physiological changes to prepare for a flight or fight response or more serious physiological changes with chronic exposure to stressors), interruptions of essential behavioral or physiological events, alteration of an animal's time budget, or some combinations of these responses (Frid and Dill 2002, Romero 2004, Sapolsky *et al*. 2000, Walker *et al*. 2005). These responses have been associated with abandonment of sites (Sutherland and Crockford 1993), reduced reproductive success (Giese 1996, Mullner *et al*. 2004), and the death of individual animals (Daan *et al*. 1996).

The information available does not allow us to assess the actual or probable effects of natural and anthropogenic phenomena on threatened or endangered species in the action area. With the exception of some sea turtles and Hawai'ian monk seals, the age composition, gender ratios, population abundance, and changes in that abundance over time remain unknown for threatened and endangered species in the action area of this consultation. Without this information or some surrogate information, it would be difficult, if not impossible, to reliably assess the impact of the activities identified in this *Environmental Baseline* on threatened and endangered species in the action area.

5.0 Effects of the Proposed Action

In *Effects of the Action* sections of Opinions, NMFS presents the results of its assessment of the probable direct and indirect effects of federal actions that the subject of a consultation as well as the direct and indirect effects of interrelated, and interdependent actions on threatened and endangered species and designated critical habitat. As we described in the *Approach to the Assessment* section of this Opinion, we organize our effects' analyses using an stressor identification - exposure – response – risk assessment framework; we conclude this section with an *Integration and Synthesis of Effects* that integrates information we presented in the *Status of the Species* and *Environmental Base* sections of this Opinion with the results of our exposure and response analyses to estimate the probable risks the proposed action poses to endangered and threatened species.

Before we begin, we need to address a few definitions. The Endangered Species Act does not define "harassment" nor has NMFS defined this term, pursuant to the ESA, through regulation. However, the Marine Mammal Protection Act of 1972, as amended, defines "harassment" as "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild or has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" [16 U.S.C. 1362(18)(A)]. For military readiness activities, this definition of "harassment" has been amended to mean "any act that disrupts or is likely to disturb a marine mammal or marine mammal stock by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behaviors are abandoned or significantly altered" (Public Law 106-136, 2004). The latter portion of these definitions (that is, "...causing disruption of behavioral patterns including…migration, breathing, nursing, breeding, feeding, or sheltering") is almost identical to the U.S. Fish and Wildlife Service's regulatory definition of harass.[3]

For the purposes of our consultation on military readiness activities, we have defined "harassment" so that it corresponds to the MMPA and USFWS definitions: "an intentional or unintentional human act or omission that creates the probability of injury to an individual animal by disrupting one or more behavioral patterns that are essential to the animal's life history or its contribution to the population the animal represents." We are particularly concerned about changes in animal behavioral that is likely to result in animals that fail to feed, fail to breed successfully, or fail

3 An intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.4)

to complete their life history because those changes may have adverse consequences for populations of those species.

5.1 Potential Stressors

The U.S. Navy has conducted military readiness activities in waters on and adjacent to the Mariana Islands Range Complex Complex for decades and the potential stressors listed in the following paragraphs have been associated with those earlier activities. As a result, it is more accurate to say that the U.S. Navy's proposes to continue conducting military readiness activities in the Action Area and the Permits Division proposes to authorize the "take" of marine mammals associated with those reseach, development, test and evaluation activities. By extension, the potential stressors associated with the Navy's proposal are stressors that have occurred previously in the Action Area as well.

We discuss the potential stressors associated with the activities the U.S. Navy proposes to conduct at the Mariana Islands Complex in greater detail in the narratives that follow this introduction. We follow those descriptions with a presentation of the results of our exposure analyses, which are designed to determine whether endangered or threatened individuals or designated critical habitat are likely to be exposed to one or more of these potential stressors. We follow those analyses with the results of our response analyses.

As discussed in the *Approach to the Assessment* section of this Opinion, because direct or indirect exposure to a stressor is a necessary condition for an effect, if endangered or threatened individuals are not likely to be exposed to a potential stressor, that "potential stressor" is not likely to be an actual stressor so we would drop it from further discussion. As outlined in the introductory paragraph of this section, we conclude our effects analyses with an *Integration and Synthesis* which contains the results of our risk analyses.

Because of the geographic location of several components of the training activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex, endangered or threatened species under NMFS' jurisdiction are not likely to be exposed to stressors those training activities might produce. Specifically, endangered or threatened species under NMFS' jurisdiction are not likely to be exposed to stressors associated with the following activities:

1. The Expeditionary Warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex, which consist of military operations in urban terrain or MOUT training (see Table 1), would occur at primary and secondary locations that are terrestrial (on Guam; Andersen Airforce Base South; Finegayan Communication Annex; Barrigada Housing; Northwest Field, Tinian; Rota; or Saipan). These exercises are not likely to directly or indirectly produce potential stressors that would reach the marine or coastal environment where endangered or threatened species under NMFS' jurisdiction might be exposed to those stressors.
2. The Anti-terrorism and Force Protection training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex would occur at primary and secondary locations that are terrestrial ((Northwest Field, Northern Land Navigation Area; and Barrigada Annex, Orote Point Airfield, Polaris Point airfield, or Tinian North Field). These exercises are not likely to directly or indirectly produce potential stressors that would reach the marine or coastal environment where endangered or threatened species under NMFS' jurisdiction might be exposed to those stressors.

3. The Marine Air Ground Task Force Exercise – Humanitarian Assistance – Disaster Relief/ Noncombatant Evacuation Operation (HADR/NEO) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex would occur at primary and secondary locations that are terrestrial (Guam with Tinian, Saipan, or Farallon de Medinilla). These exercises are not likely to directly or indirectly produce potential stressors that would reach the marine or coastal environment where endangered or threatened species under NMFS' jurisdiction might be exposed to those stressors.

4. The Urban Warfare Exercise the U.S. Navy proposes to conduct on the Mariana Islands Range Complex would occur at primary and secondary locations that are terrestrial (Finegayan Housing, Andersen South, Barrigada Housing, and Northwest Field, Tinian or Rota). These exercises are not likely to directly or indirectly produce potential stressors that would reach the marine or coastal environment where endangered or threatened species under NMFS' jurisdiction might be exposed to those stressors.

5. The Special Warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex, including breaching, direct action, hydrographic reconnaissance, insertion/extraction, parachute insertion, or urban warfare training activities would occur at primary and secondary locations that are terrestrial. These exercises are not likely to directly or indirectly produce potential stressors that would reach the marine or coastal environment where endangered or threatened species under NMFS' jurisdiction might be exposed to those stressors.

6. The Special Warfare-Expeditionary Warfare training exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex, including specific training exercises for Airfield Expeditionary, Field Training Exercise, Humanitarian Assistance/Disaster Relief Operation, Intelligence, Surveillance, Reconnaissance, Land Demolitions, Maneuver, Non-Combatant Evacuation Operation, and Airfield Seizure would occur at primary and secondary locations that are terrestrial. These exercises are not likely to directly or indirectly produce potential stressors that would reach the marine or coastal environment where endangered or threatened species under NMFS' jurisdiction might be exposed to those stressors.

Because of their terrestrial locations and because endangered or threatened species are not likely to be affected, adversely or otherwise, by potential stressors associated with these training activities, these activities are not likely to adversely affect endangered or threatened species under NMFS' jurisdiction and will not be considered further in this document.

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 on the Mariana Islands Range Complex have been or will be addressed in separate consultations with the U.S. Fish and Wildlife Service.

Stressors Associated with the Mariana Islands Range Complex

As discussed in the Approach to the Assessment section of this Opinion, the primary stressors associated with the military readiness activities the U.S. Navy proposes to conduct in waters on and adjacent to the Mariana Islands Range Complex consist of:

1. surface vessels and submarines involved in training activities and the associated risk of collisions;
2. pressure waves produced by the underwater detonations;
3. projectiles associated with firing operations;
4. sound fields produced by the low-, mid-, and high-frequency active sonar systems the U.S. Navy would employ during the training activities;
5. sound fields produced by the underwater detonations the U.S. Navy would employ during training activities;
6. disturbance produced by the surface vessels and aircraft involved in training activities;
7. the chemical constituents of explosives, ordnance, chaff, and flares; and
8. parachutes associated with flares and sonobuoys

Several elements of the research, development, test, and evaluation activities the U.S. Navy plans to conduct at the Mariana Islands Range Complex Complex are not likely to produce stressors for endangered and threatened species under the jurisdiction of the National Marine Fisheries Service (although they might represent stressors for species under the jurisdiction of the U.S. Fish and Wildlife Service).

The narratives that follow describe these stressors in greater detail, describe the probability of listed species being exposed to these stressors based on the best scientific and commercial evidence available, then describe the probable responses of listed species, given probable exposures, based on the evidence available.

5.1.1 Traffic from Surface Vessels and Submarines

As discussed in the *Description of the Proposed Action* section of this Opinion, the U.S. Navy plans to conduct several activities on the Mariana Islands Range Complex that involve surface vessels moving in waters that also might be occupied by endangered or threatened marine mammals and sea turtles. These training activities include amphibious warfare training (particularly amphibious assaults and amphibious raids), anti-submarine warfare training, major training exercises (particularly joint expeditionary exercises and joint multi-strike group exercises), mine warfare training, and surface warfare training.

Traffic from surface vessels associated with these training exercises represents a suite of stressors or stress regimes that pose several potential hazards to endangered and threatened species that occur on the Mariana Islands Range Complex (the action area for this consultation). First, the size of the ships involved in the proposed training activities would range from 362 feet (a nuclear submarine) to 1,092 feet (for a nuclear-powered aircraft carrier). A variety of smaller craft such as service vessels engaged in routine operations or employed as opposition forces during training events would also operating within the different range complexes. During training activities, ship speeds generally range from 10 to 14 knots; however, these vessels would also operate within the entire spectrum at higher speeds during specific events, such as pursuing and overtaking hostile vessels, evasive maneuvers, and maintenance or performance checks (such as ship trials). The size and speeds of smaller vessels would vary. For example, rigid hull inflatable boats or RHIBS are 35 feet in length and can reach speeds greater than 40 knots.

Given the speeds at which these vessels are likely to move, they pose some risk of collisions between these ships and marine mammals or sea turtles (although the risks of striking sea turtles is smaller than the risks of striking endangered marine mammals). The Navy's operational orders for ships that are underway are designed to prevent collisions between surface vessels participating in naval exercises and any endangered whales that might occur in the action area. These measures, which include marine observers on the bridge of ships, requirements for course and speed adjustments to maintain safe distances from whales, and having any ship that observes whales to alert other ships in the area, have historically been effective measures for avoiding collisions between surface vessels and whales.

5.1.2. Pressure waves and Sound Field Produced by Underwater Detonations

The U.S. Navy plans to continue to employ several kinds of explosive ordnance on the Mariana Island Range Complex. 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, the type of explosive material, and the detonation depth. The net explosive weight accounts for the first two parameters. The net explosive weight of an explosive is the weight of only the explosive material in a given round, referenced to the explosive power of TNT.

The detonation depth of an explosive is particularly important due to a propagation effect known as surface-image interference. For sources located near the sea surface, a distinct interference pattern arises from the coherent sum of the two paths that differ only by a single reflection from the pressure-release surface. As the source depth and/or the source frequency decreases, these two paths increasingly, destructively interfere with each other, reaching total cancellation at the surface (barring surface-reflection scattering loss). Since most of the explosives the Navy proposes to use on the Mariana Islands Range Complex are munitions that detonate essentially upon impact, the effective source depths are very shallow so the surface-image interference effect can be pronounced. In order to limit the cancellation effect (and thereby provide exposure estimates that tend toward the worst case), relatively deep detonation depths are used. To remain consistent with previous models the Navy has used, the Navy used source depths of one foot for gunnery rounds. For missiles and bombs, the Navy used source depths of 2 meters. For MK-48 torpedoes, which detonate immediately below a target's hull, the Navy used nominal depths of 50 feet for their analyses.

EXPLOSIVE SOURCE ASSOCIATED WITH THE IMPROVED EXTENDED ECHO RANGING (IEER) SYSTEM. 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 treat each in-water explosion as an independent event. The cumulative effect of a series of explosives can often be estimated by addition if the detonations are spaced widely in time and space which would provide marine animal's sufficient time to move out of an area affected by an explosion. As a result, the populations of animals that are exposed to in-water explosions are assumed to consist of different animals each time.

The number of endangered or threatened species that might be exposed to explosions associated with this ordnance treat each in-water explosion as an independent event. The cumulative effect of a series of explosives can often be estimated by addition if the detonations are spaced widely in time and space which would provide marine animal's sufficient time to move out of an area affected by an explosion. As a result, the populations of animals that are exposed to in-water explosions are assumed to consist of different animals each time.

5.1.3 Expended Ordnance

Many of the activities the U.S. Navy plans to conduct on the Mariana Islands Range Complex introduce expended ordnance and other fragments into the marine environment.

BOMBS. The majority of the bombs, the U.S. Navy would employ during training activities it conducts on the Mariana Islands Range Complex would be practice bombs that are not equipped with explosive warheads. Practice bombs entering the water would consist of materials like concrete, steel, and iron, and would not contain the combustion chemicals found in the warheads of explosive bombs. These components are consistent with the primary building blocks of artificial reef structures. The steel and iron, although durable, would corrode over time, with no noticeable environmental impacts. The concrete is also durable and would offer a beneficial substrate for benthic organisms. After sinking to the bottom, the physical structure of bombs would be incorporated into the marine environment by natural encrustation and/or sedimentation (U.S. Navy 2006b).

MISSILES. Missiles would be fired by aircraft, ships, and Naval Special Warfare operatives at a variety of airborne and surface targets on the Mariana Islands Range Complex. In general, the single largest hazardous constituent of missiles is solid propellant, which is primarily composed of rubber (polybutadiene) mixed with ammonium perchlorate (for example, solid double-base propellant, aluminum and ammonia propellant grain, and arcite propellant grain). Hazardous constituents are also used in igniters, explosive bolts, batteries (potassium hydroxide and lithium chloride), and warheads (for example, PBX-N highexplosive components; PBXN-106 explosive; and PBX (AF)-108 explosive). Chromium or cadmium may also be found in anti-corrosion compounds coating exterior missile surfaces. In the event of an ignition failure or other launch mishap, the rocket motor or portions of the unburned propellant may cause environmental effects. Experience with Hellfire missiles has shown that if the rocket motor generates sufficient thrust to overcome the launcher hold-back, all of the rocket propellant is consumed. In the rare cases where the rocket does not generate sufficient thrust to overcome the holdback (hang fire or miss fire), some propellant may remain unburned but the missile remains on the launcher. Jettisoning the launcher is a possibility for hang fire or miss fire situations, but in most cases the aircraft returns to base where the malfunctioning missile is handled by explosive ordnance disposal personnel

Non-explosive practice missiles generally do not explode upon contact with the target or sea surface. The main environmental effect would be the physical structure of the missile entering the water. Practice missiles do not use rocket motors and, therefore, do not have potentially hazardous rocket fuel. Exploding warheads may be used in air-to-air missile exercises, but those missile would explode at an offset to the target in the air, disintegrate, and fall into the ocean to avoid damaging the aerial target. High explosive missiles used in air-to-surface exercises explode near the water surface (U.S. Navy 2006a). For example, missiles employed during a HARMEX would detonate 30 - 60 feet (9.1 – 18.3 m) above the ocean surface.

The principal potential stressor from missiles would be unburned solid propellant residue. Solid propellant fragments would sink to the ocean floor and undergo changes in the presence of seawater. The concentration would decrease over time as the leaching rate decreased and further dilution occurred. The aluminum would remain in the propellant binder and eventually would be oxidized by seawater to aluminum oxide. The remaining binder material and aluminum oxide would pose no threat to the marine environment (DoN, 1996).

TARGETS. At-sea targets are usually remotely operated airborne, surface, or subsurface traveling units, most of which are designed to be recovered for reuse. Aerial and surface targets would be deployed annually on the Mariana Islands Range Complex. Small concentrations of fuel and ionic metals would be released during battery operation.

A typical aerial target drone is powered by a jet fuel engine, generates radio frequency (RF) signals for tracking purposes, and is equipped with a parachute to allow recovery. Drones also contain oils, hydraulic fluid, batteries, and explosive cartridges as part of their operating systems. There are also recoverable, remotely controlled target boats and underwater targets designed to simulate submarines. If severely damaged or displaced, targets may sink before they can be retrieved. Aerial targets employed on the Mariana Islands Range Complex would include AST/ALQ/ESM pods, Banner drones, BQM-74E drones, Cheyenne, Lear Jets, and Tactical Air-Launched Decoys, which are the only expended targets (these targets are non-powered, air-launched, aerodynamic vehicle).

Surface targets would include Integrated Maritime Portable Acoustic Scoring and Simulator Systems, Improved Surface Tow Targets, QST-35 Seaborne Powered Targets, and expendable marine markers (smoke floats). Expended surface targets commonly used in addition to marine markers include cardboard boxes, 55-gallon steel drums, and a 10-foot-diameter red balloon tethered by a sea anchor (also known as a "killer tomato"). Floating debris, such as Styrofoam, may be lost from target boats.

Most target fragments would sink quickly in the sea. Expended material that sinks to the sea floor would gradually degrade, be overgrown by marine life, and/or be incorporated into the sediments. Floating non-hazardous expended material may be lost from target boats and would either degrade over time or wash ashore as flotsam. Non-hazardous expended materials are defined as the parts of a device made of non-reactive material. Typical non-reactive material includes metals such as steel and aluminum; polymers, including nylon, rubber, vinyl, and plastics; glass; fiber; and concrete. While these items represent persistent seabed litter, their strong resistance to degradation and their chemical composition mean they do not chemically contaminate the surrounding environment by leaching heavy metals or organic compounds.

GUN AMMUNITION. Naval gun fire on the Mariana Islands Range Complex would use non-explosive and explosive 5-inch or 76 mm ordnance, 25 mm cannon, .50 cal or 7.62 mm ordnance. More than 80 percent of the 5-inch and 76-mm training rounds expended would be non-explosive and contain an iron shell with sand, iron grit, or cement filler. Rapid-detonating explosive would be used in explosive rounds. Unexploded shells and non-explosive practice munitions would not be recovered and would sink to the ocean floor. Solid metal components (mainly iron) of unexploded ordnance and non-explosive practice munitions would also sink.

High-explosive, 5-inch shells are typically fuzed to detonate within 3 feet of the water surface. Shell fragments rapidly decelerate through contact with the surrounding water and settle to the sea floor. Unrecovered ordnance would also sink to the ocean floor. Iron shells and fragments would be corroded by seawater at slow rates, with comparably slow release rates. Over time, natural encrustation of exposed surfaces would occur, reducing the rate at which corrosion occurred. Rates of deterioration would vary, depending on the material and conditions in the immediate marine and benthic environment. However, the release of contaminants from unexploded ordnance, non-explosive practice munitions, and fragments would not result in measurable degradation of marine water quality.

The rapid-detonating explosive material of unexploded ordnance would not typically be exposed to the marine environment. Should the rapid-detonating explosive be exposed on the ocean floor, it would break down within a few hours (U.S. Navy 2001). Over time, the rapid-detonating explosive residue would be covered by ocean sediments or diluted by ocean water

CHAFF. Radio frequency chaff (chaff) is an electronic countermeasure designed to reflect radar waves and obscure aircraft, ships, and other equipment from radar-tracking sources. Chaff is non-hazardous and consists of aluminum-coated glass fibers (about 60% silica and 40% aluminum by weight) ranging in lengths from 0.3 to 3 inches with a diameter of about 40 micrometers. Chaff is released or dispensed from military vehicles in cartridges or projectiles that contain millions of chaff fibers. When deployed, a diffuse cloud of fibers undetectable to the human eye is formed. Chaff is a very light material that can remain suspended in air anywhere from 10 minutes to 10 hours. It can travel considerable distances from its release point, depending on prevailing atmospheric conditions (Arfsten *et al.* 2002).

For each chaff cartridge used, a plastic end-cap and Plexiglas piston is released into the environment in addition to the chaff fibers. The end-cap and piston are both round and are 1.3 inches in diameter and 0.13 inches thick (Spargo, 2007). The fine, neutrally buoyant chaff streamers act like particulates in the water, temporarily increasing the turbidity of the ocean's surface. However, they are quickly dispersed and turbidity readings return to normal. The end-caps and pistons would sink; however, some may remain at or near the surface if it were to fall directly on a dense *Sargassum* mat. The expended material could also be transported long distances before becoming incorporated into the bottom sediments.

Based on the dispersion characteristics of chaff, large areas of open water on the Mariana Islands Range Complex would be exposed to chaff, but the chaff concentrations would be low. For example, Hullar *et al.* (1999) calculated that a 4.97-mile by 7.46-mile area (37.1 square miles or 28 square nautical miles) would be affected by deployment of a single cartridge containing 150 grams of chaff. The resulting chaff concentration would be about 5.4 grams per square nautical mile. This corresponds to fewer than 179,000 fibers per square nautical mile or fewer than 0.005 fibers per square foot, assuming that each canister contains five million fibers.

The probability of individual animals being struck by this ordnance or encountering chaff particles is sufficiently small to be treated as discountable, even after considering the amount of ordnance the U.S. Navy would expend during the training activities it plans to conduct on the Mariana Islands Range Complex, As a result, we do not consider this category of potential stressors further in our analyses.

5.1.4. Sound Fields Produced By Active Sonar

As discussed in the *Description of the Proposed Action* section of this Opinion, the U.S. Navy plans to employ mid- and high-frequency sonar systems during several of the training events it proposes to conduct in the Mariana Islands 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 on the Mariana Islands 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 which is a large, active-passive, bow-mounted sonar that has been operational since 1975. AN/SQS-53 is the U.S. Navy's most powerful surface ship sonar and is installed on *Ticonderoga* (22 units) and *Arleigh Burke* I/II/IIIa (51 units) class vessels in the U.S. Navy (Polmar 2001, D`Spain *et al.* 2006). This sonar transmits at a center frequency of 3.5 kHz at sources levels of 235 dB_{RMS} re: 1 μPa at 1 meter. The sonar has pulse durations between 1 and 2 seconds, with about 24-second intervals between pulses. AN/SQS-53 operates at depths of about 7 meters.

   The AN/SQS-53 is a computer-controlled, hull-mounted surface-ship sonar that has both active and passive operating capabilities, providing precise information for anti-submarine warfare weapons control and guidance. The system is designed to perform direct-path anti-submarine warfare search, detection, localization, and tracking from a hull-mounted transducer array. The AN/SQS-53 sonar is installed on *Arleigh Burke* Class guided missile destroyers and *Ticonderoga* Class guided missile cruisers. The AN/SQS-53 Kingfisher is a modification that provides a surface ship with the ability to detect mine-like objects.

2. The AN/SQS-56 system is a lighter active-passive bow-mounted sonar that has been operational since 1977. AN/SQS-56 is installed on FFG-7 (33 units) class guided missile frigates in the U.S. Navy (Polmar 2001, D`Spain *et al.* 2006). This sonar transmits at a center frequency of 7.5 kHz and a source level of 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 duration, rise times, and wave form of sounds sonar transmitted from these sonar systems classified; however, the characteristics of the transmissions that were used during the Bahamas exercises might help illustrate attributes of the transmissions from these two sonar sources. During the Bahamas exercises, these two sonars transmitted 1 – 2 second pulses once every 24 seconds (D'Spain *et al*. 2006). Pulses had rise times of 0.1 – 0.4 seconds and typically consisted of three waveforms with nominal bandwidths up to 100 Hz (D'Spain *et al*. 2006). Both sonar create acoustic fields that are omnidirectional in azimuth, although AN/SQS-53 also can create beams covering 120˚ azimuthal sectors that can be swept from side to side during transits (D'Spain *et al*. 2006). Waveforms of both sonar systems are frequency modulated with continuous waves (D'Spain *et al*. 2006).

SONAR SYSTEMS ASSOCIATED WITH SUBMARINES. Tactical military submarines (i.e. 29 attack submarines as of 2008) 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 submarine 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. 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 SSNs, Virginia Class SSNs, Los Angeles Class SSNs, and Ohio Class SSBN/nuclear guided missile submarines (SSGNs). The BQQ-10 systems installed on Ohio Class SSBNs do not have an active sonar capability.

2. 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 (Figure C-4) sonar system is installed on Los Angeles Class nuclear attack submarines (SSNs) and Ohio Class ballistic missile nuclear submarines (SSBNs), although the AN/BQQ-5 systems installed on Ohio Class SSBNs 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.

SONAR SYSTEMS ASSOCIATED WITH AIRCRAFT. Aircraft sonar systems that typically operate during Navy training exercises include sonobuoys and dipping sonar. Current dipping sonar systems used by the Navy are either AN/SQS-22 or AN/AQS -13. AN/AQS -13 is an older and less powerful dipping sonar system (maximum source level 215 dB re µPa-s^2 at 1m) than the AN/AQS -22 (maximum source level 217 dB re µPa-s^2 at 1m). In its modeling, the Navy assumed that all dipping sonar were AN/AQS -22. P-3 aircraft may deploy sonobuoys while helicopters may deploy sonobuoys or dipping sonars (the latter are used by carrier-based helicopters). Sonobuoys are expendable devices used by aircraft for the detection of underwater acoustic energy and for conducting vertical water column temperature measurements. Dipping sonar is an active or passive sonar device lowered on cable by helicopters to detect or maintain contact with underwater targets. In addition, the U.S. Navy employs tonal sonobuoys (DICASS, AN/SSQ-62) and the Improved Extended Echo Ranging (IEER) System discussed earlier.

1. The AN/SSQ-62C Directional Command Activated Sonobuoy System (DICASS) sonar system is part of a sonobuoy that operates under direct command of fixed-wing aircraft or helicopters. The system can determine the range and bearing of the target relative to the sonobuoys position and can deploy to various depths within the water column. After it enters the water, the sonobuoy transmits sonar pulses (continuous waveform or linear frequency modulation) upon command from the aircraft. The echoes from the active sonar signal are processed in the buoy and transmitted to the receiving station onboard the launching aircraft.
2. AN/SSQ-110A Explosive Source Sonobuoy is 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 maritime patrol aircraft.
3. 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.

In addition to these torpedoes, the U.S. Navy can employ Acoustic Device Countermeasures in their training exercises, which include 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.

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.

Training targets include MK-30 anti-submarine warfare training targets, and MK-39 Expendable Mobile anti-submarine warfare training targets. Targets may be non-evading while operating on specified tracks or they may be fully evasive, depending on the training requirements of the training operation.

5.1.5. Disturbance Produced By Surface Vessels and Aircraft

Most of the activities the U.S. Navy proposes to conduct in the Mariana Islands Range Complex involve some level of activity from surface vessels, submarines, or both. Carrier Strike Groups can include one aircraft carrier, one carrier air wing, four strike fighter squadrons, one electronic combat squadron, one airborne early warning squadron, two combat helicopter squadrons, two logistics aircraft, five surface combatant ships (guided missile cruisers, destroyers, and frigates), one attack submarine, and one logistics support ship. Expeditionary Strike Groups can include three amphibious ships, landing craft – utility, landing craft - air cushioned, amphibious assault vehicle or expeditionary fighting vehicle, three surface combatant ships, three combat helicopter detachments, one attack submarine, one marine expeditionary unit (Special Operations Capable) of 2,200 Marines, ground combat and combat logistics elements, and composite aviation squadron of fixed-wing aircraft and helicopters. Surface Strike Groups can include three surface ships, surface combatants, amphibious ships, one combat helicopter detachment, and one attack submarine. An expeditionary strike force can combine more than one carrier strike group, expeditionary strike group, or surface strike group.

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 used during Navy training activities, the available evidence suggests that major training exercises (for example, joint expeditionary exercises or joint mult-strike group exercises), unit-level, or intermediate-level exercises would represent different stress regimes because of differences in the number of vessels involved, vessel maneuvers, and vessel speeds.

Studies of interactions between surface vessels and marine mammals have demonstrated that surface vessels represent a source of acute and chronic disturbance for marine mammals (Au and Green 1990, Au and Perryman 1982, Bain *et al.* 2006, Bauer 1986, Bejder 1999, 2006a, 2006b; Bryant *et al.* 1984, Corkeron 1995, Erbé 2000, Félix 2001, Goodwin and Cotton 2004, Hewitt 1985, Lemon *et al.* 2006, Lusseau 2003, 2006; Lusseau and Bejder 2007, Magalhães *et al.* 2002, Ng and Leung 2003, Nowacek *et al.* 2001, Richter *et al.* 2003, 2006; Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams and Ashe 2007, Williams *et al.* 2002, 2006a, 2006b; Würsig *et al.* 1998). Specifically, in some circumstances, marine mammals respond to vessels with the same behavioral repertoire and tactics they employ when they encounter predators.

These studies establish that free-ranging cetaceans engage in avoidance behavior when surface vessels move toward them. It is not clear whether these responses are caused by the physical presence of a surface vessel, the underwater noise generated by the vessel, or an interaction between the two (Goodwin and Green 2004; Lusseau 2006). Several, authors, however, suggest that the noise generated by the vessels is probably an important contributing factor to the responses of cetaceans to the vessels (Blane and Jackson 1994, Evans *et al.* 1992, 1994), so we may not be able to treat the effects of vessel traffic as independent of engine and other sounds associated with the vessels.

For surface vessels, the set of variables that help determine whether marine mammals are likely to be disturbed include:

1. *number of vessels*. The behavioral repertoire marine mammals have used to avoid interactions with surface vessels appears to depend on the number of vessels in their perceptual field (the area within which animals detect acoustic, visual, or other cues) and the animal's assessment of the risks associated with those vessels (the primary index of risk is probably vessel proximity relative to the animal's flight initiation distance).

   Below a threshold number of vessels (which probably varies from one species to another, although groups of marine mammals probably shared sets of patterns), studies have shown that whales will attempt to avoid an interaction using horizontal avoidance behavior. Above that threshold, studies have shown that marine mammals will tend to avoid interactions using vertical avoidance behavior, although some marine mammals will combine horizontal avoidance behavior with vertical avoidance behavior (see Response Analyses for further discussion);

2. *the distance between vessel and marine mammals* when the animal perceives that an approach has started and during the course of the interaction;

3. *the vessel's speed and vector*;

4. *the predictability of the vessel's path*. That is, whether the vessel stays on a single path or makes continuous course changes;

6. *noise associated with the vessel* (particularly engine noise) and the rate at which the engine noise increases (which the animal may treat as evidence of the vessel's speed);

7. *the type of vessel* (displacement versus planing), which marine mammals may be interpret as evidence of a vessel's maneuverability.

Because of the number of vessels involved in U.S. Navy training exercises, their speed, their use of course changes as a tactical measure, and sounds associated with their engines and displacement of water along their bowline, the available evidence leads us to expect marine mammals to treat Navy vessels as potential stressors. Further, without considering differences in sound fields associated with any active sonar that is used during these exercises, the available evidence suggests that major training exercises (for example, COMPTUEX or JTFEX), unit- and intermediate-level exercises, and RDT&E activities would represent different stress regimes because of differences in the number of vessels involved, vessel maneuvers, and vessel speeds.

Much of the increase in ambient noise levels in the oceans over the last 50 years has been attributed to increased shipping, primarily due to the increase in the number and tonnage of ships throughout the world, as well as the growth and increasing interconnection of the global economy and trade between distant nations (National Resource

Council 2003). Commercial fishing vessels, cruise ships, transport boats, recreational boats, and aircraft, all contribute sound into the ocean (National Resource Council 2003). Military vessels underway or involved in naval operations or exercises, also introduce anthropogenic noise into the marine environment.

Sounds emitted by large vessels can be characterized as low-frequency, continuous, and tonal, and sound pressure levels at a source will vary according to speed, burden, capacity and length (Richardson *et al.* 1995). Vessels ranging from 135 to 337 meters (*Nimitz*-class aircraft carriers, for example, have lengths of about 332 meters) generate peak source sound levels from 169-200 dB between 8 Hz and 430 Hz. Given the sound propagation of low frequency sounds, a large vessel in this sound range can be heard 139-463 kilometers away (Ross 1976 *in* Polefka 2004).

We recognize that Navy vessels almost certainly incorporate quieting technologies that reduce their acoustic signature (relative to the acoustic signature of similarly-sized vessels) in order to reduce their vulnerability to detection by enemy vessels (Southall 2005). Nevertheless, we do not assume that any quieting technology would be sufficient to prevent marine mammals from detecting sounds produced by approaching Navy vessels and perceiving those sounds as predatory stimuli.

DISTURBANCE ASSOCIATED WITH AIRCRAFT. Several of the activities the U.S. Navy proposes to conduct on the Mariana Islands 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 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.* (1995) reported that there is no evidence that single or occasional aircraft flying above large whales and pinnipeds in-water cause long-term displacement of these mammals. Several authors have reported that sperm whales did not react to fixed-wing aircraft or helicopters in some circumstances (Au and Perryman 1982, Clarke 1956, Gambell 1968, Green *et al.* 1992) and reacted in others (Clarke 1956, Fritts *et al.* 1983, Mullin *et al.* 1991, Patenaude *et al.* 2006, Richter *et al.* 2003, 2006, Smultea *et al.* 2008, Würsig *et al.* 1998). Richardson *et al.* (1985) reported that bowhead whales (*Balaena mysticetus*) responded behaviorally to fixed-wing aircraft that were used in their surveys and research studies when the aircraft were less than 457 meters above sea level; their reactions were uncommon at 457 meters, and were undetectable above 610 meters. They also reported that bowhead whales did not respond behaviorally to helicopter overflights at about 153 meters above sea level.

Smultea *et al.* (2008) studied the response of sperm whales to low-altitude (233-269 m) flights by a small fixed-wing airplane Kauai and reviewed data available from either other studies. They concluded that sperm whales responded behaviorally to aircraft passes in about 12 percent of encounters. All of the reactions consisted of sudden dives and occurred when the aircraft was less than 360 m from the whales (lateral distance). They concluded that the sperm whales had perceived the aircraft as a predatory stimulus and responded with defensive behavior. In at least one case, Smultea and *et al.* (2008) reported that the sperm whales formed a semi-circular "fan" formation that was similar to defensive formations reported by other investigators.

5.1.6. The Chemical Constituents Of Explosives, Ordnance, Chaff, And Flares

The chemical products of deep underwater explosions are initially confined to a thin, circular area called a "surface pool." Young (1995) estimated that 100% of the solid explosion products and 10% of the gases remain in the pool, which is fed by upwelling currents of water entrained by the rising bubble produced by a detonation (see Table 4). After the turbulence of an explosion has dispersed, the surface pool would stabilize and chemical products would become uniformly distributed within the pool. A surface pool is usually not visible after about five minutes. As a surface pool continues to expand, chemical products would be further diluted and become undetectable. Because of continued dispersion and mixing, there would be no buildup of explosion products in the water column.

Table 4. Predicted concentrations of explosion products in seawater, compared with permissible concentrations (from U.S. Navy 2007)

Explosion Product	Predicted Concentration (mg/L)	Permissible Concentration (mg/L)
Carbon dioxide (CO2)	0.00262	1.0
Carbon monoxide (CO)	0.0293	0.552
Ammonia (NH3)	0.00230	0.092b
Ethane (C2H6)	0.00469	120
Propane (C3H8)	0.00135	120
Hydrogen cyanide (HCN)	0.000298	0.001 - 0.036
Methane (CH4)	0.000126	120
Methyl alcohol (CH3OH)	0.0000107	3.60
Formaldehyde (CH2O)	0.00000534	0.0414
Carbon (C)	0.143	NA
Acetylene (C2H2)	0.00000668	73
Phosphine (PH3)	0.00000935	0.0055
Aluminum oxide (Al2O3)	0.434	NA

The concentrations of chemicals associated with the explosive materials are not hazardous to marine mammals, sea turtles, their prey, competitors, or predators. At the concentrations associated with explosive ordnance the U.S. Navy proposes to use in its training exercises, these chemicals are not likely to have adversely affect the endangered or threatened species that are likely to occur on the Mariana Islands Range Complex, either through direct action on the organisms themselves, through their food, or as a result of their action on competitors, predators, or pathogens. As a result, we do not consider this category of potential stressors further in our analyses.

5.1.7. Parachutes Associated With Flares And Sonobuoys

When AN/SQS-62 DICASS sonobuoys impact the water surface after being deployed from aircraft, their parachute assemblies of sonobuoys are jettisoned and sink away from the sonobuoy, while a float containing an antenna is inflated. The parachutes are made of nylon and are about 8 feet in diameter. At maximum inflation, the canopies are between 0.15 to 0.35 square meters (1.6 to 3.8 squared feet). The shroud lines range from 0.30 to 0.53 meters (12 to 21 inches) in length and are made of either cotton polyester with a 13.6 kilogram (30 pound) breaking strength or nylon with a 45.4 kilogram (100 pound) breaking strength. All parachutes are weighted with a 0.06 kilogram (2 ounce) steel material weight, which would cause the parachute to sink from the surface within about 15 minutes (although actual sinking rates would depend on ocean conditions and the shape of the parachute).

The system's subsurface assembly descends to a selected depth, the sonobuoy case falls away, and sea anchors deploy to stabilize the hydrophone (underwater microphone). The operating life of the seawater battery is about eight hours, after which the sonobuoy scuttles itself and sinks to the ocean bottom. For the sonobouys, the U.S. Navy calculated concentrations of metals released from batteries as 0.0011 mg/L lead, 0.000015mg/L copper, and 0.0000001mg/L silver.

5.2 Exposure Analysis

As discussed in the *Approach to the Assessment* section of this opinion, our exposure analyses are designed to determine whether listed resources are likely to co-occur with the direct and indirect beneficial and adverse effects of actions and the nature of that co-occurrence. In this section of this biological opinion, we present the results of 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 one or more of the stressors produced by or associated with an Action and the populations or subpopulations those individuals represent.

As discussed in the *Approach to the Assessment* section of this Opinion, 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.) 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. Based on our evaluation of assumptions the U.S. Navy incorporates in its models, those models would tend to over-estimate the number of marine mammals that might be exposed to military readiness activities in waters on and adjacent to the Mariana Islands Range Complex because (1) those models assume that marine mammals would not try to avoid being exposed to the sound field associated with active sonar or would not try to avoid continued exposure to the sound field; (2) those models assume that mean densities of marine mammals within any square kilometer area of the Range Complex would be constant over time (that is, the models assume that the probability of marine mammals occurring in any square kilometer area over any time interval is 1.0, when, in fact, the probability would be much smaller than 1.0; this difference would tend to overestimate the number of animals in the action area during shorter time intervals).

The following narratives present the results of the exposure analyses we conducted for the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. The narratives that follow present the results of (1) the method we used to estimate the number of endangered or threatened species NMFS used (which is described in the *Approach to the Assessment* section of this Opinion) and (2) the approach the U.S. Navy and NMFS' Permits Division used to estimate the number of marine mammals that might be "taken" (as that term is defined pursuant to the MMPA) during active sonar training activities the U.S. Navy proposes to conduct and NMFS' Permits Division (which is also described in the *Approach to the Assessment* section of this Opinion). Before we present those results, however, we discuss whether and to what degree the measures the U.S. Navy proposes to implement or that the Permits Division proposes to include in its proposed MMPA authorization would be expected to avoid or minimize the number of endangered or threatened species that might otherwise be exposed to the U.S. Navy's training activities on the Mariana Range Complex.

MITIGATION MEASURES TO MINIMIZE THE LIKELIHOOD OF EXPOSING LISTED SPECIES 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, primarily relying on Navy lookouts, helicopter pilots, and other Navy assets to visually detect marine mammals so that the Navy can take action that are appropriate based on these detections. To the degree that the Navy detects marine mammals visually, these safety zones might reduce the number of marine mammals that are exposed to mid-frequency active sonar or the intensity of their exposure. However, the effectiveness of visual monitoring is limited to daylight hours, and its effectiveness declines during poor weather conditions (JNCC 2004). In line transect surveys, the range of effective visual sighting (the distance from the ship's track or the *effective strip width*) varies with an animal's size, group size, reliability of conspicuous behaviors (blows), pattern of surfacing behavior, and positions of the observers (which includes the observer's height above the water surface). For most large baleen whales, effective strip width can be about 3 km (1.6 nm) up through Beaufort 6 (Buckland *et al.* 1993). For harbor porpoises the effective strip width is about 250 m (273 yd), because they are much smaller and less demonstrative on the surface than baleen whales (Palka 1996).

Further, several studies of interactions between seismic surveys and marine mammals and a proposed low-frequency active sonar system and marine mammals concluded that dedicated marine mammal observers were more effective at detecting marine mammals, were more effective at detecting marine mammals at greater distances than Navy watchstanders (watchstanders of the Navies of other countries), were better at identifying the marine mammal to species, and reported a broader range of behaviors than other personnel (Aicken *et al.* 2005; Stone 2000, 2001, 2003). It is not clear, however, how the U.S. Navy's watchstanders and marine species observers, who are specifically trained to identify objects in the water surrounding Navy vessels compare with observers who are specifically trained to detect and identify marine mammals in marine water. NMFS is working with the Navy to determine the effectiveness of this component of Navy monitoring program and the degree to which it is likely to minimize the probability of exposing marine mammals to mid-frequency active sonar.

A multi-year study conducted on behalf of the United Kingdom's Ministry of Defense (Aicken *et al.* 2005) concluded that Big Eye binoculars were not helpful. Based on these studies, we would conclude that requiring surface vessels equipped with mid-frequency active sonar to have Big Eye binoculars in good working order is not likely to increase the number of marine mammals detected at distances sufficient to avoid exposing them to received levels that might result in adverse consequences.

The percentage of marine animals Navy personnel would not detect, either because they will pass unseen below the surface or because they will not be seen at or near the ocean surface, is difficult to determine. However, for minke whales, Schweder *et al.* (1992) estimated that visual survey crews did not detect about half of the animals in a strip width. Palka (1996) and Barlow (1988) estimated that visual survey teams did not detect about 25 percent of the harbor porpoises in a strip width. The information available leads us to conclude that the combinations of safety zones triggered by visual observations would still allow most marine mammals and sea turtles to be exposed to mid-frequency active sonar transmissions because most marine animals will not be detected at the ocean's surface.

MITIGATION MEASURES TO MINIMIZE THE LIKELIHOOD OF EXPOSING LISTED SPECIES TO LOW-FREQUENCY ACTIVE SONAR. 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 Permits Division has also added an additional 1-kilometer buffer zone beyond the LFA mitigation zone.

Monitoring associated with the SURTASS LFA sonar system (a) commences at least 30 minutes before the first SURTASS LFA sonar transmission; (b) continue between pings; and (c) continues for at least 15 minutes after completion of a SURTASS LFA sonar transmission exercise or, if marine mammals are showing abnormal behavior patterns, for a period of time until those behavior patterns return to normal or until conditions prevent continued observations.

The Navy typically employs 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 [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. The U.S. Navy includes daytime observations from the SURTASS LFA sonar vessel for potentially affected species. This monitoring typically begins 30 minutes before sunrise, for ongoing transmissions, or 30 minutes before SURTASS LFA sonar is deployed and continue 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 and 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. Passive acoustic monitoring for low frequency sounds generated by marine mammals is conducted when SURTASS is deployed and result in the following actions:

- 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 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. As described in the *Description of the Proposed Action* section of this Opinion, 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 HF/M3 source is ramped-up slowly to operating levels over a period of no less than 5 minutes:

- No later than 30 minutes before the first SURTASS LFA sonar transmission;
- Prior to any SURTASS LFA sonar calibrations or tests that are not part of regular SURTASS LFA sonar transmissions; and
- Anytime after the HF/M3 source has been powered down for a period of time greater than 2 minutes.

The HF/M3 source does not increase its sound pressure level once a marine mammal is detected; ramp-up may proceed once marine mammals are no longer detected. 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*. 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 or suspension of SURTASS LFA sonar transmissions until the animal is determined to have moved beyond the mitigation zone.

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.

The SURTASS LFA sonar system is required to operate in a manner that would not cause sonar sound fields to exceed 180 dB (re 1 μPa_{rms}) within "coastal exclusion zones" or within 1 kilometer of designated offshore areas that are designated as biologically important and NMFS' regulations establish a minimum coastal exclusion zone of 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular areas. When in the vicinity of known recreational and commercial dive sites, SURTASS LFA sonar is required to operate to ensure that the sound field at these sites would not exceed 145 dB.

MITIGATION MEASURES TO MINIMIZE THE LIKELIHOOD OF EXPOSING LISTED SPECIES TO UNDERWATER DETONATIONS. During the sinking exercises, the U.S. Navy proposes to conduct on the Mariana Islands Range Complex, the U.S. Navy plans to incorporate the monitoring protocols associated with the shock trials of the USS *Winston Churchill*. These monitoring protocols were studied extensively and those studies concluded that these monitoring protocols effectively insured that marine mammals or sea turtles did not occur within 3.7 kilometers of the underwater detonations, which would prevent them from being exposed to shock waves at pressures that would cause serious injuries (Clarke and Norman 2005). By incorporating safety zones, monitoring, and shut down procedures similar to those associated with the *Winston Churchill* shock trials into the protocols for its proposed sinking exercises, 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 the U.S. Navy plans to conduct on the Mariana Islands Range Complex each year for the next five year. Because they are likely to prevent endangered or threatened marine mammals and sea turtles from being exposed to shock waves or the sound fields associated with these exercises, endangered and threatened species that occur in the action area are not likely to be adversely affected by this component of the proposed action.

Exposure Estimates for the Mariana Islands Range Complex

To estimate the number of marine mammals that might be exposed to active sonar during the training activities the U.S. Navy plans to conduct on the Mariana Islands Range, we present the results of our exposure analyses as well as the U.S. Navy's estimates of the number of endangered or threatened species that might be "taken" (as that term is defined by the MMPA) as a result of being exposed to active sonar during military readiness activities the U.S. Navy plans to conduct on the Mariana Islands Range Complex from June 2010 through June 2015.

Although the Navy's estimates are not exposure estimates, per se, they provide some insight into the number of times different species might be exposed to active sonar because exposure is a pre-requisite for "take" — that is, an organism that is not exposed, directly or indirectly, to the effects of a stimulus, cannot be "taken" by the stimulus — although the actual number of exposures will usually exceed the number of "takes." For underwater detonations, we relied entirely on the U.S. Navy's exposure models because we did not develop separate models for that purpose. Our analyses of the evidence available led us to conclude that the following species are likely to co-occur, in space and time, with U.S. Navy training activities on the Mariana Islands Range Complex as follows:

BLUE WHALE. Blue whales undertake seasonal migrations and were historically hunted on their summer, feeding areas. Whalers located few blue whales in wintering areas from December to February. Observations made after whaling was banned revealed a similar pattern: blue whales spend most of the summer foraging at higher latitudes where the waters are more productive (Calambokidis *et al.* 1990, Calambokidis 1995, Sears 1990, Scammon 1874). Because of this migratory pattern, we assume that blue whales are more likely to occur on the Mariana Islands Range Complex during the winter months than during the summer month when they are most likely to occur on their summer, foraging range north of Japan, along the Aleutian Islands, and in the southern Bering Sea.

Exposure to Vessel Traffic. We did not estimate the number of blue whales or other endangered or threatened whales that might be exposed to vessel traffic independent of the number of individuals that might be exposed to active sonar associated with those exercises because the data we would have needed to support those analyses were not available. Because of their seasonal occurrence on the Mariana Islands Range Complex, blue whales are not likely to be exposed to training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, blue whales are more likely to be exposed to vessel traffic associated with unit-level training, which primarily involves single vessels.

Nevertheless, we assumed that any individuals of the endangered or threatened species that were likely to be exposed to active sonar at received levels equal to or greater than 190 dB might find themselves close enough to the bow of Navy vessels to have some risk of being struck. For the purposes of these analyses, we assumed that a whale that occurred within 560 meters (1,968 feet) of a Navy vessel moving at speeds greater than 14 knots would have some risk of being struck. As a result, we assumed that one blue whale would occur close enough to a Navy vessel that is underway to have some risk of being struck by the vessel.

Exposure to Mid-frequency Active Sonar. Because of their seasonal occurrence on the Mariana Islands Range Complex, blue whales are not likely to be exposed to active sonar associated with training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, blue whales are more likely to be exposed to active sonar associated with unit-level training, which primarily involves sonar transmissions from fewer sources and exposures that occur over shorter periods of time.

Based on the results of our exposure analyses, each year we would expect about 197 exposure events involving blue whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May).

Of this total, about 139 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when blue whales would be between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 34 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 197 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 8 of the 197 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when blue whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

The U.S. Navy estimated that 128 blue whales might be exposed to active sonar associated with the training activities it proposes to conduct on the Mariana Islands Range Complex and exhibit behavioral responses that would qualify as “take,” in the form of behavioral harassment, as a result of that exposure. The U.S. Navy estimated that another two blue whales would be exposed to mid-frequency active sonar and experience temporary threshold shifts as a result of that exposure.

Exposure to Low-frequency Active Sonar. The U.S. Navy’s exposure models identified about 23 instances in which blue whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex each year. We assume that these whales would be exposed during the winter months and would not be exposed within 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular areas.

Exposure to Underwater Detonations. Based on the results of the U.S. Navy's models, we would not expect blue whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 177 dB sound exposure level SEL, at received levels greater than or equal to 182 dB SEL or 23 psi-ms (these two received levels are considered thresholds for Level B "take" or behavioral harassment by NMFS' Permits Division), at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture, or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division).

We would treat these exposure estimates to be minimal estimates because some whales are likely to be exposed to the sound fields produced by underwater detonations at lower received levels; that is, at received levels that would be expected to cause whales to change their behavioral state even if those changes in behavior might not qualify as "take" as that term is defined by the MMPA.

FIN WHALE. Like blue whales, fin whales also undertake seasonal migrations and were historically hunted on their summer, feeding areas. Whalers located few blue whales in wintering areas from December to February. Observations made after whaling was banned revealed a similar pattern: fin whales spend most of the summer foraging north of 20°N latitude where the waters are more productive (Calambokidis *et al.* 1990, Calambokidis 1995, Miyashita *et al.* 1995, Sears 1990, Scammon 1874). Investigators who compiled observations of cetaceans in the North Pacific Ocean that had been made from commercial fisheries vessels from 1964 through 1990 reported that no fin whales had been sighted south of 20°N in August but were sighted more commonly north of 40°N during that month (Miyashita *et al*. 1995). Because of this migratory pattern, we assume that fin whales are more likely to occur on the Mariana Islands Range Complex during the winter months than during the summer month when they are most likely to occur on their summer, foraging range north of Japan, along the Aleutian Islands, and in the southern Bering Sea.

Exposure to Vessel Traffic. We did not estimate the number of fin whales that might be exposed to vessel traffic independent of the number of individuals that might be exposed to active sonar associated with those exercises because the data we would have needed to support those analyses were not available. Because of their seasonal occurrence on the Mariana Islands Range Complex, fin whales are not likely to be exposed to training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, they are more likely to be exposed to vessel traffic associated with unit-level training, which primarily involves single vessels.

Nevertheless, using the approach we described for blue whales (see the preceding narrative) we assumed that two fin whales would occur close enough to a Navy vessel that is underway to have some risk of being struck by the vessel. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to occur each time one of these whales occurs this close to a Navy vessels.

Exposure to Mid-frequency Active Sonar. Because of their seasonal occurrence on the Mariana Islands Range

Complex, fin whales are not likely to be exposed to active sonar associated with training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, they are more likely to be exposed to active sonar associated with unit-level training, which primarily involves sonar transmissions from fewer sources and exposures that occur over shorter periods of time.

Based on the results of our exposure analyses, each year we would expect about 590 exposure events involving fin whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May).

Of this total, about 418 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when fin whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 101 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 197 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 23 of the 590 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when fin whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

The U.S. Navy estimated that 180 fin whales might be exposed to active sonar associated with the training activities it proposes to conduct on the Mariana Islands Range Complex and exhibit behavioral responses that would qualify as "take," in the form of behavioral harassment, as a result of that exposure. The U.S. Navy estimated that another two fin whales would be exposed to mid-frequency active sonar and accumulate sufficient energy to experience temporary threshold shifts as a result of that exposure.

Exposure to Low-frequency Active Sonar. The U.S. Navy's exposure models identified about 69 instances in which fin whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex each year. We assume that these whales would be exposed during the winter months and would not be exposed within 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular areas.

Exposure to Underwater Detonations. Based on the results of the U.S. Navy's models, we would not expect fin whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 177 dB sound exposure level SEL, at received levels greater than or equal to 182 dB SEL or 23 psi-ms (these two received levels are considered thresholds for Level B "take" or behavioral harassment by NMFS' Permits Division), at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture, or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division).

As we discussed with blue whales, we would treat these exposure estimates to be minimal estimates because some fin whales are likely to be exposed to the sound fields produced by underwater detonations at lower received levels; that is, at received levels that would be expected to cause whales to change their behavioral state even if those changes in behavior might not qualify as "take" as that term is defined by the MMPA.

HUMPBACK WHALE. A "population" of humpback whales winters in an area extending roughly from the South China Sea east through the Philippines, Ryukyu Retto, Ogasawara Gunto, Mariana Islands, and Marshall Islands (Rice 1998). Based on whaling records, humpback whales wintering in this area have also occurred in the southern Marianas from November through the month of May (Eldredge 1991). There are several recent records of humpback whales in the Mariana Islands, at Guam, Rota, and Saipan during January through March (Darling and Mori 1993; Eldredge 1991, 2003, Taitano 1991). Most contemporary reports of humpback whales in the Marianas place them there from February and March (Anonymous 2004, SRS-Parsons 2007). During the remainder of the year, humpback whales are most likely to occur on their summer, feeding range in the Kuril Islands, Bering Sea, Aleutian Islands, Kodiak, Southeast Alaska, and British Columbia (Angliss and Outlaw 2007; Calambokidis 1997, 2001).

Although humpback whales, particularly juvenile whales, might choose to leave their summer foraging range prematurely or that a humpback whale from wintering areas in the South Pacific (French Polynesia, the Cook islands, Tonga, New Zealand and New Caledonia; Greaves and Garrigue 1998; Garrigue and Greaves 2001) it is not likely; virtually no humpback whales, however, are reported to have left their foraging areas prematurely and there are no reports of humpback whales migrating to the Marianas from their wintering areas in the South Pacific. As a result, we would only expect humpback whales to occur on the Mariana Islands Range Complex during the winter months, which would prevent them from being exposed to the major training events the U.S. Navy conducts on the range complex during the summer (joint multi-strike group exercises such as Valiant Shield). As a result, humpback whales are more likely to be exposed to unit-level training exercises, which the U.S. Navy conducts throughout the year.

Exposure to Vessel Traffic. Like blue and fin whales, we did not estimate the number of humpback whales that might be exposed to vessel traffic independent of the number of individuals that might be exposed to active sonar associated with those exercises because the data we would have needed to support those analyses were not available. Nevertheless, using the approach we described for blue whales (see the preceding narrative) we assumed that fifty three humpback whales would occur close enough to a Navy vessel that is underway to have some risk of being struck by the vessel. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to occur each time one of these whales occurs this close to a Navy vessels.

Exposure to Mid-frequency Active Sonar. Because of their seasonal occurrence on the Mariana Islands Range Complex, humpback whales are not likely to be exposed to mid-frequency active sonar associated with training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, humpback are more likely to be exposed to this active sonar associated with unit-level training, which primarily involves sonar transmissions from fewer sources and exposures that occur over shorter periods of time.

Based on the results of our exposure analyses, each year we would expect about 13,571 exposure events involving humpback whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May).

Of this total, about 9,604 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when humpback whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 2,327 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 13,571 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 531 of the 13,571 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when humpback whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

The U.S. Navy estimated that 795 humpback whales might be exposed to active sonar associated with the training activities it proposes to conduct on the Mariana Islands Range Complex and exhibit behavioral responses that would qualify as “take,” in the form of behavioral harassment, as a result of that exposure. The U.S. Navy estimated that another 10 humpback whales would be exposed to mid-frequency active sonar and accumulate sufficient energy to experience temporary threshold shifts as a result of that exposure.

Exposure to Low-frequency Active Sonar. Because of their seasonal occurrence on the Mariana Islands Range Complex, humpback whales are not likely to be exposed to low-frequency active sonar associated with training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, humpback whales are more likely to be exposed to active sonar associated with unit-level training, which primarily involves sonar transmissions from fewer sources and exposures that occur over shorter periods of time.

The U.S. Navy’s exposure models identified about 1,740 instances in which humpback whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex each year. We assume that these whales would be exposed during the winter months and would not be exposed within 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular areas.

Exposure to Underwater Detonations. Based on the results of the U.S. Navy’s models, we would expect one humpback whale to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 182 dB SEL or 23 psi-ms, which NMFS’ Permits Division considers as a threshold for Level B “take” or behavioral harassment. We would not expect humpback whales to be exposed to underwater detonations at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A “take” or injury by NMFS’ Permits Division).

As we discussed with blue and fin whales, we would treat these exposure estimates to be minimal estimates because some humpback whales are likely to be exposed to the sound fields produced by underwater detonations at lower received levels; that is, at received levels that would be expected to cause whales to change their behavioral state even if those changes in behavior might not qualify as “take” as that term is defined by the MMPA.

SEI WHALE. Sei whales occur throughout the North Pacific Ocean and are most often found in deep, oceanic waters of the cool temperate zone. They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins situated between banks and ledges (Kenney and Winn 1987, Gregr and Trites 2001). During marine mammal and sea turtles surveys conducted in the Mariana Islands from January through April 2007, sei whales were observed in the offshore areas of Guam and the Mariana Islands south to nearly 10° N (SRS-Parsons 2007). During these surveys, sei whales were most commonly observed in waters between 3,164 and 9,322 meters (10,381 – 30,583 ft) in depth; all of these sightings were south of Saipan (about 15°N).

Exposure to Vessel Traffic. Like the three whales we have discussed thus far, we did not estimate the number of sei whales that might be exposed to vessel traffic independent of the number of individuals that might be exposed to active sonar associated with those exercises because the data we would have needed to support those analyses were not available. Nevertheless, using the approach we just described for blue whales (see the preceding narrative) we assumed that two sei whales would occur close enough to a Navy vessel that is underway to have some risk of being struck by the vessel. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to occur each time one of these whales occurs this close to a Navy vessels.

Exposure to Mid-frequency Active Sonar. Because of their seasonal occurrence on the Mariana Islands Range Complex, sei whales are also not likely to be exposed to active sonar associated with training exercises that occur in the summer months, such as one of the joint multi-strike group exercises; as a result, sei whales are more likely to be exposed to active sonar associated with unit-level training, which primarily involves sonar transmissions from fewer sources and exposures that occur over shorter periods of time.

Based on the results of our exposure analyses, each year we would expect about 570 exposure events involving sei whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May).

Of this total, about 404 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when sei whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 98 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of the 570 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 20 of the 570 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when sei whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

The U.S. Navy estimated that 319 sei whales might be exposed to active sonar associated with the training activities it proposes to conduct on the Mariana Islands Range Complex and exhibit behavioral responses that would qualify as “take,” in the form of behavioral harassment, as a result of that exposure. The U.S. Navy estimated that another 6 sei whales would be exposed to mid-frequency active sonar and accumulate sufficient energy to experience temporary threshold shifts as a result of that exposure.

Exposure to Low-frequency Active Sonar. The U.S. Navy's exposure models identified about 65 instances in which sei whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex each year. We assume that these whales would be exposed during the winter months and would not be exposed within 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular areas.

Exposure to Underwater Detonations. Based on the results of the U.S. Navy's models, we would not expect sei whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 177 dB sound exposure level SEL, at received levels greater than or equal to 182 dB SEL or 23 psi-ms (these two received levels are considered thresholds for Level B "take" or behavioral harassment by NMFS' Permits Division), at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture, or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division).

As with the whale species we discussed earlier, we would treat these exposure estimates to be minimal estimates because some sei whales are likely to be exposed to the sound fields produced by underwater detonations at lower received levels; that is, at received levels that would be expected to cause whales to change their behavioral state even if those changes in behavior might not qualify as "take" as that term is defined by the MMPA.

SPERM WHALE. Based on whaling records, sperm whales occur in waters off the Mariana Islands archipelago throughout the year (Miyashita *et al*. 1995, 1996; Townsend 1935). During marine mammal and sea turtles surveys conducted in the Mariana Islands from January through April 2007 (SRS-Parsons 2007), sperm whales were encountered (visually or acoustically) more frequently than any other cetacean; they were detected acoustically three times more than they were observed. During these surveys, sperm whales were most commonly observed in waters between 809 to 9,874 meters (2,670-32,584 ft.) in depth; however, sperm whales are also known to occur in water less than 100 meters (330 ft) in depth (Scott and Sadove 1997, Croll *et al.* 1999).

Because they occur in the Mariana Islands archipelago throughout the year, we assume that sperm whales would exposed to the U.S. Navy's training activities in any month of the year; however, because of their tendency to remain in deep, pelagic waters, we assume that sperm whales would not be exposed to training activities that would occur in coastal features of the Mariana Islands (such as Apra Harbor or Agat Bay) or in coastal areas associated with the islands.

Exposure to Vessel Traffic. Like the whales we have discussed thus far, we did not estimate the number of sperm whales that might be exposed to vessel traffic independent of the number of individuals that might be exposed to active sonar associated with those exercises because the data we would have needed to support those analyses were not available. Nevertheless, using the approach we described for blue whales (see the preceding narrative) we assumed that 60 sperm whales would occur close enough to a Navy vessel that is underway to have some risk of being struck by the vessel. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to occur each time one of these whales occurs this close to a Navy vessels.

Exposure to Mid-Frequency Active Sonar. Based on the results of our exposure analyses, each year we would expect about 15,186 exposure events involving sperm whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May).

Of this total, about 10,747 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when sperm whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 2,604 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of the 570 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 534 of the 15,186 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when sperm whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

The U.S. Navy estimated that 806 sperm whales might be exposed to active sonar associated with the training activities it proposes to conduct on the Mariana Islands Range Complex and exhibit behavioral responses that would qualify as “take,” in the form of behavioral harassment, as a result of that exposure. The U.S. Navy estimated that another 10 sperm whales would be exposed to mid-frequency active sonar and accumulate sufficient energy to experience temporary threshold shifts as a result of that exposure; one of these sperm whales would experience permanent threshold shift as a result of that exposure.

Exposure to Low-frequency Active Sonar. The U.S. Navy’s exposure models identified about 153 instances in which sperm whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex each year. We assume that these whales would be exposed during the winter months and would not be exposed within 12 nautical miles of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals outside the 12 nautical mile coastal exclusion zone during seasons specified for a particular areas.

Exposure to Underwater Detonations. Based on the results of the U.S. Navy’s models, we would expect six or seven sperm whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 177 dB SEL and two or three sperm whales to be exposed at received levels greater or equal to 182 dB SEL or 23 psi-ms, which NMFS’ Permits Division considers as a threshold for Level B “take” or behavioral harassment. We would not expect sperm whales to be exposed to underwater detonations at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division).

As with the whale species we discussed earlier, we would treat these exposure estimates to be minimal estimates because some sperm whales are likely to be exposed to the sound fields produced by underwater detonations at lower received levels; that is, at received levels that would be expected to cause whales to change their behavioral state even if those changes in behavior might not qualify as "take" as that term is defined by the MMPA.

GREEN SEA TURTLE. Of the four species of turtles that have been reported to occur in the Mariana Islands archipelago or in waters off of the archipelago, only green and hawksbill sea turtles have been reported in almost every survey of sea turtles conducted in the Mariana Islands since the mid-1990s (Dollar and Stefansson 2000, Eldredge 2003, Kolinski 2001, Kolinski *et al*. 1999, 2004, 2006; NMFS and U.S. FWS 1998a, Pultz *et al*. 1999). Green sea turtles are the most abundant sea turtles found in the Mariana Islands archipelago; in addition to foraging in the archipelago, these sea turtles also nest in the archipelago. Within the archipelago, green sea turtles have been reported to nest on Aguijan, Farallon de Medinilla, Guam, Rota, Saipan, and Tinian (Dollar and Stefansson 2000, Eldredge 2003, Kolinski 2001, Kolinski *et al*. 1999, 2004, 2006; NMFS and U.S. FWS and NMFS 1998a, Pultz *et al*. 1999). Throughout the archipelago, green sea turtles appear to concentrate in waters less than 50 meters (164 ft) deep, which provide the reefs, reef flats, and seagrass beds where the sea turtles typically forage or rest.

Between 1,000 and 2,000 green sea turtles were estimated to occur in the southern Mariana Islands archipelago, with more than half of these turtles occurring along the coast of Tinian (54 percent) or Saipan (38 percent; Kolinski *et al*. 2004, 2006). On Aguijan, fourteen green sea turtles were observed during surveys that covered about 95 percent of the island's coastline in March 2001 (Kolinski *et al*. 2004). Of these, twelve (86 percent) were juveniles with two adults. On Farallon de Medinilla, at least nine green sea turtles were observed during surveys conducted in 1999 and 2000, while at least 12 green turtles were observed during surveys in 2001. Four green turtles were observed at the northern end of the island during surveys sponsored by the U.S. Navy in 2003 (U.S. Navy 2004). Monthly aerial surveys conducted on Farallon de Medinilla reported seven sea turtles, which were assumed to be green sea turtles because of their prevalence in the Mariana archipelago, in 2006 and 19 in 2007 (U.S. Navy 2008). Most green turtles observed on Farallon de Medinilla were either swimming over a reef platform or resting in holes or caves (Belt Collins 2001).

On Guam, green sea turtles have been reported from coastal waters throughout the year and aggregations of foraging or resting green sea turtles have been reported from seagrass beds and reef flats in Inner Apra Harbor (Smith *et al*. no date), Apra Harbor, Cocos Lagoon, in deeper waters south of Falcona Beach, Hilaan, Tarague Beach (Wiles *et al.* 1995, U.S. Navy 2003), and on the Explosive Ordnance Beach on Andersen Air Force Base (Guam Division of Aquatic and Wildlife Resources 2000). Recreational SCUBA divers have reported green sea turtles at numerous dive sites along the coast of Guam, including Ane Caverns, Boulder Alley, Gab Gab I, Napoleon Cut, and the Wall (U.S. Navy 2009). Green sea turtles have been reported to have nested at eight separate beaches on Guam: Asiga Beach, Falcona Beach, Ritidian Beach, Tarague Beach, Urunao Point, as well as the beaches along Cocos Island and Sella Bay (Gutierrez 2004, Pritchard 1995, Wiles *et al.* 1995).

On Rota, the green sea turtle population was estimated at 92 turtles in 2001 (Kolinski *et al*. 2004) and 118 turtles in

September 2003 (Kolinski *et al*. 2006). Coastal habitats associated with this island were estimated to support about six percent of the 1,000 to 2,000 green sea turtles that we estimated to occur in the southern Mariana Islands archipelago (Kolinski *et al*. 2004, 2006). On Saipan, sixty percent of the green sea turtles observed in surveys conducted in August 1999 were observed along the eastern coast of the island, which is relatively uninhabited. The highest concentrations were located at Central Naftan, Forbidden Island, North Naftan, the Kingfisher Golf Course, and the Balisa Area of the island's west coast.

On Tinian, 832 green sea turtles were estimated to inhabit coastal waters in 2001 (Kolinski *et al.* 2006), which the highest abundance reported from the Mariana Archipelago. Based on nesting surveys conducted on Tinian, green sea turtles appear to nest on most, if not all, beaches on the island (NMFS and U.S. FWS 1998a), although green sea turtle nests are most common on Unai Barcinas, Unai Dankulo (Long Beach), Unai Leprosarium, and Unai Lamlam (Pultz *et al.* 1999, U.S. Navy 2005).

Although green sea turtles nest in the Marianas Islands archipelago, most of the green sea turtles that are observed in the archipelago are juvenile or sub-adult sea turtles (Kolinski 2001, NMFS 2007, Pultz *et al*. 1999), so the archipelago appears to support a small adult nesting population and a large juvenile rearing population. Adults that migrate to the Mariana Islands to nest appear to originate elsewhere in the western Pacific.

Exposure to Training Activities. Because they tend to occur near the coast of islands in the Mariana Islands archipelago, green sea turtles are not likely to be exposed to stressors associated with air warfare or electronic combat, surface warfare, or joint multi-strike group exercises, which would occur more than 12 nautical miles from land (with the exception of small arms gunnery exercises). The available data do not allow us to assess the probability of ships striking sea turtles.

The primary site for the amphibious assault (Marine Air Ground Task Force) exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Unai Chulu Beach on the island of Tinian where green sea turtles are likely to nest. This beach is a secondary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Adult green sea turtles that might arrive on this beach to nest would be potentially exposed to human disturbance associated with these training activities; any nests that might occur on this beach during such an exercise has some probably of being trampled or destroyed.

Apra Harbor is a primary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. This harbor is a secondary site for the amphibious assaults (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Although green sea turtles are not known to nest in this area, they forage and rest in several areas of the harbor and are likely to be exposed to human disturbance associated with these training activities.

Exposure to Low-frequency Active Sonar. The SURTASS LFA sonar system generally operates in deeper, pelagic waters, and NMFS regulations require the U.S. Navy to operate SURTASS LFA sonar so that the sound field produced by this sonar do not exceed 180 dB (re 1 μPa_{rms}) within 12 nautical miles (about 22 kilometers) of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals. Because of this distance, the majority of the green sea turtles that occur in the Mariana Islands archipelago are not likely to be exposed to active sonar transmissions produced with the SURTASS LFA sonar system at received levels greater than 130 dB (assuming cylindrical and spherical spreading and ignoring the effect of shallow water and ambient noise on transmissions).

Exposure to Mid-frequency Active Sonar. Anti-submarine warfare exercises would occur more than 3 nautical miles (about 5 kilometers) from shore. Because of this distance, hawksbill sea turtles are not likely to be exposed to mid-frequency active sonar associated with anti-submarine warfare at received levels greater than 160 dB. Because joint multi-strike group exercises would occur more than 12 nautical miles (about22 kilometers) from land, juvenile, sub-adult, and nesting adult green sea turtles are not likely to be exposed to mid-frequency active sonar associated with those exercises at received levels greater than 150 dB. More importantly, because they tend to remain in relatively shallow coastal waters where sounds produced by rain, wind, and waves, juvenile, sub-adult, and nesting adult green sea turtles are not likely to be aware of energy produced by mid-frequency active sonar from sources more than 3 or 12 nautical miles offshore.

Exposure to Underwater Detonations. Because the U.S. Navy plans to conduct sinking exercises more than 50 nautical miles (92 kilometers) from land, green sea turtles are not likely to be exposed to shock waves or sound fields associated with those training exercises. However, because the primary site for the floating mine neutralization and underwater demolition exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Agat Bay on Guam where green sea turtles are likely to forage and rest, these sea turtles would have some risk of being exposed to shock waves and sound fields associated with these training exercises.

However, the U.S. Navy proposes to establish 700-yard (640 meter) exclusion zones for sea turtles (and marine mammals) for all mine warfare and mine countermeasure training activities. Thirty-minutes before a detonation, U.S. Navy personnel involved in the training exercises must determine that the area is clear of marine mammals and sea turtles. If an animal is present within the area, the U.S. Navy proposes to pause the exercise until the animal leaves the area on its own.

HAWKSBILL SEA TURTLE. Of the four species of turtles that have been reported to occur in the Mariana Islands region, surveys that have been conducted in the region over the past decade hawksbill sea turtles are the only sea turtle, other than green sea turtles, that have been reported in the action area (Dollar and Stefansson 2000, Kolinski 2001, Kolinski *et al*. 1999, Pultz *et al*. 1999, U.S. Navy 2007b). Nevertheless, hawksbill sea turtles sightings are relatively uncommon in the Mariana Islands archipelago, even in surveys that focus on sea turtles (Kolinski 2001, Kolinski *et al*. 1999, 2001, 2004, 2006; Pultz *et al*. 1999,

Historically, hawksbill sea turtles were reported to have been uncommon, but not rare, on the island of Guam (Wiles *et al*. 1995); these turtles nested between Urunao Point and Tarague Beach in 1984 and at Sumay Cove, Apra Harbor in 1991 and 1992 (U.S. FWS and NMFS 1998b). Hawksbill sea turtles were reported to have been common in Cocos Lagoon (on the southern tip of Guam) during surveys conducted on the island in the mid-1970s (Randall 1975, Stojkovich 1977). Between 1989 and 1991, hawksbill sea turtles represented about 13 percent of the sea turtles observed along the coast of Guam from Tanguisso Beach to Pago Bay (Wiles *et al*. 1995). Hawksbill sea turtles are regularly observed inside Apra Harbor, particularly in Sasa Bay in which sponges, their preferred food, are common

(Kolinski *et al.* 2001, NMFS 2007, Wiles *et al.* 1995)

Hawksbill sea turtles also occur along the coasts of Farallon de Medinilla, Rota, and Tinian. The U.S. Navy observed two juvenile hawksbill sea turtles during surveys in waters off Farallon de Medimilla in 2004 (U.S. Navy 2004). In 1996, a hawksbill sea turtle had been exposed to shock wave associated with a detonation of unexploded ordinance off the island of Rota; the turtle was recovered near the explosion sight and subsequently died from internal injuries resulting from its exposure to the blast. And hawksbill turtles are reported to occur regularly off Tinian (Wiles et al. 1989), although they have not been reported during several surveys conducted in those waters (Wiles *et al.* 1989; Pultz *et al.* 1999; Kolinski *et al.* 2001).

Exposure to Training Activities. Because they tend to occur near the coast of islands in the Mariana Islands archipelago, hawksbill sea turtles are not likely to be exposed to stressors associated with air warfare or electronic combat, surface warfare, or joint multi-strike group exercises, which would occur more than 12 nautical miles from land (with the exception of small arms gunnery exercises), The available data do not allow us to assess the probability of ships striking hawksbill sea turtles.

Apra Harbor is a secondary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. This harbor is a secondary site for the amphibious assaults (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Although hawksbill sea turtles are not known to nest in this area, they forage and rest in several areas of the harbor and are likely to be exposed to human disturbance associated with these training activities.

Exposure to Low-frequency Active Sonar. The SURTASS LFA sonar system generally operates in deeper, pelagic waters, and NMFS regulations require the U.S. Navy to operate SURTASS LFA sonar so that the sound field produced by this sonar do not exceed 180 dB (re 1 μPa_{rms}) within 12 nautical miles (about 22 kilometers) of any coastline, including offshore islands, or designated offshore areas that are biologically important for marine mammals. Because of this distance, hawksbill sea turtles are not likely to be exposed to active sonar transmissions produced with the SURTASS LFA sonar system at received levels greater than 130 dB (assuming cylindrical and spherical spreading and ignoring the effect of shallow water and ambient noise on transmissions).

Exposure to Mid-frequency Active Sonar. Hawksbill sea turtles tend to occur near the coast of islands in the Mariana Islands archipelago and anti-submarine warfare exercises would occur more than 3 nautical miles (about 5 kilometers) from shore. Because of this distance, hawksbill sea turtles are not likely to be exposed to mid-frequency active sonar associated with anti-submarine warfare at received levels greater than 160 dB. Because joint multi-strike group exercises would occur more than 12 nautical miles (about22 kilometers) from land, hawksbill sea turtles are not likely to be exposed to mid-frequency active sonar associated with those exercises at received levels greater than 150 dB. More importantly, because they tend to remain in relatively shallow coastal waters where sounds produced by rain, wind, and waves, hawksbill sea turtles are not likely to be aware of energy produced by mid-frequency active sonar from sources more than 3 or 12 nautical miles offshore.

Exposure to Underwater Detonations. Because the U.S. Navy plans to conduct sinking exercises more than 50 nautical miles (92 kilometers) from land, hawksbill sea turtles are not likely to be exposed to shock waves or sound fields associated with those training exercises. However, because the primary site for the floating mine neutralization and underwater demolition exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Agat Bay on Guam where hawksbill sea turtles are likely to forage and rest, these sea turtles would have some risk of being exposed to shock waves and sound fields associated with these training exercises.

However, the U.S. Navy proposes to establish 700-yard (640 meter) exclusion zones for sea turtles (and marine mammals) for all mine warfare and mine countermeasure training activities. Thirty-minutes before a detonation, U.S. Navy personnel involved in the training exercises must determine that the area is clear of marine mammals and sea turtles. If an animal is present within the area, the U.S. Navy proposes to pause the exercise until the animal leaves the area on its own.

Exposure to Parachutes. 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 squared feet). The shroud lines range from 0.30 to 0.53 meters (12 to 21 inches) in length and are made of either cotton polyester with a 13.6 kilogram (30 pound) breaking strength or nylon with a 45.4 kilogram (100 pound) breaking strength. All parachutes are weighted with a 0.06 kilogram (2 ounce) steel material weight, which would cause the parachute to sink from the surface within about 15 minutes, although actual sinking rates depend on ocean conditions and the shape of the parachute.

The subsurface assembly descends to a selected depth, and the sonobuoy case falls away and sea anchors deploy to stabilize the hydrophone (underwater microphone). The operating life of the seawater battery is eight hours, after which the sonobuoy scuttles itself and sinks to the ocean bottom. For the sonobouys, concentrations of metals released from batteries were calculated to be 0.0011 mg/L lead, 0.000015mg/L copper, and 0.0000001mg/L silver.

Sea turtles that occur on the Mariana Islands Range Complex might encounter one or more of the parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. Whales also might encounter one or more of these parachutes and become entangled as it sinks to the bottom or once it is on the seafloor. We cannot, however, determine whether such interactions are probable, given the relatively small number of sonobuoys that would be employed in each of the exercises, the relatively large geographic area involved, and the relatively low densities of endangered or threatened marine mammals and sea turtles on the range complex.

5.3 Response Analysis

As discussed in the *Approach to the Assessment* section of this opinion, our response analyses are designed to identify how endangered or threatened species (or designated critical habitat, when it is applicable) are likely to respond given their exposure to one or more of the stressors produced by different components of a proposed action. Our response analyses consider and weigh all of the evidence available, including the best scientific and commercial data available, to identify the probable responses of endangered and threatened species upon being exposed to stressors associated with proposed actions.

In this consultation, we consider their probable responses to the following stressors (1) surface vessels and submarines involved in training activities and the associated risk of collisions; (2) pressure waves produced by the underwater detonations; (3) sound fields produced by the low-, mid-, and high-frequency active sonar systems the U.S. Navy would employ during training activities; (4) sound fields produced by the underwater detonations the U.S. Navy would employ during training activities; and (5) disturbance produced by the surface vessels and aircraft involved in training activities. The narratives that follow summarize the literature on the potential responses of marine animals to each of these stressors in sequence. We follow those summaries with the probable responses of the endangered or threatened species that are likely to be exposed to the different stressors on the Mariana Islands Range Complex.

5.3.1 Responses to Traffic from Surface Vessels and Submarines

Collisions with surface vessels are a well-established threat to endangered and threatened marine mammals and sea turtles (Anonymous 2001a, 2001b; Clapham 1999, Jensen and Silber 2003, Laist 2001, Panigada 2006, 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.

Vanderlaan and her co-authors (2008) developed a method for estimating the probability of an encounter between North Atlantic right whales and surface vessels in the Bay of Fundy and the Scotia Shelf, including an encounter that results in the death of a whale. They calculated a whale's probability of occurring in particular cell in a grid and the probability of a ship also occurring in that cell (relative to other cells in the grid). They calculated the probability of an encounter being lethal as:

$$[Pr(Lethal|Encounter)] = 1/[1+exp^{-(-4.89+0.41x)}]$$

where x is the mean vessel speed, in knots, in a particular cell. This equation presupposed an estimate of the probability of an encounter. Based on this equation, a vessel moving at a speed of 10 knots would have a 0.3122 probability of killing a whale in a collision, a vessel moving at a speed of 14 knots would have a 0.7006 probability of killing a whale in a collision, and a vessel moving at a speed of 20 knots would have a 0.9648 probability of killing a whale in a collision.

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 were 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 on or in transit to the Mariana Islands Range Complex.

The reduce the probability of collisions, the U.S. Navy proposes to employ measures that would increase a whale'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 report any marine mammals that observe. 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 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. Large or slow-moving species would be more at risk of being struck than smaller, faster swimmers. However, after reviewing the 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 being struck (Navy 2002b). Historically there has not been a reported torpedo striking a marine mammal within the vicinity of the Mariana Islands Range Complex.

5.3.2. Responses 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, U.S. Navy 1998).

Non-lethal injuries include slight lung hemorrhage and tympanic membrane rupture from which the mammal is expected to recover (Yelverton *et al*. 1973; Richmond, *et al*. 1973). Eardrum damage criteria are based upon a limited number of small charge tests (Yelverton et al. 1973; Richmond 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 (U.S. 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 (Ridgeway *et al*. 1997); 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 USS JOHN PAUL JONES shock trial analyses predicted safety ranges for smaller charges calculated for distances based on slight lung injury associated with a 10,000 lb charge, slant range, doubled[5] (NMFS 1993).

Table 6. Estimated safety ranges for explosive charges of different sizes (after NMFS 1993)

Charge Weight (lbs)	Safety Range (feet)	Maximum Pressure (psi)
1	600	18
10	1,500	16
100	3,000	17
1000	6,076	19

RESPONSES OF SEA TURTLES TO UNDERWATER DETONATIONS. Klima *et. al.* (1988) conducted an experiment in which Kemp's ridley and loggerhead turtles were placed in cages at four distances from a oil platform to be removed with explosives. The cages were submerged to a depth of 4.52 meters (15 feet) over the 9 meter (30 foot) 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 4.88 meters (16 feet) below the mudline. Loggerhead and Kemp's ridley turtles at 228.6 meters (750 feet) and 365 meters (1,200 feet), as well as one loggerhead at 914 meters (3,000 feet) were rendered unconscious. The Kemp's ridley turtle closest to the explosion (range of 228.6 meters) was slightly injured, with an everted cloacal lining; ridleys at ranges of 365 meters, 546 meters, and 914 meters 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 36.6 meters (120 feet) deep. At least three turtles were noted in the area following the detonations. One turtle at a range of 152 to 213 meters (500 to 700 feet) was killed. A second turtle at a range of 365 meters received minor injuries. A third turtle at 609.6 meters (2,000 feet) was apparently unaffected. At a depth of 18 meters (60 feet), calculated shock wave pressures were 239, 161, 85, and 47 psi at ranges of 152, 213, 365, and 609.6 meters, respectively.

Based on a parametric evaluation of the effects of charge weight and depth using the Goertner (1982) model, Young (1991) concluded that a conservative safe range for non-injury to a small mammal (representative of a dolphin calf) was approximated by $R=578w^{0.28}$ (*R* is in feet and *w* is in pounds of explosive). O'Keeffe and Young (1984) proposed that a safe range for turtles from an underwater explosion could be expressed by $R = 200\ w^{1/3}$, where R is the safe range in feet and w is the charge weight in pounds. This equation was subsequently modified by Young (1991) based on safe ranges established by the NMFS for platform removal operations using explosives. The revised equation is $R = 560\ w^{1/3}$. Applied to the Klima *et. al.* (1988) observations, this equation predicts a safe range of 3,291 ft, which exceeds the greatest distance at which an effect was observed (turtle unconscious at 3,000 ft).

5 Each calculation is scaled by the cube root for the different charge weights

Applied to the O'Keeffe and Young (1984) report, this equation predicts a safe range of 5,951 ft, nearly triple the range from the charge of the uninjured turtle.

The safe ranges calculated previously addressed physical injury to sea turtles but did not identify problems associated with detecting damage to sea turtle auditory systems. These effects include physical changes to the auditory system that permanently or temporarily destroy or alter a turtle's hearing. Sea turtles do not have an auditory meatus or pinna that channels sound to the middle ear, nor do they have a specialized eardrum. Instead, they have a cutaneous layer and underlying subcutaneous fatty layer, that function as a tympanic membrane. The subcutaneous fatty layer receives and transmits sound to the extra-columella, a cartilaginous disk, located at the entrance to the columella, a long, thin bone that extends from the middle ear cavity to the entrance of the inner ear or otic cavity (Ridgway *et al.* 1969). Sound arriving at the inner ear via the columella is transduced by the bones of the middle ear. Sound also arrives by bone conduction through the skull. Low frequency sounds at high source levels can also be detected by vibration-sensitive touch receptors in various other parts of the turtle's body (mechano-reception). Any disruption (permanent or temporary) of a turtle's hearing may kill or injure the turtle. On the other hand, some effects may be temporary or slight and will not have lethal results.

Sea turtle auditory sensitivity has not been well studied. A few preliminary investigations suggest that it is limited to low frequency band-widths, such as the sounds of waves breaking on a beach. The role of underwater low frequency hearing in sea turtles is unclear. It has been suggested that sea turtles may use acoustic signals from their environment as guideposts during migration and as a cue to identify their natal beaches (Moein *et al.* 1983).

Although green turtles in the vicinity of an in-water detonation might experience temporary or permanent threshold shifts, the evidence does not allow us to estimate the energy levels or received levels that would be necessary to induce threshold shifts. The few studies on the auditory capabilities of sea turtles (adult green, loggerhead, and Kemp's ridley sea turtles) suggest that sea turtles are capable of hearing low frequency sounds (Ridgway *et al.* 1969; Moein *et al.* 1983; Lenhardt,1994). Ridgway *et al.* (1969) reported maximal sensitivity for green turtles occurred at 300 to 400 Hz, with a rapid decline in sensitivity for lower and higher tones. Similarly, Moein *et al.* (1994) reported a hearing range of about 250 to 1,000 Hz for loggerhead sea turtles, and Lenhardt (1994) stated that maximal sensitivity in sea turtles generally occurs in the range from 100 to 800 Hz. Calculated in-water hearing thresholds within the useful range appear to be high (e.g., about 160 to 200 dB re 1 μPa; Lenhardt, 1994). In the absence of more specific information that could be used to determine the acoustic harassment range for sea turtles, the U.S. Navy assumed that frequencies ≥100 Hz (which are the acoustical harassment ranges predicted for odontocetes) would be conservative for sea turtles.

Moein *et al.* (1983) and O'Hara and Wilcox (1990) indicate that low frequency acoustic sound transmissions at source levels of 141-150 dB could potentially cause increased surfacing behavior and deterrence from the area near a sound source. In this instance, if they surface more frequently, green turtles will not be at a greater risk of collision with vessels transiting the action area because vessel traffic will be halted during detonation operations.

5.3.3 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. Nevertheless, 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 on the Mariana Islands Range Complex.

Figure 11 is the conceptual model we use to organize our assessment of the probable effects (that is, exposure, responses, and the pathways that connect those responses to changes in the fitness of individual animals) of active sonar transmissions or sound fields produced by an underwater detonations on endangered or threatened species. Our first consideration are exposures, which we have already addressed. Following one pathway (sound as a systemic stressor), exposing marine animals to active sonar transmissions or the sounds produced by underwater detonations might physically damage tissues or hearing structures in the marine animals (Box P in Figure 11). Following a second pathway (sound as a processive stressor), we consider the “salience” of those sounds to an animal, given that the animal’s environment contains other sounds (Box B1 of Figure 11; by “salience” we mean whether or to what degree a sound is distinguishable from other sounds in a particular context). Other sounds in an animal’s environment might reduce the salience of sounds produced by U.S. Navy training activities (for example, wind, wave, or rain in a shallow coastal environment would reduce the salience or mask distant sonar transmissions) or they might compete for an animal’s attentional resources. An animal’s physiological and behavioral state (Box B2.a in Figure 11) would help determine whether sounds produced by U.S. Navy training activities would be salient to the animal; that physiological state would be influenced by any noise-induced losses in hearing sensitivity. If a sound was not salient to an animal or if the animal did not devote attentional resources to the sound, the animal is not likely to respond to the sound (Box BR.0 in Figure 11).

An animal’s physiological and behavioral state and prior experience (Box B2.b in Figure 11) would help determine the animal would classify sounds produced (Box B2 in Figure 11); that is, whether the animal would classify a sound as an noxious or annoying stimulus or as a cue produced by food, conspecifics, competers, predators, etc. How the animal classifies a sound would determine its behavioral decision rule or the probability that the animal will respond in a particular way (Box B3 in Figure 11). An animal’s behavioral decision rule, however, is also determined by an animal’s motivation (Box B.2.a.2 in Figure 11) ─ for example, hungry animals will be highly motivated to feed, cows with calves will be highly motivated to remain with their calf ─ and those motivations might over-ride a behavioral decision rule. Once an animal responds (or does not respond) to a sound produced by U.S. Navy training activities, those responses have several potential consequences or costs (Boxes S1, S2, B4) that each have different consequences for the animal’s lifetime reproductive success (that is, the animal’s longevity, current reproductive success, or expected future reproductive success).

The narratives that follow are generally organized around the boxes identified Figure 11. 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.

5.3.3.1 Physical Damage

For the purposes of this assessment, "injuries" represents physical trauma or damage that is a direct result of an acoustic exposure, regardless of the potential consequences of those injuries to an animal (we distinguish between injuries that result from an acoustic exposure and injuries that result from an animal's behavioral reaction to an acoustic exposure, which is discussed later in this section of the Opinion). Based on the literature available, active sonar might injure marine animals through two mechanisms (see "Box P" in Figure 11): acoustic resonance and noise-induced loss of hearing sensitivity (more commonly-called "threshold shift").

ACOUSTIC RESONANCE. Acoustic resonance results from hydraulic damage in tissues that are filled with gas or air that resonates when exposed to acoustic signals (Box P1 of Figure 11 illustrates the potential consequences of acoustic resonance; see Rommel *et al*. 2007). Based on studies of lesions in beaked whales that stranded in the Canary Islands and Bahamas associated with exposure to naval exercises that involved sonar, investigators have identified two physiological mechanisms that might explain some of those stranding events: tissue damage resulting from resonance effects (Ketten 2004, Cudahy and Ellison 2001) and tissue damage resulting from "gas and fat embolic syndrome" (Fernandez *et al*. 2005, Jepson *et al*. 2003, 2005). Fat and gas embolisms are believed to occur when tissues are supersaturated with dissolved nitrogen gas and diffusion facilitated by bubble-growth is stimulated within those tissues (the bubble growth results in embolisms analogous to the "bends" in human divers).

Cudahy and Ellison (2001) analyzed the potential for resonance from low frequency sonar signals to cause injury and concluded that the expected threshold for *in vivo* (in the living body) tissue damage for underwater sound is on the order of 180 to 190 dB. There is limited direct empirical evidence (beyond Schlundt *et al*. 2000) to support a conclusion that 180 dB is "safe" for marine mammals; however, evidence from marine mammal vocalizations suggests that 180 dB is not likely to physically injure marine mammals. For example, Frankel (1994) estimated the source level for singing humpback whales to be between 170 and 175 dB; McDonald *et al*. (2001) calculated the average source level for blue whale calls as 186 dB, Watkins *et al*. (1987) found source levels for fin whales up to 186 dB, and Møhl *et al*. (2000) recorded source levels for sperm whale clicks up to 223 dB_{rms}. Because whales are not likely to communicate at source levels that would damage the tissues of other members of their species, this evidence suggests that these source levels are not likely to damage the tissues of the endangered and threatened species being considered in this consultation.

Crum and Mao (1996) hypothesized that received levels would have to exceed 190 dB in order for there to be the possibility of significant bubble growth due to super-saturation of gases in the blood. Jepson *et al*. (2003, 2005) and Fernández *et al*. (2004, 2005) concluded that *in vivo* bubble formation, which may be exacerbated by deep, long-duration, repetitive dives may explain why beaked whales appear to be particularly vulnerable to sonar exposures.

Based on the information available, the endangered or threatened marine mammals and sea turtles that we are considering in this Opinion are not likely to experience acoustic resonance. All of the evidence available suggests that this phenomenon poses potential risks to smaller cetaceans like beaked whales rather than the larger cetaceans that have been listed as endangered. Thus far, this phenomenon has not been reported for or associated with sea turtles, perhaps because they do not engage in dive patterns that are similar to those of beaked whales.

NOISE-INDUCED LOSS OF HEARING SENSITIVITY. Noise-induced loss of hearing sensitivity[6] 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 an animal to detect and recognize it. Noise-induced loss of hearing sensitivity is usually represented by the increase in intensity (in decibels) sounds must have to be detected. 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 (Miller 1974, Ward 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 cells damage does not accompany TTS and loss 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.

Compound threshold shift or CTS, occurs when some loss in hearing sensitivity is permanent and some is temporary (for example, there might be a permanent loss of hearing sensitivity at some frequencies and a temporary loss at other frequencies or a loss of hearing sensitivity followed by partial recovery; Miller 1974).

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 marine mammals. Most of the few studies available have reported the responses of captive animals exposed to sounds in controlled experiments. Schlundt *et al.* (2000; see also Finneran *et al.* 2001, 2003) provided a detailed summary of the behavioral responses of trained marine

6 Animals can experience losses in hearing sensitivity through other mechanisms. The processes of aging and several diseases cause some humans to experience permanent losses in their hearing sensitivity. Body burdens of toxic chemicals can also cause animals, including humans, to experience permanent and temporary losses in their hearing sensitivity (for example, see Mills and Going 1982 and Fechter and Pouyanos 2005).

mammals during TTS tests conducted at the Navy's SPAWAR Systems Center with 1-second tones. Schlundt *et al.* (2000) reported on eight individual TTS experiments that were conducted in San Diego Bay. Fatiguing stimuli durations were 1 second. Because of the variable ambient noise in the bay, low-level broadband masking noise was used to keep hearing thresholds consistent despite fluctuations in the ambient noise.

Finneran *et al.* (2001, 2003) conducted TTS experiments using 1-second duration tones at 3 kHz. The test method was similar to that of Schlundt *et al.* except the tests were conducted in a pool with a very low ambient noise level (below 50 dB re 1 $\mu Pa^2/Hz$), and no masking noise was used. The signal was a sinusoidal amplitude modulated tone with a carrier frequency of 12 kHz, modulating frequency of 7 Hz, and SPL of approximately 100 dB re 1 μPa. Two separate experiments were conducted. In the first, fatiguing sound levels were increased from 160 to 201 dB SPL. In the second experiment, fatiguing sound levels between 180 and 200 dB re 1 μPa were randomly presented.

Richardson *et al*. (1995) 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 μPa 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* 1995). 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 (Miller 1974, Ward 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 exposure 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 (Box P2 of Figure 11 illustrates the potential consequences of noise-induced loss in hearing sensitivity). 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 how animals that experience noise-induced hearing loss alter their behavior or the 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.

5.3.3.2 Behavioral Responses

Marine animals have not had the time and have not experienced the selective pressure necessary for them to have evolved a behavioral repertoire containing a set of potential responses to active sonar, other potential stressors associated with naval military readiness activities, or human disturbance generally. Instead, marine animals invoke behavioral responses that are already in their behavioral repertoire to decide how they will behaviorally respond to active sonar, other potential stressors associated with naval military readiness activities, or human disturbance generally. An extensive number of studies have established that these animals will invoke the same behavioral responses they would invoke when faced with predation and will make the same ecological considerations when they experience human disturbance that they make when they perceive they have some risk of predation (Beale and Monaghan 2004, Bejder *et al*. 2009, Berger *et al*. 1983, Frid 2003, Frid and Dill 2002, Gill *et al*. 2000, 2001; Gill and Sutherland 2000, 2001; Harrington and Veitch 1992, Lima 1998, Lima & Dill 1990, Madsen 1994, Romero 2004). Specifically, when animals are faced with a predator or predatory stimulus, they consider the risks of predation, the costs of anti-predator behavior, and the benefits of continuing a pre-existing behavioral pattern when deciding which behavioral response is appropriate in a given circumstance (Bejder *et al*. 2009, Gill *et al*. 2001, (Houston and McNamara 1986, Lima 1998, Lima and Bednekoff 1999, Ydenberg and Dill 1996). Further, animals appear to detect and adjust their responses to temporal variation in predation risks (Kat and Dill 1998, Lima and Bednekoff 1999, Rodriguez-Prieto *et al*. 2008).

The level of risk an animal perceives results from a combination of factors that include the perceived distance between an animal and a potential predator, whether the potential predator is approaching the animal or moving tangential to the animal, the number of times the potential predator changes its vector (or evidence that the potential predator might begin an approach), the speed of any approach, the availability of refugia, and the health or somatic condition of the animal, for example, along with factors related to natural predation risk (e.g., Frid 2001, Frid and Dill 2002, Papouchis *et al*. 2001). In response to a perceived threat, animals can experience physiological changes that prepare them for flight or fight responses or they can experience physiological changes with chronic exposure to stressors that have more serious consequences such as interruptions of essential behavioral or physiological events, alteration of an animal’s time budget, or some combinations of these responses (Frid and Dill 2002, Romero 2004, Sapolsky *et al*. 2000, Walker *et al*. 2005).

The behavioral responses of animals to human disturbance have been documented to cause animals to abandon nesting and foraging sites (Bejder *et al*. 2009, Gill *et al*. 2001, Sutherland and Crockford 1993), cause animals to increase their activity levels and suffer premature deaths or reduced reproductive success when their energy expenditures exceed their energy budgets (Daan *et al*. 1996, Feare 1976, Giese 1996, Mullner *et al*. 2004, Waunters *et al*. 1997), or cause animals to experience higher predation rates when they adopt risk-prone foraging or migratory strategies (Frid and Dill 2002).

Based on the evidence available from empirical studies of animal responses to human disturbance, marine animals are likely to exhibit one of several behavioral responses upon being exposed to sonar transmissions: (1) they may 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 (Boxes BR1.1 and BR1.2 of Figure 11); (2) they may engage in evasive behavior to escape exposure or continued exposure to a sound that is painful, noxious, or that they perceive as threatening, which we would assume would be accompanied by acute stress physiology (Box BR1.3 of Figure 11); (3) they may remain continuously vigilant of the source of the acoustic stimulus, which would alter their time budget. That is, the during the time they are vigilant, they are not engaged in other behavior (Box BR1.4 of Figure 11); and (4) they may continue their pre-disturbance behavior and cope with the physiological consequences of continued exposure.

Marine animals might experience one of these behavioral responses, they might experience a sequence of several of these behaviors (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 EXPOSURES OR CONTINUED EXPOSURE (HORIZONTAL AND VERTICAL AVOIDANCE. 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 to the area after they have abandoned it), animals that avoid being exposed to the entire sound field produced by active sonar; and animals that avoid being exposed to particular received levels within a sound field produced by active sonar.

Richardson *et al*. (1995) noted that avoidance reactions are the most obvious manifestations of disturbance in marine mammals. There are few empirical studies of avoidance responses of free-living cetaceans to mid-frequency sonar. However, Kvadsheim *et al*. (2007) conducted a controlled exposure experiment in which killer whales (*Orcinus orca*) that had been fitted with D-tags were exposed to mid-frequency active sonar (Source A: was a 1.0 s upsweep 209 dB @ 1 - 2 kHz every 10 seconds for 10 minutes; Source B: was a 1.0 s upsweep 197 dB @ 6 - 7 kHz every 10 s for 10 min).

When exposed to Source A, a tagged killer 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 (the received level associated with this response was not reported). 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.

Maybaum (1993) conducted sound playback experiments to assess the effects of mid-frequency active sonar on humpback whales in Hawai'ian waters. Specifically, she exposed focal pods to sounds of a 3.3-kHz sonar pulse, a sonar frequency sweep from 3.1 to 3.6 kHz, and a control (blank) tape while monitoring the behavior, movement, and underwater vocalizations. The two types of sonar signals differed in their effects on the humpback whales, the whales exhibited avoidance behavior when exposed to both sounds. The whales responded to the pulse by increasing their distance from the sound source and responded to the frequency sweep by increasing their swimming speeds and track linearity.

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 1997, 1998, 2000, 2001). However, fin and sei whale sighting rates were higher when airguns were shooting, which may result from their tendency to remain at or near the surface at times of airgun operation (Stone 2003). The analysis of the combined data from all years indicated that baleen whales stayed farther from airguns during periods of shooting (Stone 2003). Baleen whales also altered course more often during periods of shooting and more were headed away from the vessel at these times, indicating some level of localized avoidance of seismic activity (Stone 2003).

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 *et al.* 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 are several days after the seismic activities stopped. The potential fitness consequences of displacing these whales, especially mother-calf pairs and "skinny whales," outside of their the normal feeding area is not known; however, because gray whales, like other large whales, must gain enough energy during the summer foraging season to last them the entire year. Sounds or other stimuli that cause them to abandon a foraging area for several days seems almost certain to disrupt their energetics and force them to make trade-offs like delaying their migration south, delaying reproduction, reducing growth, or migrating with reduced energy reserves.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 second pulsed sounds at frequencies similar to those emitted by the multi-beam sonar that is used by geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid a sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such responses to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). It is not clear whether or to what degree the responses of captive animals might be representative of the responses of marine animals in the wild. For example, wild cetaceans sometimes avoid sound sources well before they are exposed to received levels such as those used in these experiments. Further, the responses of marine animals in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

Richardson *et al*. (1995a) and Richardson (1997, 1998) used controlled playback experiments to study the response of bowhead whales in Arctic Alaska. In their studies, bowhead whales tended to avoid drill ship noise at estimated received levels of 110 to 115 dB and seismic sources at estimated received levels of 110 to 132 dB. Richardson *et al*. (1995) concluded that some marine mammals would tolerate continuous sound at received levels above 120 dB re 1 μPa for a few hours. These authors concluded that most marine mammals would avoid exposures to received levels of continuous underwater noise greater than 140 dB when source frequencies were in the animal's most sensitive hearing range.

Several authors noted that migrating whales are likely to avoid stationary sound sources by deflecting their course slightly as they approached a source (LGL and Greenridge 1987 in Richardson *et al*. 1995). Malme *et al*. (1983, 1984) studied the behavioral responses of gray whales (*Eschrictius robustus*) that were migrating along the California coast to various sound sources located in their migration corridor. The whales they studied showed statistically significant responses to four different underwater playbacks of continuous sound at received levels of approximately 120 dB. The sources of the playbacks were typical of a drillship, semisubmersible, drilling platform, and production platform.

Morton *et al*. (2004) exposed killer whales (*Orcinus orca*) to sounds produced by acoustic harassment devices (devices that were designed to harass harbor seals, source levels were 194 dB at 10 kHz re 1μPa at 1 meter). They concluded that observations of killer whales declined dramatically in the experimental area (Broughton Archipelago) during the time interval the harassment devices had been used (but not before or after the use). Other investigators have concluded that gray whales and humpback whales abandoned some of their coastal habitat in California and Hawai'i, respectively, because of underwater noise associated with extensive vessel traffic (Gard 1974, Reeves 1977, Salden 1988).

Nowacek *et al*. (2004) conducted controlled exposure experiments on North Atlantic right whales using ship noise, social sounds of con-specifics, and an alerting stimulus (frequency modulated tonal signals between 500 Hz and 4.5 kHz). Animals were tagged with acoustic sensors (D-tags) that simultaneously measured movement in three dimensions. Whales reacted strongly to alert signals at received levels of 133-148 dB SPL, mildly to conspecific signals, and not at all to ship sounds or actual vessels. The alert stimulus caused whales to immediately cease foraging behavior and swim rapidly to the surface.

Several studies have demonstrated that cetaceans will avoid human activities such as vessel traffic, introduced sounds in the marine environment, or both. Lusseau (2003) reported that bottlenose dolphins in Doubtful Sound, New Zealand, avoided approaching tour boats by increasing their mean diving interval. Male dolphins began to avoid tour boats before the boats were in visible range, while female dolphins only began to avoid the boats when the boats became intrusive (he attributed the differential responses to differences in energetics: the larger body size of male dolphins would allow them to compensate for the energy costs of the avoidance behavior more than female dolphins). Bejder *et al*. (2006) studied the effects of vessel traffic on bottlenose dolphins in Shark Bay, Australia, over three consecutive 4.5-year periods. They reported that the dolphins avoided the bay when two tour operators began to operate in the bay.

Marine mammals may avoid or abandon an area temporarily during periods of high traffic or noise, returning when the source of the disturbance declines below some threshold (Lusseau 2004, Allen and Read 2000). Alternatively, they might abandon an area for as long as the disturbance persists. For example, Bryant *et al*. (1984 *in* Polefka 2004) reported that gray whales abandoned a calving lagoon in Baja California, Mexico following the initiation of dredging and increase in small vessel traffic. After the noise-producing activities stopped, the cow-calf pairs returned to the lagoon; the investigators did not report the consequences of that avoidance on the gray whales. Gard (1974) and Reeves (1977) reported that underwater noise associated with vessel traffic had caused gray whales to abandon some of their habitat in California for several years. Salden (1988) suggested that humpback whales avoid some nearshore waters in Hawai'i for the same reason.

As Bejder *et al*. (2006 and 2009) argued, animals that are faced with human disturbance must evaluate the costs and benefits of relocating to alternative locations; those decisions would be influenced by the availability of alternative locations, the distance to the alternative locations, the quality of the resources at the alternative locations, the conditions of the animals faced with the decision, and their ability to cope with or "escape" the disturbance (citing Beale and Monaghan 2004a, 2004b; Gill *et al*. 2001, Frid and Dill 2002, Lima and Dill 1990). Specifically, animals delay their decision to flee from predators and predatory stimuli that they detect, or until they decide that the benefits of fleeing a location are greater than the costs of remaining at the location or, conversely, until the costs of remaining at a location are greater than the benefits of fleeing (Ydenberg and Dill 1996). Ydenberg and Dill (1996) and Blumstein (2003) presented an economic model that recognized that animals will almost always choose to flee a site over some short distance to a predator; at a greater distance, animals will make an economic decision that weighs the costs and benefits of fleeing or remaining; and at am even greater distance, animals will almost always choose not to flee.

Based on a review of observations of the behavioral responses of 122 minke whales, 2,259 fin whales, 833 right whales, and 603 humpback whales to various sources of human disturbance, Watkins (1986) reported that fin, humpback, minke, and North Atlantic right whales ignored sounds that occurred at relatively low received levels, that had the most energy at frequencies below or above their hearing capacities appeared not to be noticed, or that were from distant human activities, even when those sounds had considerable energies at frequencies well within the whale's range of hearing. Most of the negative reactions that had been observed occurred within 100 m of a sound source or when sudden increases in received sound levels were judged to be in excess of 12 dB, relative to previous ambient sounds

From these observations, we would have to conclude that the distance between marine mammals and a source of sound, as well as the received level of the sound itself, will help determine whether individual animals are likely to respond to the sound and engage in avoidance behavior. At the limits of the range of audibility, endangered and threatened marine mammals are likely to ignore cues that they might otherwise detect. At some distance that is closer to the source, endangered or threatened marine mammals may be able to detect a sound produced by military readiness activities, but they would not devote attentional resources to the sound (that is, they would filter it out as background noise or ignore it). For example, we would not expect endangered or threatened marine mammals that find themselves between 51 and 130 kilometers (between about 32 and 81 miles) from the source of a sonar ping to devote attentional resources to that stimulus, even though received levels might be as high as 140 dB (at 51 kilometers) because those individuals are more likely to be focusing their attention on stimuli and environmental cues that are considerably closer, even if they were aware of the signal.

Those animals that are closer to the source and not engaged in activities that would compete for their attentional resources (for example, mating or foraging) might engage in low-level avoidance behavior (changing the direction or their movement to take them away from or tangential to the source of the disturbance) possibly accompanied by short-term vigilance behavior, but they are not likely to change their behavioral state (that is, animals that are foraging or migrating would continue to do so). For example, we would expect endangered or threatened marine mammals that find themselves between 25 and 51 kilometers (between about 15.5 and 32 miles) from a sonar transmission where received levels might range from 140 and 150 dB to engage in low-level avoidance behavior or short-term vigilance behavior, but they are not likely to change their behavioral state as a result of that exposure.

At some distance that is closer still, these species are likely to engage in more active avoidance behavior followed by subsequent low-level avoidance behavior that does not bring them closer to the training activity. At the closest distances, we assume that endangered and threatened marine mammals would engage in vertical and horizontal avoidance behavior unless they have a compelling reason to remain in a location (for example, to feed). In some circumstances, this would involve abrupt vertical or horizontal movement accompanied by physiological stress responses. On the Mariana Islands Range Complex, we would expect these kind of responses at distances between 0 and 0.56 kilometers where received levels from active sonar would be greater than 180 dB. However, at these distances endangered or threatened marine mammals would be aware of a wide array of visual and acoustic cues associated with Navy vessels (including sound associated with a ship's engines, the bow wake, etc.) and an animal's decision to change its behavior might be a response to active sonar, one of these other cues, or the entire suite of cues.

The evidence available also suggests that marine mammals might experience more severe consequences if an acoustic cue associated with active sonar leads them to perceive they face an imminent threat, but circumstances do not allow them to avoid or "escape" further exposure. At least six circumstances might prevent an animal's from escaping further exposure to mid-frequency active sonar and could produce any of one the following outcomes:

1. when swimming away (an attempted "escape") brings marine mammals into a shallow coastal feature that causes them to strand;

2. they cannot swim away because the exposure occurred in a coastal feature that leaves marine mammals no "escape" route (for example, a coastal embayment or fjord that surrounds them with land on three sides, with the sound field preventing an "escape");

3. they cannot swim away because the marine mammals are exposed to multiple sound fields in a coastal or oceanographic feature that act in concert to prevent their escape;

4. they cannot dive "below" the sound field while swimming away because of shallow depths;

5. to remain "below" the sound field, they must engage in a series of very deep dives with interrupted attempts to swim to the surface (which might lead to pathologies similar to those of decompression sickness);

6. any combination of these phenomena.

Although causal relationships between beaked whale stranding events and active sonar remain unknown, several authors have hypothesized that stranding events involving these species in the Bahama and Canary Islands may have been triggered when the whales changed their dive behavior to avoid exposure to active sonar (Cox *et al*. 2006, Rommel *et al*. 2006). These authors proposed two mechanisms by which the behavioral responses of beaked whales upon being exposed to active sonar might result in a stranding event. First, beaked whales that occur in deep waters that are in close proximity to shallow waters (for example, the "canyon areas" that are cited in the Bahamas stranding event; see D'Spain and D'Amico 2006), may respond to active sonar by swimming into shallow waters to avoid further exposures and strand if they were not able to swim back to deeper waters.

Second, beaked whales exposed to active sonar might alter their dive behavior (see Boxes BR1.2 and BR1.3 of Figure 11). Changes in their dive behavior might cause them to remain at the surface or at depth for extended periods of time which could lead to hypoxia directly by increasing their oxygen demands or indirectly by increasing their energy expenditures (to remain at depth) and increase their oxygen demands as a result. If beaked whales are at depth when they detect a ping from an active sonar transmission and change their dive profile leading to formation of significant gas bubbles, which damage multiple organs or interfere with normal physiological function (Cox *et al*. 2006, Rommel *et al*. 2006, Zimmer and Tyack 2007).

Because many species of marine mammals make repetitive and prolonged dives to great depths, it has long been assumed that marine mammals have evolved physiological mechanisms to protect against the effects of rapid and repeated decompressions. Although several investigators have identified physiological adaptations that may protection marine mammals against nitrogen gas supersaturation (alveolar collapse and elective circulation; Kooyman *et al*. 1972; Ridgway and Howard 1979), Ridgway and Howard (1979) reported that bottlenose dolphins (*Tursiops truncatus*) that were trained to dive repeatedly had muscle tissues that were substantially supersaturated with nitrogen gas. Houser *et al.* (2001) used these data to model the accumulation of nitrogen gas within the muscle tissue of other marine mammal species and concluded that cetaceans that dive deep and have slow ascent or descent speeds would have tissues that are more supersaturated with nitrogen gas than other marine mammals.

Based on these data, Cox *et al*. (2006) hypothesized that a critical dive sequence might make beaked whales more prone to stranding in response to acoustic exposures. The sequence began with (1) very deep (to depths as deep as 2 kilometers) and long (as long as 90 minutes) foraging dives with (2) relatively slow, controlled ascents, followed by

(3) a series of "bounce" dives between 100 and 400 meters in depth (also see Zimmer and Tyack 2007). They concluded that acoustic exposures that disrupted any part of this dive sequence (for example, causing beaked whales to spend more time at surface without the bounce dives that are necessary to recover from the deep dive) could produce excessive levels of nitrogen super-saturation in their tissues, leading to gas bubble and emboli formation that produces pathologies similar to decompression sickness.

The evidence available suggests that sperm whales are likely to engage in vertical or horizontal avoidance behavior in an attempt to avoid continued exposed 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.

If sperm whales respond to a Navy vessel that is transmitting active sonar in the same way that they might respond to a predator, their probability of flight responses should increase when they perceive that Navy vessels are approaching them directly, because a direct approach may convey detection and intent to capture (Burger and Gochfeld 1981, 1990, Cooper 1997, 1998). The probability of 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 2001*a*, 2001*b*), ringed seals *Phoca hispida* (Born *et al*. 1999), Pacific brant (*Branta bernicl nigricans*) and Canada geese (*B. Canadensis*) increased as a helicopter or fixed-wing aircraft approached groups of these animals more directly (Ward *et al*. 1999). Bald eagles (*Haliaeetus leucocephalus*) perched on trees alongside a river were also more likely to flee from a paddle raft when their perches were closer to the river or were closer to the ground (Steidl and Anthony 1996).

VIGILANCE. Attention is the cognitive process of selectively concentrating on one aspect of an animal's environment while ignoring other things (Posner 1994). Because animals (including humans) have limited cognitive resources, there is a limit to how much sensory information they can process at any time. The phenomenon called "attentional capture" occurs when a stimulus (usually a stimulus that an animal is not concentrating on or attending to) "captures" an animal's attention. This shift in attention can occur consciously or unconsciously (for example, when an animal hears sounds that it associates with the approach of a predator) and the shift in attention can be sudden (Dukas 2002, van Rij 2007). Once a stimulus has captured an animal's attention, the animal can respond by ignoring the stimulus, assuming a "watch and wait" posture, or treat the stimulus as a disturbance and respond accordingly, which includes scanning for the source of the stimulus or "vigilance" (Cowlishaw *et al*. 2004).

Vigilance is normally an adaptive behavior that helps animals determine the presence or absence of predators, assess their distance from conspecifics, or to attend cues from prey (Bednekoff and Lima 1998, Treves 2000). Despite those benefits, however, vigilance has a cost of time: when animals focus their attention on specific environmental cues, it is not attending to other activities such a foraging. These costs have been documented best in foraging animals, where vigilance has been shown to substantially reduce feeding rates (Saino 1994, Beauchamp and Livoreil 1997, Fritz *et al*. 2002).

Animals will spend more time being vigilant, which translates to less time foraging or resting, when disturbance stimuli approach them more directly, remain at closer distances, have a greater group size (for example, multiple surface vessels), or when they co-occur with times that an animal perceives increased risk (for example, when they are giving birth or accompanied by a calf). Most of the published literature, however, suggests that direct approaches will increase the amount of time animals will dedicate to being vigilant. For example, bighorn sheep and Dall's sheep dedicated more time being vigilant, and less time resting or foraging, when aircraft made direct approaches over them (Frid 2001, Stockwell *et al*. 1991).

Several authors have established that long-term and intense disturbance stimuli can cause population declines by reducing the body condition of individuals that have been disturbed, followed by reduced reproductive success, reduced survival, or both (Daan *et al*. 1996, Madsen 1994, White 1983). For example, Madsen (1994) reported that pink-footed geese (*Anser brachyrhynchus*) in undisturbed habitat gained body mass and had about a 46% reproductive success compared with geese in disturbed habitat (being consistently scared off the fields on which they were foraging) which did not gain mass and has a 17% reproductive success. Similar reductions in reproductive success have been reported for mule deer (*Odocoileus hemionus*) disturbed by all-terrain vehicles (Yarmoloy *et al*. 1988), caribou disturbed by seismic exploration blasts (Bradshaw *et al*. 1998), caribou disturbed by low-elevation military jet-fights (Luick *et al*. 1996), and caribou disturbed by low-elevation jet flights (Harrington and Veitch 1992). Similarly, a study of elk (*Cervus elaphus*) that were disturbed experimentally by pedestrians concluded that the ratio of young to mothers was inversely related to disturbance rate (Phillips and Alldredge 2000).

The primary mechanism by which increased vigilance and disturbance appear to affect the fitness of individual animals is by disrupting an animal's time budget and, as a result, reducing the time they might spend foraging and resting (which increases an animal's activity rate and energy demand). For example, a study of grizzly bears (*Ursus horribilis*) reported that bears disturbed by hikers reduced their energy intake by an average of 12 kcal/min (50.2 x 10^{3}kJ/min), and spent energy fleeing or acting aggressively toward hikers (White *et al*. 1999).

CONTINUED PRE-DISTURBANCE BEHAVIOR, HABITUATION, OR NO RESPONSE. Under some circumstances, some individual animals that would be exposed to active sonar transmissions and other sounds associated with military readiness activities will continue the behavioral activities they were engaged in before they were exposed (Richardson *et al*. 1995). For example, Watkins (1986) reviewed data on the behavioral reactions of fin, humpback, right and minke whales that were exposed to continuous, broadband low-frequency shipping and industrial noise in Cape Cod Bay is informative. He concluded that underwater sound was the primary cause of behavioral reactions in these species of whales and that the whales responded behaviorally to acoustic stimuli within their respective hearing ranges. Watkins also noted that whales showed the strongest behavioral reactions to sounds in the 15 Hz to 28 kHz range, although negative reactions (avoidance, interruptions in vocalizations, etc.) were generally associated with sounds that were either unexpected, too loud, suddenly louder or different, or perceived as being associated with a potential threat (such as an approaching ship on a collision course). In particular, whales seemed to react negatively when they were within 100 m of the source or when received levels increased suddenly in excess of 12 dB relative to ambient sounds. At other times, the whales ignored the source of the signal and all four species habituated to these sounds.

Nevertheless, Watkins concluded that whales ignored most sounds in the background of ambient noise, including the sounds from distant human activities even though these sounds may have had considerable energies at frequencies well within the whale's range of hearing. Further, he noted that fin whales were initially the most sensitive of the four species of whales, followed by humpback whales; right whales were the least likely to be disturbed and generally did not react to low-amplitude engine noise. By the end of his period of study, Watkins (1986) concluded that fin and humpback whales had 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).

There are several reasons why such animals might continue their pre-exposure activity:

1. RISK ALLOCATION. When animals are faced with a predator or predatory stimulus, they consider the risks of predation, the costs of anti-predator behavior, and the benefits of continuing a pre-existing behavioral pattern when deciding which behavioral response is appropriate in a given circumstance (Bejder *et al*. 2008, Gill *et al*. 2001, (Houston and McNamara 1986, Lima 1998, Lima and Bednekoff 1999, Ydenberg and Dill 1996). Further, animals appear to detect and adjust their responses to temporal variation in predation risks (Kat and Dill 1998, Lima and Bednekoff 1999, Rodriguez-Prieto *et al*. 2008). As a result, animals that decide that the ecological costs of changing their behavior exceeds the benefits of continuing their behavior, we would expect them to continue their pre-existing behavior. For example, baleen whales, which only feed during part of the year and must satisfy their annual energetic needs during the foraging season, are more likely to continue foraging in the face of disturbance. Similarly, a cow accompanied by her calf is less likely to flee or abandon an area at the cost of her calf's survival.

   This does not mean, however, that there are no costs involved with continuing pre-disturbance behavior in the face of predation or disturbance. When animals make risk allocation decisions, they accept they tolerate some exposure to a stressor, which means they accept We assume that individual animals that are exposed to sounds associated with military readiness activities will apply the economic model we discussed earlier (Ydenberg and Dill 1996). By extension, we assume that animals that choose to continue their pre-disturbance behavior would have to cope with the costs of doing so, which will usually involve physiological stress responses and the energetic costs of stress physiology (Frid and Dill 2002).

2. HABITUATION. When free-ranging animals do not appear to respond when presented with a stimulus, they are commonly said to have become habituated to the stimulus (Bejder *et al*. 2008, Rodriguez-Prieto *et al*. 2008, and

the example cited earlier from Watkins 1986). Habituation has been given several definitions, but we apply the definition developed by Thompson and Spencer (1966) and Groves and Thompson (1970), which are considered classic treatments of the subject, as modified by Rankin *et al*. (2009): *an incremental reduction in an animal's behavioral response to a stimulus that results from repeated stimulation to that stimulus and that does not involve sensory adaptation, sensory fatigue, or motor fatigue*. The value of this definition, when compared with other definitions (for example, Bejder *et al*. 2009 citing Thorpe 1963), is that it would lead us to establish that an animal did not experience reduced sensory sensitivity to a stimulus (which would be accompanied by threshold shifts, for example) before we would conclude that the animal had become habituated to the stimulus. Habituation has been traditionally distinguished from sensory adaptation or motor fatigue using dishabituation (presentation of a different stimulus that results in an increase of the decremented response to the original stimulus), by demonstrating stimulus specificity (the response still occurs to other stimuli), or by demonstrating frequency dependent spontaneous recovery (more rapid recovery following stimulation delivered at a high-frequency than following stimulation delivered at a low frequency).

Animals are more likely to habituate (and habituate more rapidly) to a stimulus, the less intense the stimulus (Rankin *et al*. 2009). Conversely, numerous studies suggest that animals are less likely to habituate (that is, exhibit no significant decline in their responses) as the intensity of the stimulus increases (Rankin *et al*. 2009). Further, after animals have become habituated to a stimulus, their responses to that stimulus recover (a process that is called "spontaneous recovery") over time, although habituation becomes more rapid and pronounced after a series of habituation-recovery events (a process that is called "potentiation of habituation").

3 the individuals that might be exposed may have lowered sensitivity to the stimulus. This might occur because the animals are naïve to the potential risks associated with military readiness activities (which would be more common among juveniles than adults) or they have limited sensory sensitivity by physiological constitution or constitutional endowment.

The results reported by Watkins (1986) and Aicken *et al*. (2005) could be explained either by concluding that the marine mammals had habituated to the sounds or they could be explained by concluding that the animals had made a decision to continue their pre-disturbance behavior despite the potential risks represented by the sounds (that is, the animals tolerated the disturbance). The results reported by Watkins (1986) are better explained using risk allocation than habituation because he associated the strongest, negative reactions (avoidance, interruptions in vocalizations, etc.) with sounds that were either unexpected, too loud, suddenly louder or different, were perceived as being associated with a potential threat (such as an approaching ship on a collision course), or were from distant human activities despite having considerable energy at frequencies well within the whale's range of hearing (whales would be less likely to respond to cues they would associate with a predator if their distance predator from the predator preserved their ability to escape a potential attack).

Because it would be difficult to distinguish between animals that continue their pre-disturbance behavior when exposed to active sonar because of a risk-decision and animals that habituate to disturbance (that is, they may have experienced low-level stress responses initially, but those responses abated over time), we do not assume that endangered or threatened marine mammals that do not appear to respond to active sonar or other sounds associated with military readiness activities have become habituated to those sounds. Without more evidence of actual habituation, such an assumption would lead us to fail to protect these species when protection was warranted.

5.3.3.3 Impaired Communication

Communication is an important component of the daily activity of animals and ultimately contributes to their survival and reproductive success. Animals communicate to find food (Elowson *et al*. 1991, Marler *et al*. 1986, Stokes 1971), acquiring mates (Patricelli *et al*. 2002, Ryan 1985, Stokes 1971), assessing other members of their species (Owings *et al*. 2002, Parker 1974, Sullivan 1984), evading predators (Greig-Smith 1980, Marler 1955, Vieth *et al*. 1980), and defending resources (Alatalo *et al*. 1990, Falls 1963, Zuberbuehler *et al*. 1997). Human activities that impair an animal's ability to communicate effectively might have significant effects on the animals experiencing the impairment.

Communication usually involves individual animals that are producing a vocalization or visual or chemical display for other individuals. Masking, which we discuss separately (below), affects animals that are trying to receive acoustic cues in their environment, including cues vocalizations from other members of the animals' species or social group. However, anthropogenic noise presents separate challenges for animals that are vocalizing. This subsection addresses the probable responses of individual animals whose attempts to vocalize or communicate are affected by active sonar.

When they vocalize, animals are aware of environmental conditions that affect the "active space" of their vocalizations, which is the maximum area within which their vocalizations can be detected before it drops to the level of ambient noise (Brenowitz 2004, Brumm *et al*. 2004, Lohr *et al*. 2003). Animals are also aware of environment conditions that affect whether listeners can discriminate and recognize their vocalizations from other sounds, which are more important than detecting a vocalization (Brenowitz 1982, Brumm *et al*. 2004, Dooling 2004, Marten and Marler 1977, Patricelli *et al*. 2006).

Most animals that vocalize have evolved with an ability to make vocal adjustments to their vocalizations to increase the signal-to-noise ratio, active space, and recognizability of their vocalizations in the face of temporary changes in background noise (Brumm *et al*. 2004, Cody and Brown 1969, Patricelli *et al*. 2006). Vocalizing animals will make one or more of the following adjustments to preserve the active space and recognizability of their vocalizations:

1. Adjust the amplitude of vocalizations (Box BR2.1 of Figure 11). Animals responding in this way increase the amplitude or pitch of their calls and songs by placing more energy into the entire vocalization or, more commonly, shifting the energy into specific portions of the call or song.

This response is called the "Lombard reflex" or "Lombard effect" and represents a short-term adaptation to vocalizations in which a signaler increases the amplitude of its vocalizations in response to an increase in the amplitude of background noise (Lombard 1911). This phenomenon has been studied extensively in humans, who raise the amplitude of the voices while talking or singing in the face of high, background levels of sound (Lombard 1911, Tonkinson 1990).

Other species experience the same phenomenon when they vocalize in the presence of high levels of background sound. Brumm (2004) studied the songs of territorial male nightingales (*Luscinia megarhynchos*) in the city of

Berlin, Germany, to determine whether and to what degree background noise (from automobile traffic) produced a Lombard effect in these birds. Based on his studies, the birds increased the volume of their songs in response to traffic noise by 14 dB (their songs were more than 5 times louder than birds vocalizing in quiet sites). Cynx *et al*. (1998) reported similar results based on their study of zebra finches (*Taeniopygia guttata*) exposed to white noise.

Although this type of response also has not been studied extensively in marine animals, Holt *et al*. (2007) reported that endangered southern resident killer whales (*Orcinus orca*) in Haro Strait off the San Juan Islands in Puget Sound, Washington, increased the amplitude of their social calls in the face of increased sounds levels of background noise.

2. Adjust the frequency structure of vocalizations (Box BR2.2 of Figure 11). Animals responding in this way adjust the frequency structure of their calls and songs by increasing the minimum frequency of their vocalizations while maximum frequencies remain the same. This reduces the frequency range of their vocalizations and reduces the amount of overlap between their vocalizations and background noise.

Slabbekorn and Ripmeister (2008), Slabbekorn and den Boer-Visser (2006), and Slabbekorn and Peet (2003) studied patterns of song variation among individual great tits (*Parus major*) in an urban population in Leiden, The Netherlands, and among 20 different urban and forest populations across Europe and the United Kingdom. Adult males of this species that occupied territories with more background noise (primarily traffic noise) sang with higher minimum frequencies than males occupying non-urban or quieter sites. Peak or maximum frequencies of these songs did not shift in the face of high background noise.

3. Adjust temporal structure of vocalizations (Box BR2.3 of Figure 11). 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. Miller *et al*. (2000) recorded the vocal behavior of singing humpback whales continuously for several hours using a towed, calibrated hydrophone array. They recorded at least two songs in which the whales were exposed to low-frequency active sonar transmissions (42 second signals at 6 minute intervals;

sonar was broadcast so that none of the singing whales were exposed at received levels greater than 150 dB re 1µPa). They followed sixteen singing humpback whales during 18 playbacks. In nine follows, whales sang continuously throughout the playback; in four follows, the whale stopped singing when he joined other whales (a normal social interaction); and in five follows, the singer stopped singing, presumably in response to the playback. Of the six whales whose songs they analyzed in detail, songs were 29% longer, on average, during the playbacks. Song duration returned to normal after exposure, suggesting that the whale's response to the playback was temporary.

Foote *et al*. (2004) compared recordings of endangered southern resident killer whales that were made in the presence or absence of boat noise in Puget Sound during three time periods between 1977 and 2003. They concluded that the duration of primary calls in the presence of boats increased by about 15% during the last of the three time periods (2001 to 2003). They suggested that the amount of boat noise may have reached a threshold above which the killer whales needs to increase the duration of their vocalization to avoid masking by the boat noise.

4. Adjust the temporal delivery of vocalizations (Boxes BR2.4 and BR2.5 of Figure 11). Animals responding in this way change when they vocalize or changing the rate at which they repeat calls or songs.

For example, tawny owls (*Strix aluco*) reduce the rate at which they call during rainy conditions (Lengagne and Slater 2002). Brenowitz (1982) concluded that red-winged blackbirds (*Agelaius phoeniceus*) had the largest active space, or broadcast area, for their calls at dawn because of relatively low turbulence and background noise when compared with other times of the day. Brown and Handford (2003) concluded that swamp and white-throated sparrows (*Melospiza georgiana* and *Zonotrichia albicollis*, respectively) tended to sing at dawn, as opposed to other times of the day, because they encountered the fewest impediments to acoustic transmissions during that time of the day.

Many animals will combine several of these strategies to compensate for high levels of background noise. For example, Brumm *et al*. (2004) reported that common marmosets (*Callithrix jacchus*) increased the median amplitude of the twitter calls as well as the duration of the calls in response to increased background noise. King penguins (*Aptenodytes patagonicus*) increase the number of syllables in a call series and the rate at which they repeat their calls to compensate for high background noise from other penguins in a colony or high winds (Lengagne *et al*. 1999). California ground squirrels (*Spermophilus beecheyi*) shifted the frequencies of their alarm calls in the face of high ambient noise from highway traffic (Rabin *et al*. 2003). However, they only shifted the frequency of the second and third harmonic of these alarm calls, without changing the amount of energy in the first harmonic. By emphasizing the higher harmonics, the ground squirrels placed the peak energy of their alarm calls above the frequency range of the masking noise from the highway. Wood and Yezerinac (2006) reported that song sparrows (*Melospiza melodus*) increased the frequency of the lowest notes in their songs and reduced the amplitude of the low frequency range of their songs. Fernandez-Juricic *et al*. (2005) reported that house finches (*Carpodacus mexicanus*) adopted the same strategy to compensate for background noise.

Although this form of vocal adjustment has not been studied extensively in marine animals, Dahlheim (1987) studied the effects of man-made noise, including ship, outboard engine and oil-drilling sounds, on gray whale calling and surface behaviours in the San Ignacio Lagoon, Baja, California. She reported statistically significant increases in the calling rates of gray whales and changes in calling structure (as well as swimming direction and surface behaviours) after exposure to increased noise levels during playback experiments. Although whale responses varied with the type and presentation of the noise source, she reported that gray whales generally increased their calling rates, the level of calls received, the number of frequency-modulated calls, number of pulses produced per pulsed-call series and call repetition rate as noise levels increased.

Park and Tyack (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.

FITNESS CONSEQUENCES OF VOCAL ADJUSTMENTS. Although the fitness consequences of these vocal adjustments remain unknown, like most other trade-offs animals must make, some of these strategies probably come at a cost (Patricelli *et al*. 2006). For example, vocalizing more loudly in noisy environments may have energetic costs that decrease the net benefits of vocal adjustment and alter the bird's energy budget (Brumm 2004, Wood and Yezerinac 2006). Lambrechts (1996) argued that shifting songs and calls to higher frequencies was also likely to incur energetic costs.

In addition, Patricelli *et al*. (2006) argued that females of many species use the songs and calls of males to determine whether a male is an appropriate potential mate (that is, the must recognize the singer as a member of their species); if males must adjust the frequency or temporal features of their vocalizations to avoid masking by noise, they may no longer be recognized by conspecific females (Brumm 2004, Slabbekoorn and Peet 2003, Wood and Yezerinac 2006). Although this line of reasoning was developed for bird species, the same line of reasoning should apply to marine mammals, particularly for species like fin and sei whales whose song structures appear to be very similar.

However, if an animal fails to make vocal adjustments in presence of masking noise, that failure might cause the animal to experience reduced reproductive success or longevity because it fails to communicate effectively with other members of its species or social group, including potential mates.

Based on the evidence available, endangered sperm whales may experience impaired communication because they vocalize at frequencies that overlap with those of the high- and mid-frequency active sonar systems the U.S. Navy plans to employ during the military readiness activities the U.S. Navy plans to conduct on the Mariana Islands Range Complex. As a result, we assume that some of the sperm whales that are exposed to active sonar transmissions during one or more of the proposed missions might experience impaired communication as a result of that exposure. To preserve the saliency of their vocalizations, these whales may have to make one or more of the vocal adjustments discussed in this subsection. Because any reductions in the active space of whale vocalizations that result from active sonar transmissions associated with the proposed missions would be temporary and episodic, vocal adjustments these whales would have to make would also be temporary.

Because the endangered and threatened sea turtles that are considered in this Opinion do not appear to vocalize, they are not likely to experience impaired communication by active sonar transmissions associated with the proposed training activities the U.S. Navy proposes to conduct.

MASKING. Marine mammals use acoustic signals for a variety of purposes, which differ among species, but include communication between individuals, navigation, foraging, reproduction, and learning about their environment (Erbe and Farmer 2000, Tyack 2000). Masking, or *auditory interference*, generally occurs when sounds in an animal's environment are louder than and of a similar frequency to, acoustic signals on which the animal is trying to focus. Masking can occur (1) when a competing sounds reduce or eliminate the salience of the acoustic signal or cue on which the animal is trying to focus or (2) when the spectral characteristics of a competing sounds reduce or eliminate the coherence of acoustic signal or on which the animal is trying to focus. In the former, the masking noise might prevent a focal signal from being salient to an animal; in the latter, the masking noise might prevent a focal signal from being coherent to an animal. 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. Masking these acoustic signals can disturb the behavior of individual animals, groups of animals, or entire populations (Box BR2 of Figure 11 illustrates the potential responses of animals to acoustic masking).

Richardson *et al*. (1995b) argued that the maximum radius of influence of an industrial noise (including broadband low frequency sound transmission) on a marine mammal is the distance from the source to the point at which the noise can barely be heard. This range is determined by either the hearing sensitivity of the animal or the background noise level present. Industrial masking is most likely to affect some species' ability to detect communication calls and natural sounds (i.e., vocalizations from other members of its species, surf noise, prey noise, etc.; Richardson *et al*. 1995).

Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses produced by echosounders and submarine sonar (Watkins and Schevill 1975; Watkins *et al.* 1985). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995). Sperm whales have moved out of areas after the start of air gun seismic testing (Davis *et al.* 1995). Seismic air guns produce loud, broadband, impulsive noise (source levels are 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*.

(1974, 1985, 1993) indicate that some species may use various processes to reduce masking effects (e.g., adjustments in echolocation call intensity or frequency as a function of background noise conditions). There is also evidence that the directional hearing abilities of odontocetes are useful in reducing masking at the high frequencies these cetaceans use to echolocate, but not at the low-to-moderate frequencies they use to communication (Zaitseva *et al*. 1980).

Based on the evidence available, endangered sperm whales might experience acoustic masking because they are high-frequency hearing specialists who attend to environmental cues at frequencies that overlap with those produced by high- or mid-frequency active sonar transmissions. The evidence available leads us to the opposite conclusion for sea turtles because their hearing sensitivities do not overlap with the high- and mid-frequency range of the active sonar the U.S. Navy plans to employ at the Naval Surface Warfare Center so those transmissions are not likely to mask sea turtle hearing.

5.3.3.4 Allostasis

Classic stress responses begin when an animal's central nervous system perceives a potential threat to its homeostasis. That perception triggers stress responses regardless of whether a stimulus actually threatens the animal; the mere perception of a threat is sufficient to trigger a stress response (Moberg 2000, Sapolsky *et al*. 2005, Seyle 1950). Once an animal's central nervous system perceives a threat, it mounts a biological response or defense that consists of a combination of the four general biological defense responses: behavioral responses, autonomic nervous system responses, neuroendocrine responses, or immune response.

In the case of many stressors, an animal's first and most economical (in terms of biotic costs) response is behavioral avoidance of the potential stressor or avoidance of continued exposure to a stressor (Box S! of Figure 11). An animal's second line of defense to stressors involves the autonomic nervous system and the classical "fight or flight" response which includes the cardiovascular system, the gastrointestinal system, the exocrine glands, and the adrenal medulla to produce changes in heart rate, blood pressure, and gastrointestinal activity that humans commonly associate with "stress." These responses have a relatively short duration and may or may not have significant long-term effect on an animal's welfare.

An animal's third line of defense to stressors involves its neuroendocrine or sympathetic nervous systems; the system that has received the most study has been the hypothalmus-pituitary-adrenal system (also known as the HPA axis in mammals or the hypothalamus-pituitary-interrenal axis in fish and some reptiles). Unlike stress responses associated with the autonomic nervous system, virtually all neuroendocrine functions that are affected by stress – including immune competence, reproduction, metabolism, and behavior – are regulated by pituitary hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Moberg 1987, Rivier 1995, Box S2 of Figure 11) and altered metabolism (Elasser *et al*. 2000), reduced immune competence (Blecha 2000) and behavioral disturbance. Increases in the circulation of glucocorticosteroids (cortisol, corticosterone, and aldosterone in marine mammals; see Romano *et al*. 2004) have been equated with stress for many years.

The primary distinction between *stress* (which is adaptive and does not normally place an animal at risk) and *distress* is the biotic cost of the response. During a stress response, an animal uses glycogen stores that can be quickly replenished once the stress is alleviated. In such circumstances, the cost of the stress response would not pose a risk to the animal's welfare. However, when an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other biotic functions which impairs those functions that experience the diversion. For example, when mounting a stress response diverts energy away from growth in young animals, those animals may experience stunted growth. When mounting a stress response diversts energy from a fetus, an animal's reproductive success and its fitness will suffer. In these cases, the animals will have entered a pre-pathological or pathological state which is called "distress" (*sensu* Seyle 1950) or "allostatic loading" (*sensu* McEwen and Wingfield 2003). This pathological state will last until the animal replenishes its biotic reserves sufficient to restore normal function.

Relationships between these physiological mechanisms, animal behavior, and the costs of stress responses have also been documented fairly well through controlled experiment; because this physiology exists in every vertebrate that has been studied, it is not surprising that stress responses and their costs have been documented in both laboratory and free-living animals (for examples see, Holberton *et al*. 1996, Hood *et al*. 1998, Jessop *et al*. 2003, Krausman *et al*. 2004, Lankford *et al*. 2005, Reneerkens *et al*. 2002, Thompson and Hamer 2000). Although no information has been collected on the physiological responses of marine mammals upon exposure to anthropogenic sounds, studies of other marine animals and terrestrial animals would lead us to expect some marine mammals to experience physiological stress responses and, perhaps, physiological responses that would be classified as "distress" upon exposure to mid-frequency and low-frequency sounds.

For example, Jansen (1998) reported on the relationship between acoustic exposures and physiological responses that are indicative of stress responses in humans (for example, elevated respiration and increased heart rates). Jones (1998) reported on reductions in human performance when faced with acute, repetitive exposures to acoustic disturbance. Trimper *et al*. (1998) reported on the physiological stress responses of osprey to low-level aircraft noise while Krausman *et al*. (2004) reported on the auditory and physiology stress responses of endangered Sonoran pronghorn to military overflights. Smith *et al*. (2004a, 2004b) identified noise-induced physiological stress responses in hearing-specialist fish that accompanied short- (TTS) and long-term (PTS) hearing losses. Welch and Welch (1970), reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Hearing is one of the primary senses cetaceans use to gather information about their environment and to communicate with other members of their species. Although empirical information on the relationship between sensory impairment (TTS, PTS, and acoustic masking) on cetaceans remains limited, it seems reasonable to assume that reducing an animal's ability to gather information about its environment and to communicate with other members of its species would be stressful for animals that use hearing as their primary sensory mechanism. Therefore, we assume that acoustic exposures sufficient to trigger onset PTS or TTS would be accompanied by physiological stress responses because terrestrial animals exhibit those responses under similar conditions (NRC 2003). More importantly, marine mammals might experience stress responses at received levels lower than those necessary to trigger onset TTS. Based on empirical studies of the time required to recover from stress responses (Moberg 2000), we also assume that stress responses are likely to persist beyond the time interval required for animals to recover from TTS and might result in pathological and pre-pathological states that would be as significant as behavioral responses to TTS.

5.3.3.5 Stranding Events

In what follows, we address the evidence bearing on assertions from several NGOs and scientific investigator that low-frequency active sonar causes marine mammals to "strand." Some authors seemed to have contradicted themselves by first publishing articles that initially identified low frequency active sonar as the "cause" of marine mammal stranding events in the Canary Islands and the Mediterranean Sea, then later publishing articles that identify mid-frequency active sonar as the "cause" of those stranding events after the Bahamas stranding report became available. These causal claims are incoherent: the beaked whale stranding events had a causal association with either low frequency active sonar, mid-frequency active sonar, a combination of the two, or neither of the two. The earlier claims (for example, Frantis 1998) asserting low-frequency active sonar as causal are not compatible with the revised claims of a causal relationship between the stranding events and mid-frequency active sonar. As of the date of this Opinion, none of these authors have published retractions, corrections, or clarifications of their published arguments on whether they believe exposure to low-frequency active sonar, mid-frequency active sonar, or both, caused the stranding events or was a contributing cause of those events.

Despite the small number of instances in which marine mammal stranding events have been associated with mid-frequency active sonar usage and despite the fact that none of these stranding events involved endangered or threatened species, the amount of controversy that surrounds this issue requires us to address it. For these analyses, we defined a "stranded marine mammal" as "any dead marine mammal on a beach or floating nearshore; any live cetacean on a beach or in water so shallow that it is unable to free itself and resume normal activity; any live pinniped which is unable or unwilling to leave the shore because of injury or poor health" (Gulland *et al.* 2001, Wilkinson 1991).

Marine mammals are known to strand for a variety of reasons, although the cause or causes of most stranding are unknown (Geraci *et al.* 1976, Eaton 1979, Odell *et al.* 1980, Best 1982). Klinowska (1985, 1986) correlated marine mammal stranding events and geomagnetism and geomagnetic disturbance. Numerous other studies suggest that the physiology, behavior, habitat relationships, age, or condition of cetaceans may cause them to strand or might pre-dispose them the strand when exposed to another phenomenon. For example, several studies of stranded marine mammals suggest a linkage between unusual mortality events and body burdens of toxic chemicals in the stranded animals (Kajiwara *et al.* 2002, Kuehl and Haebler 1995, Mignucci-Giannoni *et al.* 2000). These suggestions are consistent with the conclusions of numerous other studies that have demonstrated that combinations of dissimilar stressors commonly combine to kill an animal or dramatically reduce its fitness, even though one exposure without the other does not produce the same result (Chroussos 2000, Creel 2005, DeVries *et al.* 2003, Fair and Becker 2000, Foley *et al.* 2001, Moberg 2000, Relyea 2005a, 2005b, Romero 2004, Sih *et al.* 2004).

Those studies suggest that, in many animal species, disease, reproductive state, age, experience, stress loading, energy reserves, and genetics combine with other stressors like body burdens of toxic chemicals to create fitness consequences in individual animals that would not occur without these risk factors. The contribution of these potential risk factors to stranding events (or causal relationships between these risk factors and stranding events) is still unknown, but the extensive number of published reports in the literature suggests that an experiment investigation into a causal relationship is warranted

Over the past three decades, several "mass stranding" events — stranding events that involve two or more individuals of the same species (excluding a single cow-calf pair) — that have occurred over the past two decades have been associated with naval operations, seismic surveys, and other anthropogenic activities that introduce sound into the marine environment.

Although only one of these events involved threatened or endangered species, we analyzed the information available on stranding events to determine if listed cetaceans are likely to strand following an exposure to mid-frequency active sonar. To conduct these analyses, we searched for and collected any reports of mass stranding events of marine mammals and identified any causal agents that were associated with those stranding events.

Global Stranding Patterns

Several sources have published lists of mass stranding events of cetaceans during attempts to identify relationships between those stranding events and military sonar (Hildebrand 2004, IWC 2005, Taylor *et al.* 2004). For example, based on a review of stranding records between 1960 and 1995, the International Whaling Commission (2005) identified ten mass stranding events of Cuvier's beaked whales had been reported and one mass stranding of four Baird's beaked whale (*Berardius bairdii*). The IWC concluded that, out of eight stranding events reported from the mid-1980s to the summer of 2003, seven had been associated with the use of mid-frequency sonar, one of those seven had been associated with the use of low-frequency sonar, and the remaining stranding event had been associated with the use of seismic airguns.

Taxonomic Patterns

Most of the stranding events reviewed by the International Whaling Commission involved beaked whales. A mass stranding of Cuvier's beaked whales (*Ziphius cavirostris*) in the eastern Mediterranean Sea occurred in 1996 (Franzis 1998) and mass stranding events involving Gervais' beaked whales (*Mesoplodon europaeus*), de Blainville's dense-beaked whales (*M. densirostris*), and Cuvier's beaked whales occurred off the coast of the Canary Islands in the late 1980s (Simmonds and Lopez-Jurado 1991). Other stranding events of beaked whales have also occurred in the Bahamas and Canary Islands (which included Gervais' beaked whales, *Mesoplodon europaeus*, de Blainville's dense-beaked whales, *M. densirostris*, and Cuvier's beaked whales; Simmonds and Lopez-Jurado 1991). The stranding events that occurred in the Canary Islands and Kyparissiakos Gulf in the late 1990s and the Bahamas in 2000 have been the most intensively-studied mass stranding events and have been associated with naval maneuvers that were using sonar. These investigations did not evaluate information associated with the stranding of Cuvier's beaked whales, *Ziphius cavirostris*, around Japan (IWC Scientific Committee 2005).

Between 1960 and 2006, 48 (68%) involved beaked whales, 3 (4%) involved dolphins, and 14 (20%) involved whale species. Cuvier's beaked whales were involved in the greatest number of these events (48 or 68%), followed by sperm whales (7 or 10%), and Blainville and Gervais' beaked whales (4 each or 6%). Naval activities that might have involved active sonar are reported to have coincided with 9 (13%) or 10 (14%) of those stranding events. Between the mid-1980s and 2003 (the period reported by the International Whaling Commission), we identified reports of 44 mass cetacean stranding events of which at least 7 have been correlated with naval exercises that were using mid-frequency sonar.

Stranding events involving baleen whales (blue, bowhead, Bryde's, fin, gray, humpback, minke, right, and sei whales) and stranding events involving sperm whales have very different patterns than those of beaked whales and other smaller cetaceans. First, mass stranding events of baleen whales are very rare. Fourteen humpback whales stranded on the beaches of Cape Cod, Massachusetts between November 1987 and January 1988 (Geraci *et al.* 1989); however, that stranding event has been accepted as being caused by neurotoxins in the food of the whales. In 1993, three humpback whales stranded on the east coast of Sao Vincente Island in the Cape Verde Archipelago, but they were in an advanced state of decay when they stranded so their cause of death remains unknown (Reiner *et al.* 1996). Finally, two minke whales (*Balaenoptera acutirostra*) stranded during the mass stranding event in the Bahamas in 2000 (see further discussion of this stranding event below) and is noteworthy because it the only mass stranding of baleen whales that has coincided with the Navy's use of mid-frequency active sonar and because there are so few mass stranding events involving baleen whales.

Sperm whales, however, commonly strand and commonly strand in groups. Our earliest record of a mass stranding of sperm whales is for six sperm whales that stranded in Belgium in 1403 or 1404 (De Smet 1997). Since then, we have identified 85 mass stranding events involving sperm whales have been reported. Of those 85 mass stranding events, 29 represent stranding events that occurred before 1958; 25 of those 29 (about 34%) stranding events occurred before 1945 (which would pre-date the use of this mid-frequency active sonar). Ten of these stranding events involved sperm whales and long-finned pilot whales (*Globicephala melas*). These mass stranding events have been reported in Australia, Europe, North America, Oceania, and South America.

Major Mass Stranding Events

In 1998, the North Atlantic Treaty Organization (NATO) Supreme Allied Commander, Atlantic Center Undersea Research Centre that conducted the sonar tests convened panels to review the data associated with the maneuvers in 1996 and beaked whale stranding events in the Mediterranean Sea. The report of these panels presented more detailed acoustic data than were available for beaked whales stranded in the Canary Islands (SACLANTCEN 1998). The NATO sonar transmitted two simultaneous signals lasting four seconds and repeating once every minute.

The simultaneous signals were broadcast at source levels of just under 230 dB re 1 µPa at 1 m. One of the signals covered a frequency range from 450-700 Hz and the other one covered 2.8-3.3 kHz. The *Ziphius* stranding events in the Kyparissiakos Gulf occurred during the first two sonar runs on each day of 12 and 13 May 1996. The close timing between the onset of sonar transmissions and the first stranding events suggests closer synchrony between the onset of the transmissions and the stranding events than was presented in Frantzis (1998). However, the Bioacoustics Panel convened by NATO concluded that the evidence available did not allow them to accept or reject sonar exposures as a causal agent in these stranding events. Their official finding was "An acoustic link can neither be clearly established nor eliminated as a direct or indirect cause for the May 1996 strandings."

KYPARISSIAKOS GULF, GREECE (1996). Frantzis (1998) reported an 'atypical' mass stranding of 12 Cuvier's beaked whales on the coast of Greece that was associated with acoustic trials by vessels from the North Atlantic Treaty Organisation (NATO). He was the first to hypothesize that these stranding events were related to exposure to low-frequency military sonar. However, the sonar in question produced both low- and mid-frequency signals (600Hz, 228 dB SPL re: 1µPa at 1m rms and 3kHz, 226 dB SPL, D'Amico and Verboom, 1998). Frantzis' hypothesis prompted an in-depth analysis of the acoustic activity during the naval exercises, the nature of the stranding events and the possibility that the acoustic source was related to the stranding events (D'Amico and Verboom, 1998). Since full necropsies had not been conducted and no gross or histological abnormalities were noted, the cause of the stranding events could not be determined unequivocally (D'Amico and Verboom, 1998). The analyses thus provided some support but no clear evidence for the hypothesized cause-and-effect relationship of sonar operations and stranding events.

BAHAMAS (2000). Concern about potential causal relationships between low-frequency sonar and marine mammal stranding resurfaced after a beaked whale stranding in the Bahamas in 2000. Fox *et al.* (2001) ruled out natural sound sources as a possible cause of the stranding, which pointed to an anthropogenic source. In 2001, the *Joint Interim Report, Bahamas Marine Mammal Stranding Event of 14-16 March 2000* (U.S. Department of Commerce and Secretary of the Navy 2001) exonerated the low-frequency sonar but concluded that "tactical mid-range frequency sonar onboard U.S. Navy ships that were in use during the sonar exercise in question were the most plausible source of this acoustic or impulse trauma." The report also went on to conclude, "the cause of this stranding event was the confluence of Navy tactical mid-range frequency sonar and the contributory factors acting together." The contributory factors identified included "a complex acoustic environment that included the presence of a strong surface duct, unusual underwater bathymetry, intensive use of multiple sonar over an extended period of time, a constricted channel with limited access, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars."

MADEIRA, SPAIN (2000). The stranding in the Bahamas was soon followed by another atypical mass stranding of Cuvier's beaked whales in the Madeira Islands. Between 10 and 14 May 2000, three Cuvier's beaked whales stranded on two islands in the Madeira archipelago. NATO naval exercises involving multiple ships occurred concurrently with these stranding events, although NATO has thus far been unwilling to provide information on the sonar activity during their exercises. Only one of the stranded animals was marginally fresh enough for a full necropsy (24 hours post-stranding). The necropsy revealed evidence of haemorrhage and congestion in the right lung and both kidneys (Freitas, 2004), as well as evidence of intracochlear and intracranial haemorrhage similar to that observed in the Bahamas beaked whales (D. Ketten, unpublished data).

CANARY ISLANDS (2002). In September 2002, a beaked whale stranding event occurred in the Canary Islands. On 24 September, 14 beaked whales (7 Cuvier's beaked whales, 3 Blainville's beaked whales, 1 Gervais' beaked whale, *M. europeaus*, and 3 unidentified beaked whales) stranded on the beaches of Fuerteventura and Lanzarote Islands, close to the site of an international naval exercise (called Neo-Tapon 2002) held that same day. The first animals are reported to have stranded about four hours after the onset of the use of mid-frequency sonar activity (3- 10kHz, D'Spain *et al.* 2006; Jepson *et al.* 2003). Seven whales (1 female Blainville's beaked whale, 1 female Gervais' beaked whale and 5 male Cuvier's beaked whales) are known to have died that day (Fernández *et al.* 2005). The remaining seven live whales were returned to deeper waters. Over the next three days, three male and one female Cuvier's beaked whales were found dead and a carcass of an unidentified beaked whale was seen floating offshore.

A total of nine Cuvier's beaked whales, one Blainville's beaked whale and one Gervais' beaked whale were examined post mortem and studied histopathologically (one Cuvier's beaked whale carcass was lost to the tide). No inflammatory or neoplastic processes were noted grossly or histologically and no pathogens (e.g. protozoa, bacteria and viruses, including morbillivirus) were identified. Stomach contents were examined in seven animals and six of them had recently eaten, possibly indicating that the event(s) leading to their deaths had had a relatively sudden onset (Fernández *et al.* 2005). Macroscopic examination revealed that the whales had severe, diffuse congestion and haemorrhages, especially in the fat in the jaw, around the ears, in the brain (e.g. multifocal subarachnoid haemorrhages) and in the kidneys (Fernandez, 2004; Fernandez *et al.* 2004). Gas bubble-associated lesions were observed in the vessels and parenchyma (white matter) of the brain, lungs, subcapsular kidney veins and liver; fat emboli were observed in epidural veins, liver sinusoids, lymph nodes and lungs (Jepson *et al.* 2003; Fernandez, 2004; Fernandez *et al.* 2004; 2005). After the event, researchers from the Canary Islands examined past stranding records and found reports of eight other stranding events of beaked whales in the Canaries since 1985, at least five of which coincided with naval activities offshore (Martín *et al.* 2004).

GULF OF CALIFORNIA (2002). In September 2002, marine mammal researchers vacationing in the Gulf of California, Mexico discovered two recently deceased Cuvier's beaked whales on an uninhabited island. They were not equipped to conduct necropsies and in an attempt to contact local researchers, found that a research vessel had been conducting seismic surveys approximately 22km offshore at the time that the stranding events occurred (Taylor *et al.* 2004). The survey vessel was using three acoustic sources: (1) seismic air guns (5-500Hz, 259dB re: 1mPa Peak to Peak (p-p); Federal Register, 2003); (2) sub-bottom profiler (3.5kHz, 200dB SPL; Federal Register, 2004); and (3) multi-beam sonar (15.5kHz, 237dB SPL; Federal Register, 2003). Whether or not this survey caused the beaked whales to strand has been a matter of debate because of the small number of animals involved and a lack of knowledge regarding the temporal and spatial correlation between the animals and the sound source. This stranding underlines the uncertainty regarding which sound sources or combinations of sound sources may cause beaked whales to strand. Although some of these stranding events have been reviewed in government reports or conference proceedings (e.g. Anonymous 2001, Evans and Miller 2004), many questions remain. Specifically, the mechanisms by which beaked whales are affected by sound remain unknown. A better understanding of these mechanisms will facilitate management and mitigation of sound effects on beaked whales.

HANALEI BAY, KAUA'I, HAWAI'I (2004). On 3 – 4 July 2004, between 150 and 200 melon-headed whales (*Peponocephala electra*) occupied the shallow waters of Hanalei Bay, Kaua'i, Hawai'i for over 28 hours. These whales, which are usually pelagic, milled in the shallow confined bay and were returned to deeper water with human assistance. The whales are reported to have entered the Bay in a single wave formation on July 3, 2004, and were observed moving back into shore from the mouth of the Bay shortly thereafter. On the next morning, the whales were herded out of the Bay with the help of members of the community, the Hanalei Canoe Club, local and Federal employees, and staff and volunteers with the Hawai'ian Islands Stranding Response Group and were out of visual sight later that morning.

One whale, a calf, had been observed alive and alone in Hanalei Bay on the afternoon of 4 July 2004 and was found dead in the Bay the morning of 5 July 2004. A full necropsy performed on the calf could not determine the cause of its death, although the investigators concluded that maternal separation, poor nutritional condition, and dehydration was probably a contributing factor in the animal's death.

Environmental factors, abiotic and biotic, were analyzed for any anomalous occurrences that would have contributed to the animals entering and remaining in Hanalei Bay. The bathymetry in the bay is similar to many other sites in the Hawai'ian Island chain and dissimilar to that which has been associated with mass stranding events in other parts of the U.S. The weather conditions appeared to be normal for the time of year with no fronts or other significant features noted. There was no evidence for unusual distribution or occurrence of predator or prey species or unusual harmful algal blooms. Weather patterns and bathymetry that have been associated with mass stranding events elsewhere were not found to occur in this instance.

This stranding event was spatially and temporally correlated with 2004 Rim of the Pacific exercises. Official sonar training and tracking exercises in the Pacific Missile Range Facility warning area did not commence until about 0800 hrs (local time) on 3 July and were ruled out as a possible trigger for the initial movement into Hanalei Bay. However, the six naval surface vessels transiting to the operational area on 2 July had been intermittently transmitting active mid-frequency sonar [for ~9 hours total] as they approached from the south. After ruling out other phenomena that might have caused this stranding, NMFS concluded that the active sonar transmissions associated with the 2004 Rim of the Pacific exercise were a plausible contributing causal factor in what may have been a confluence of events. Other factors that may have contributed to the stranding event include the presence of nearby deep water, multiple vessels transiting in a directed manner while transmitting active sonar over a sustained period, the presence of surface sound ducting conditions, or intermittent and random human interactions while the animals were in the Bay.

OTHER MASS STRANDING EVENTS. Several unusual stranding events have also occurred in Chinese waters in 2004 during a period when large-scale naval exercises were taking place in nearby waters south of Taiwan (IWC 2005). Between 24 February and 10 March 2004, 9-10 short-finned pilot whales (*Globicephala macrorhynchus*), one ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*), one striped dolphin (*Stenella coeruleoalba*), seven short-finned pilot whales, and one short-finned pilot whale were reported to have stranded. The stranding events were unusual (with respect to the species involved) compared to previous stranding records since 1994 for the region. Gross examination of the only available carcass, a ginkgo-toothed beaked whale, revealed many unusual injuries to structures that are associated with, or related to acoustics or diving. The injuries, the freshness of the carcass, its discovery location and the coincidence of the event with a military exercise suggest that this beaked whale died from acoustic or blast trauma that may have been caused by exposure to naval activities south of Taiwan. Taiwanese newspapers reported that live ammunition was used during these exercises. At the same time, natural phenomena that might cause whales to strand – such as earthquakes and underwater volcanoes – have not been ruled out in these cases.

Association Between Mass Stranding Events and Exposure to Active Sonar

Several authors have noted similarities between some of these stranding incidents: they occurred in islands or archipelagoes with deep water nearby, several appeared to have been associated with acoustic waveguides like surface ducting, and the sound fields created by ships transmitting mid-frequency sonar (Cox *et al.* 2006, D'Spain *et al.* 2006). Although Cuvier's beaked whales have been the most common species involved in these stranding events (81 percent of the total number of stranded animals), other beaked whales (including *Mesoplodon europeaus*, *M. densirostris*, and *Hyperoodon ampullatus*) comprise 14% of the total. Other species (*Stenella coeruleoalba*, *Kogia* *breviceps* and *Balaenoptera acutorostrata*) have stranded, but in much lower numbers and less consistently than beaked whales.

Based on the evidence available, however, we cannot determine whether (a) *Ziphius cavirostris* is more prone to injury from high-intensity sound than other species, (b) their behavioral responses to sound makes them more likely to strand, or (c) they are more likely to be exposed to mid-frequency active sonar that other cetaceans (for reasons that remain unknown). Because the association between active sonar exposures and marine mammals mass stranding events is not consistent — some marine mammals strand without being exposed to sonar and some sonar transmissions are not associated with marine mammal stranding events despite their co-occurrence — other risk factors or a groupings of risk factors probably contribute to these stranding events.

5.3.6. Responses to Vessel 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 Green 2004; Lusseau 2006). However, several authors suggest that the noise generated during motion is probably an important factor (Blane and Jackson 1994, Evans *et al.* 1992, 1994). These studies suggest that the behavioral responses of marine mammals to surface vessels is similar to their behavioral responses to predators.

As we discussed previously, based on the suite of studies of cetacean behavior to vessel approaches (Au and Green 1990, Au and Perryman 1982, Bain *et al.* 2006, Bauer 1986, Bejder 1999, 2006a, 2006b; Bryant *et al.* 1984, Corkeron 1995, David 2002, Erbé 2000, Félix 2001, Magalhães *et al.* 2002, Goodwin and Cotton 2004, Hewitt 1985, Lusseau 2003, 2006; Lusseau and Bejder 2007, Ng and Leung 2003, Nowacek *et al.* 2001, Richter *et al.* 2003, 2006; Scheidat *et al.* 2004, Simmonds 2005, Watkins 1986, Williams and Ashe 2007, Williams *et al.* 2002, 2006a, 2006b; Würsig *et al.* 1998), the set of variables that help determine whether marine mammals are likely to be disturbed by surface vessels include:

1. *number of vessels*. The behavioral repertoire marine mammals have used to avoid interactions with surface vessels appears to depend on the number of vessels in their perceptual field (the area within which animals detect acoustic, visual, or other cues) and the animal's assessment of the risks associated with those vessels (the primary index of risk is probably vessel proximity relative to the animal's flight initiation distance).

   Below a threshold number of vessels (which probably varies from one species to another, although groups of marine mammals probably share sets of patterns), studies have shown that whales will attempt to avoid an interaction using horizontal avoidance behavior[7]. Above that threshold, studies have shown that marine

7 As discussed in the *Approach to the Assessment* section of this Opinion, we distinguish between "avoidance," "evasion," and "escape" using the distinctions proposed by Weihs and Webb (1984): "avoidance" is a shift in position by prey before a potential predator begins an attack; "evasion" is a response by potential prey to a perceived attack from a potential predator; and "escape" is the most acute form of evasive behavior.

mammals will tend to avoid interactions using vertical avoidance behavior, although some marine mammals will combine horizontal avoidance behavior with vertical avoidance behavior (Bryant *et al.* 1984, Cope *et al.* 2000, David 2002, Lusseau 2003, Kruse 1991, Nowacek *et al.* 2001, Stensland and Berggren 2007, Williams and Ashe 2007);

2. *the distance between vessel and marine mammals* when the animal perceives that an approach has started and during the course of the interaction (Au and Perryman 1982, David 2002, Hewitt 1985, Kruse 1991);

3. *the vessel's speed and vector* (David 2002);

4. *the predictability of the vessel's path*. That is, cetaceans are more likely to respond to approaching vessels when vessels stay on a single or predictable path (Acevedo 1991, Angradi *et al.* 1993; Browning and Harland 1999; Lusseau 2003, 2006; Williams *et al.* 2002, 2006a, 2006b) than when it engages in frequent course changes (Evans *et al. 1*994, Lusseau 2006, Williams *et al.* 2002)

6. *noise associated with the vessel* (particularly engine noise) and the rate at which the engine noise increases (which the animal may treat as evidence of the vessel's speed; David 2002, Lusseau 2003, 2006);

7. *the type of vessel* (displacement versus planing), which marine mammals may be interpret as evidence of a vessel's maneuverability (Goodwin and Cotton 2004);

8. the behavioral state of the marine mammals (David 2002, Lusseau 2003, 2006; Würsig *et al.* 1998). For example, Würsig *et al.* (1998) concluded that whales were more likely to engage in avoidance responses when the whales were "milling" or "resting" than during other behavioral states.

Most of the investigations cited earlier reported that animals tended to reduce their visibility at the water's surface and move horizontally away from the source of disturbance or adopt erratic swimming strategies (Corkeron 1995, Lusseau 2003, Lusseau 2004, 2005*a*; Notarbartolo di Sciara *et al.* 1996, Nowacek *et al.* 2001, Van Parijs and Corkeron 2001, Williams *et al.* 2002). In the process, their dive times increased, vocalizations and jumping were reduced (with the exception of beaked whales), individuals in groups move closer together, swimming speeds increased, and their direction of travel took them away from the source of disturbance (Edds and Macfarlane 1987, Baker and Herman 1989, Kruse 1991, Polacheck and Thorpe 1990, Evans *et al. 1*992, Lütkebohle 1996, Nowacek *et al. 1*999). Some individuals also dove and remained motionless, waiting until the vessel moved past their location. Most animals finding themselves in confined spaces, such as shallow bays, during vessel approaches tended to move towards more open, deeper waters (Stewart *et al.* 1982, Kruse 1991). We assume that this movement would give them greater opportunities to avoid or evade vessels as conditions warranted.

Although most of these studies focused on small cetaceans (for example, bottlenose dolphins, spinner dolphins, spotted dolphins, harbor porpoises, beluga whales, and killer whales), studies of large whales have reported similar results for fin and sperm whales (David 2002, Notarbartolo di Sciara *et al.* 1996, 2002). Baker *et al.* (1983) reported that humpbacks in Hawai'i responded to vessels at distances of 2 to 4 km. Richardson *et al.* (1985) reported that bowhead whales (*Balaena mysticetus*) swam in the opposite direction of approaching seismic vessels at distances between 1 and 4 km and engage in evasive behavior at distances under 1 km. Fin whales also responded to vessels at a distances of about 1 km (Edds and Macfarlane 1987).

Some cetaceans detect the approach of vessels at substantial distances. Finley *et al.* (1990) reported that beluga whales seemed aware of approaching vessels at distances of 85 km and began to avoid the approach at distances of 45-60 km. Au and Perryman (1982) studied the behavioral responses of eight schools of spotted and spinner dolphins (*Stenella attenuata* and *S. longirostris*) to an approaching ship (the NOAA vessel *Surveyor*: 91.4 meters, steam-powered, moving at speeds between 11 and 13 knots) in the eastern Pacific Ocean (10°15 N lat., 109°10 W long.). They monitored the response of the dolphin schools to the vessel from a Bell 204 helicopter flying a track line ahead of the ship at an altitude of 366 – 549 meters (they also monitored the effect of the helicopter on dolphin movements and concluded that it had no observable effect on the behavior of the dolphin schools). All of the schools continuously adjusted their direction of swimming by small increments to continuously increase the distance between the school and the ship over time. The animals in the eight schools began to flee from the ship at distances ranging from 0.9 to 6.9 nm. When the ship turned toward a school, the individuals in the school increased their swimming speeds (for example, from 2.8 to 8.4 knots) and engaged in sharp changes in direction.

Hewitt (1985) reported that five of 15 schools of dolphin responded to the approach of one of two ships used in his study and none of four schools of dolphin responded to the approach of the second ship (the first ship was the NOAA vessel *David Jordan Starr*; the second ship was the *Surveyor*).Spotted dolphin and spinner dolphins responded at distances between 0.5 to 2.5 nm and maintained distances of 0.5 to 2.0 nm from the ship while striped dolphins allows much closer approaches. Lemon *et al.*(2006) reported that bottlenose dolphin began to avoid approaching vessels at distances of about 100 m.

Würsig *et al.* (1998) studied the behavior of cetaceans in the northern Gulf of Mexico in response to survey vessels and aircraft. They reported that *Kogia* species and beaked whales (ziphiids) showed the strongest avoidance reactions to approaching ships (avoidance reactions in 11 of 13 approaches) while spinner dolphins, Atlantic spotted dolphins, bottlenose dolphins, false killer whales, and killer whales either did not respond or approached the ship (most commonly to ride the bow). Four of 15 sperm whales avoided the ship while the remainder appeared to ignore its approach.

Because of the number of vessels involved in U.S. Navy training exercises, their speed, their use of course changes as a tactical measure, and sounds associated with their engines and displacement of water along their bowline, the available evidence leads us to expect marine mammals to treat Navy vessels as potential stressors. Animals that perceive an approaching potential predator, predatory stimulus, or disturbance stimulus have four behavioral options (see Blumstein 2003 and Nonacs and Dill 1990):

a. ignore the disturbance stimulus entirely and continue behaving as if a risk of predation did not exist;

b. alter their behavior in ways that minimize their perceived risk of predation, which generally involves fleeing immediately;

c. change their behavior proportional to increases in their perceived risk of predation which requires them to monitor the behavior of the predator or predatory stimulus while they continue their current activity, or

d. take proportionally greater risks of predation in situations in which they perceive a high gain and proportionally lower risks where gain is lower, which also requires them to monitor the behavior of the predator or disturbance stimulus while they continue their current activity.

The latter two options are energetically costly and reduce benefits associated with the animal's current behavioral state. As a result, animals that detect a predator or predatory stimulus at a greater distance are more likely to flee at a greater distance (see Holmes *et al.* 1993, Lord *et al.* 2001). Some investigators have argued that short-term avoidance reactions can lead to longer term impacts such as causing marine mammals to avoid an area (Salden 1988, Lusseau 2005) or alter a population's behavioral budget (Lusseau 2004) which could have biologically significant consequences on the energetic budget and reproductive output of individuals and their populations.

Of the endangered and threatened species that occur in the Action Area for this consultation, the endangered and threatened sea turtles are most likely to ignore U.S. Navy vessels entirely and continue behaving as if the vessels and any risks associated with those vessels did not exist. Sperm whales might engage in any one of these options.

RESPONSES TO DISTURBANCE ASSOCIATED WITH AIRCRAFT. There are few studies of the responses of marine animals to air traffic (there are no studies of the responses of sea turtles to this traffic) and the few that are available have produced mixed results. Some investigators report some responses while others report no responses. Richardson *et al.* (1995) reported that there is no evidence that single or occasional aircraft flying above large whales and pinnipeds in-water cause long-term displacement of these mammals. Several authors have reported that sperm whales did not react to fixed-wing aircraft or helicopters in some circumstances (Au and Perryman 1982, Clarke 1956, Gambell 1968, Green *et al.* 1992) and reacted in others (Clarke 1956, Fritts *et al.* 1983, Mullin *et al.* 1991, Patenaude *et al.* 2006, Richter *et al.* 2003, 2006, Smultea *et al.* 2008, Würsig *et al.* 1998). Richardson *et al.* (1985) reported that bowhead whales (*Balaena mysticetus*) responded behaviorally to fixed-wing aircraft that were used in their surveys and research studies when the aircraft were less than 457 meters above sea level; their reactions were uncommon at 457 meters, and were undetectable above 610 meters. They also reported that bowhead whales did not respond behaviorally to helicopter overflights at about 153 meters above sea level.

Smultea *et al.* (2008) studied the response of sperm whales to low-altitude (233-269 m) flights by a small fixed-wing airplane Kauai and reviewed data available from either other studies. They concluded that sperm whales responded behaviorally to aircraft passes in about 12 percent of encounters. All of the reactions consisted of sudden dives and occurred when the aircraft was less than 360 m from the whales (lateral distance). They concluded that the sperm whales had perceived the aircraft as a predatory stimulus and responded with defensive behavior. In at least one case, Smultea and *et al.* (2008) reported that the sperm whales formed a semi-circular "fan" formation that was similar to defensive formations reported by other investigators.

5.4 Probable Responses of Endangered or Threatened Species

Thus far, we have identified the endangered and threatened species that might be exposed to different stressors associated with the training activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex and the potential responses of those species given that exposure. The narratives that follow discuss the probable responses of those species.

BLUE WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect blue whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect blue whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; one blue whale might occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a blue whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015 we would expect about 197 exposure events involving blue whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 23 instances in which blue whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 139 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when blue whales would be between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 34 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 197 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 8 of the 197 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when blue whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

Blue whale vocalizations include a variety of sounds described as low frequency moans or long pulses in the 10-100 Hz band (Cummings and Thompson 1971; Edds 1982; Thompson and Friedl 1982; McDonald *et al.* 1995; Clark and Fristrup 1997; Rivers 1997). The most typical signals are very long, patterned sequences of tonal infrasonic sounds in the 15-40 Hz range. Ketten (1997) reports the frequencies of maximum energy between 12 and 18 Hz. Short sequences of rapid calls in the 30-90 Hz band are associated with animals in social groups (see Clark personal observation and McDonald personal communication cited in Ketten 1997). The context for the 30-90 Hz calls suggests that blue whales use these calls to communicate but they do not appear to be related to the reproductive ecology of blue whales. 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.

While we recognize that animal hearing evolved separately from animal vocalizations and, as a result, it may be inappropriate to make inferences about an animal's hearing sensitivity from their vocalizations, we have no data on blue whale hearing. As a result, we assume that blue whale vocalizations are partially representative of their hearing sensitivities. This assumption and the evidence available lead us to conclude that blue whales are not likely to respond if they are exposed to high-frequency sound sources associated with the proposed training activities because of their hearing sensitivities.

We would not expect the 139 blue whales that find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar ping to devote attentional resources to those sounds, even though received levels might be as high as 140 dB (at 36 kilometers). Although blue whales appear to be able to hear mid-frequency (1 kHz–10 kHz) sounds, this frequency range appears to lie at the periphery of their hearing range and blue whales are less likely to devote attentional resources to stimuli in this frequency range. Similarly, we would not expect the 34 blue whales that find themselves between 15 and 36 kilometers from a sonar transmission to change their behavioral state8, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 19 instances (of the 24 instances in which blue whales might occur within 15 kilometers of a sonar ping) in which blue whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In five of the 24 instances in which blue whales might occur within 15 kilometers of a sonar ping, we would expect the blue whale to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales. We would also expect the 23 instances in which blue whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the fin whales to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect blue whales to be exposed to underwater detonations on the Mariana

8 Changes in behavioral state consist of shifts from one behavioral category to another behavioral category. For example, they represent shifts from a resting state to an active state or from a foraging state to a migratory state. Low-level avoidance behavior or vigilance generally would not represent changes in behavioral state because they consist of a moving animal making minor adjustments in the trajectory of their motion (low-level avoidance) or an animal continuing their behavioral activity while paying attention to a distance stimulus.

Islands Range Complex at received levels at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or that would be expected to produce slight lung injury as a result of their exposure.

FIN WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect fin whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect fin whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; two fin whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a fin whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 590 exposure events involving fin whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 69 instances in which fin whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 418 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when fin whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 101 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 197 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 23 of the 590 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when fin whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

As discussed in the *Status of the Species* section of this Opinion, fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981; Watkins *et al.* 1987a; Edds 1988; Thompson *et al.* 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (Patterson and Hamilton 1964; Watkins *et al.* 1987a; Thompson *et al.* 1992; McDonald *et al.* 1995). In temperate waters intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald *et al.* 1995). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999).

While we recognize that animal hearing evolved separately from animal vocalizations and, as a result, it may be inappropriate to make inferences about an animal's hearing sensitivity from their vocalizations, we have no data on fin whale hearing. As a result, we assume that fin whale vocalizations are partially representative of their hearing sensitivities. This assumption and the evidence available lead us to conclude that fin whales are not likely to respond to high-frequency sound sources associated with the proposed training activities because of their hearing sensitivities.

Based on in-situ observations of the responses of 122 minke whales, 2,259 fin whales, 833 right whales, and 603 humpback whales exposed to human activities in waters off Cape Cod, whales appeared to respond to acoustic stimuli within their range of hearing. Sounds that were of relatively low amplitude at the whales' location or that had the most energy at frequencies below or above their hearing capacities appeared not to be noticed. The whales appeared to ignore 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 (Watkins 1986). In particular, whales responded negatively to underwater sounds that appeared to be unexpected, too loud, suddenly louder or different or were perceived as being associated with a potential threat (such as the noise of a rapidly approaching ship or outboard on a collision course). Furthermore, whales' assessments of relative movements of a sound source also apparently influenced their reactions (for example, a vessel moving on a parallel course with the whales usually caused less reaction than the same vessel at the same distance that was approaching on a collision course. Whales often ignored continuous sound sequences, such as echosounder signals that gradually increased in amplitude as a vessel slowly approached (perhaps because these sounds were expected).

Based on this body of evidence, we would not expect fin whales to devote attentional resources to the sounds they receive from sonar pings in the 417 instances in which fin whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). Although fin whales appear to be able to hear mid-frequency (1 kHz–10 kHz) sounds, this frequency range appears to lie at the periphery of their hearing range and fin whales are less likely to devote attentional resources to stimuli in this frequency range. Similarly, we would not expect fin whales to change their behavioral state when exposed to sonar pings in the 101 instances in which they might find themselves between 15 and 36 kilometers from a sonar transmission, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 56 instances (of the 71 instances in which fin whales might occur within 15 kilometers of a sonar ping) in which fin whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 15 of the 71 instances in which fin whales might occur within 15 kilometers of a sonar ping, we would expect the fin whale to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales. We would also expect the 69 instances in which fin whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the fin whales to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect fin whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or that would be expected to produce slight lung injury as a result of their exposure.

HUMPBACK WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect humpback whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Like the other baleen whales we consider in this Opinion, we would not expect humpback whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea. As a result humpback whales are not likely to be exposed to training activities that occurred on the range complex from mid-May through mid-November.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; 53 humpback whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a humpback whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 13,571 exposure events involving humpback whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 1,740 instances in which humpback whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 9,604 exposure events would occur at received levels of lower than 140 dB, when humpback whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 2,327 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 13,571 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 531 of the 13,571 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when humpback whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

As discussed in the *Status of the Species* section of this Opinion, humpback whales produce a wide variety of sounds. During the winter, breeding season male humpback whales sing long, complex songs, with frequencies in the 25-5000 Hz range and intensities as high as 181 dB (Payne 1970; Winn *et al.* 1970a; Thompson *et al.* 1986). Animals in mating groups produce a variety of sounds (Tyack 1981; Tyack and Whitehead 1983, Silber 1986). Source levels average 155 dB and range from 144 to 174 dB (Thompson *et al.* 1979). The songs appear to have an effective range of approximately 10 to 20 km. Assuming that humpback whale vocalizations are partially representative of their hearing sensitivities, we assume that humpback whales are more likely to hear sounds in the frequency range of mid-frequency active sonar than blue, fin, or sei whales.

Humpback whales have been observed 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). However, humpback whales do not appear to be as responsive to anthropogenic sounds on their breeding areas, Humpback whales on breeding areas did not stop singing in response to underwater explosions (Payne and McVay 1971) and breeding humpbacks showed only a slight statistical reaction to playbacks of 60 - 90 Hz sounds with a received level of up to 190 dB (Frankel and Clark 1998). We assume that humpback whales engaged in reproductive activity will focus most or all of their attentional resources on vocalizations, other environmental cues, the process of giving birth to calves, or feeding calves that have just been born.

Based on observations of the responses of fin, humpback, and minke whales to anthropogenic sounds in Cape Cod Bay (discussed in the preceding narrative on fin whales) and the other evidence available to us, we would not expect humpback whales to devote attentional resources to the sounds they receive from sonar pings in the 9,538 instances in which humpback whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). Similarly, we would expect humpback whales to hear sonar pings in the 2,311 instances in which they might find themselves between 15 and 36 kilometers from a sonar ping, although we would not expect these whales to devote attentional resources to those sounds for the reasons we just discussed.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect about 1,306 instances (of the 1,640 instances in which humpback whales might occur within 15 kilometers of a sonar ping) in which humpback whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 334 of the 1,640 instances in which humpback whales might occur within 15 kilometers of a sonar ping, we would expect the humpback whale to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales. We would also expect the 1,740 instances in which humpback whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the humpback whales to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect humpback whales to be exposed to underwater detonations at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division). However, we would expect one humpback whale to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 182 dB SEL or 23 psi-ms, which NMFS' Permits Division considers as a threshold for Level B "take" or behavioral harassment.

SEI WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect sei whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect sei whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; two sei whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a sei whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 570 exposure events involving sei whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 65 instances in which sei whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 404 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when sei whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 98 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of the 570 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 20 of the 570 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when sei whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

As discussed in the *Status of the Species* section of this Opinion, we have almost no information on vocalizations produced by sei whales. 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. That is, we assume 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. Furthermore, we assume that sei whale vocalizations are partially representative of their hearing sensitivities so we assume that sei whales are not likely to respond to high-frequency sound sources associated with the proposed training activities because of their hearing sensitivities.

Based on observations of the responses of fin, humpback, and minke whales to anthropogenic sounds in Cape Cod Bay (discussed in the preceding narrative on fin whales) and the other evidence available to us, we would not expect sei whales to devote attentional resources to the sounds they receive from sonar pings in the 404 instances in which sei whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). We assume that sei whales, like blue and fin whales, hear mid-frequency (1 kHz–10 kHz) sounds although sounds in this frequency range lie at the periphery of their hearing range. As a result, we assume that sei whales are less likely to devote attentional resources to stimuli in this frequency range. Similarly, we would not expect sei whales to change their behavioral state when exposed to sonar pings in the 98 instances in which they might find themselves between 15 and 36 kilometers from a sonar transmission, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 55 instances (of the 69 instances in which sei whales might occur within 15 kilometers of a sonar ping) in which sei whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 14 of the 69 instances in which sei whales might occur within 15 kilometers of a sonar ping, we would expect the sei whale to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales. We would also expect the 65 instances in which sei whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the sei whales to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect sei whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or that would be expected to produce slight lung injury as a result of their exposure.

SPERM WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect sperm whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect sperm whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; 60 sperm whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a sperm whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 15,186 exposure events involving sperm whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 153 instances in which sperm whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 10,747 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when sperm whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 2,604 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of the 570 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 534 of the 15,186 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when sperm whales would occur within 5 kilometers (about

3.1 miles) of the source of a sonar ping.

If exposed to mid-frequency sonar transmissions, sperm whales are likely to hear and respond to those transmissions. The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1990). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz. Sperm whales also produce loud broad-band clicks from about 0.1 to 20 kHz (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). These clicks were estimated to have source levels at 171 dB re 1 μPa (Levenson 1974). Current evidence suggests that the disproportionately large heads of sperm whales are adaptations that allow them to produce these vocalizations (Norris and Harvey 1972; Cranford 1992; but see Clarke 1979). This suggests that the production of these loud low-frequency clicks is extremely important to the survival of individual sperm whales. The function of these vocalizations is relatively well-studied (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995): long series of monotonous regularly spaced clicks are associated with feeding and are thought to help sperm whales echolocate while the 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, sonar transmissions might temporarily reduce the active space of sperm whale vocalizations. Most of the energy of sperm whales clicks is concentrated at 2 to 4 kHz and 10 to 16 kHz, which overlaps with the mid-frequency sonar. Other studies indicate sperm whales' wide-band clicks contain energy between 0.1 and 20 kHz (Weilgart and Whitehead 1993, Goold and Jones 1995). Ridgway and Carder (2001) measured low-frequency, high amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a neonate sperm whale.

There is some evidence of disruptions of clicking and behavior from sonars (Goold 1999, Watkins and Scheville1975, Watkins *et al.* 1985), pingers (Watkins and Scheville 1975), the Heard Island Feasability Test (Bowles *et al.* 1994), and the Acoustic Thermometry of Ocean Climate (Costa *et al.*1998). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders (Watkins and Scheville 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise, echosounder, and fishfinder emissions from a flotilla of 10 vessels. Watkins and Scheville (1975) showed that sperm whales interrupted click production in response to pinger (6 to 13 kHz) sounds. They also stopped vocalizing for brief periods when codas were being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

As discussed previously, sperm whales have been reported to have reacted to military sonar, apparently produced by a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins *et al.* 1985). Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 sec pulsed sounds at frequencies similar to those emitted by multi-beam sonar that is used in geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans some-times avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

Published reports identify instances in which sperm whales have responded to an acoustic source and other instances in which they did not appear to respond behaviorally when exposed to seismic surveys. Mate *et al.* (1994) reported an opportunistic observation of the number of sperm whales to have decreased in an area after the start of airgun seismic testing. However, Davis *et al.* (2000) noted that sighting frequency did not differ significantly among the different acoustic levels examined in the northern Gulf of Mexico, contrary to what Mate *et al.* (1994) reported. In one DTAG deployment in the northern Gulf of Mexico on July 28, 2001, researchers documented that the tagged whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μPa (Johnson and Miller 2002). Sperm whales may also have responded to seismic airgun sounds by ceasing to call during some (but not all) times when seismic pulses were received from an airgun array >300 km away (Bowles *et al.* 1994).

A recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa peak-to-peak (Madsen *et al.* 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels (Stone 1997, 1998, 2000, 2001, 2003). However, the compilation and analysis of the data led the author to conclude that seismic surveys did not result in observable effects to sperm whales (Stone 2003). The results from these waters seem to show that some sperm whales tolerate seismic surveys.

Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins and Schevill 1975; Watkins *et al.* 1985). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

Preliminary data from an experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico and a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys show that during two controlled exposure experiments in which sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa over octave band with most energy, the whales did not avoid the vessel or change their feeding efficiency (National Science Foundation 2003). Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway.

Other studies identify instances in which sperm whales did not respond to anthropogenic sounds. Sperm whales did not alter their vocal activity when exposed to levels of 173 dB re 1 μPa from impulsive sounds produced by 1 g TNT detonators (Madsen and Mohl 2000). Richardson *et al.* (1995) citing a personal communication with J. Gordon suggested that sperm whales in the Mediterranean Sea continued calling when exposed to frequent and strong military sonar signals. When Andre *et al.* (1997) exposed sperm whales to a variety of sounds to determine what sounds may be used to scare whales out of the path of vessels, sperm whales were observed to have startle reactions to 10 kHz pulses (180 db re 1 μPa at the source), but not to the other sources played to them.

These studies suggest that the behavioral responses of sperm whales to anthropogenic sounds are highly variable, but do not appear to result in the death or injury of individual whales or result in reductions in the fitness of individuals involved. Responses of sperm whales to anthropogenic sounds probably depend on the age and sex of animals being exposed, as well as other factors. There is evidence that many individuals respond to certain sound sources, provided the received level is high enough to evoke a response, while other individuals do not.

Based on observations of the responses of fin, humpback, and minke whales to anthropogenic sounds in Cape Cod Bay (discussed in the narrative on fin whales) and the other evidence available to us, we would not expect sperm whales to devote attentional resources to the sounds they receive from sonar pings in the 10,734 instances in which sperm whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). Similarly, we would not expect sperm whales to change their behavioral state when exposed to sonar pings in the 2,601 instances in which they might find themselves between 15 and 36 kilometers from a sonar transmission, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 1,461 instances (of the 1,835 instances in which sperm whales might occur within 15 kilometers of a sonar ping) in which sperm whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 374 of the 1.835 instances in which sperm whales might occur within 15 kilometers of a sonar ping, we would expect the sperm whale to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales. We would also expect the 153 instances in which sperm whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the sperm whales to engage in evasive behavior or change their behavioral state, which would have consequences for the fitness of those whales.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect sperm whales to be exposed to underwater detonations at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division). However, we would expect three sperm whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 182 dB SEL or 23 psi-ms, which NMFS' Permits Division considers as a threshold for Level B "take" or behavioral harassment.

GREEN SEA TURTLES. Because they tend to occur near the coast of islands in the Mariana Islands archipelago, green sea turtles are not likely to be exposed to stressors associated with air warfare or electronic combat, surface warfare, or joint multi-strike group exercises, which would occur more than 12 nautical miles from land (with the exception of small arms gunnery exercises),

The primary site for the amphibious assault (Marine Air Ground Task Force) exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Unai Chulu Beach on the island of Tinian where green sea turtles are likely to nest. This beach is a secondary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Adult green sea turtles that might arrive on this beach to nest would be potentially exposed to human disturbance associated with these training activities; any nests that might occur on this beach during such an exercise has some probably of being trampled or destroyed.

Apra Harbor is a primary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. This harbor is a secondary site for the amphibious assaults (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Although green sea turtles are not known to nest in this area, they forage and rest in several areas of the harbor and are likely to be exposed to human disturbance associated with these training activities.

Because of the distance between the locations in which the U.S. Navy is likely to conduct anti-submarine warfare exercises, joint multi-strike group exercises, sinking exercises and operate SURTASS LFA sonar and the coastal locations in which green sea turtles are most likely to occur, the majority of the green sea turtles that occur in the Mariana Islands archipelago are not likely to be exposed to active sonar transmissions or the sounds of underwater detonations associated with these training activities. Because they tend to remain in relatively shallow coastal waters where sounds produced by rain, wind, and waves, juvenile, sub-adult, and nesting adult green sea turtles are not likely to be aware of energy produced by mid-frequency active sonar from these training activities.

However, because the primary site for the floating mine neutralization and underwater demolition exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Agat Bay on Guam where green sea turtles are likely to forage and rest, these sea turtles would have some risk of being exposed to shock waves and sound fields associated with these training exercises. Nevertheless, because the U.S. Navy proposes to establish 700-yard (640 meters or about 2,100 feet) exclusion zones for sea turtles (and marine mammals) for all mine warfare and mine countermeasure training activities, these sea turtles are not likely to be killed or injured as a result of their exposure to pressure waves produced by these detonations.

Klima *et. al.* (1988) conducted an experiment in which Kemp's ridley and loggerhead turtles were placed in cages at four distances from a oil platform to be removed with explosives. The cages were submerged to a depth of 4.52 meters (15 feet) over the 9 meter (30 foot) 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 4.88 meters (16 feet) below the mudline. Loggerhead and Kemp's ridley turtles at 228.6 meters (750 feet) and 365 meters (1,200 feet), as well as one loggerhead at 914 meters (3,000 feet) were rendered unconscious. The Kemp's ridley turtle closest to the explosion (range of 228.6 meters) was slightly injured, with an everted cloacal lining; ridleys at ranges of 365 meters, 546 meters, and 914 meters 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 36.6 meters (120 feet) deep. At least three turtles were noted in the area following the detonations. One turtle at a range of 152 to 213 meters (500 to 700 feet) was killed. A second turtle at a range of 365 meters received minor injuries. A third turtle at 609.6 meters (2,000 feet) was apparently unaffected. At a depth of 18 meters (60 feet), calculated shock wave pressures were 239, 161, 85, and 47 psi at ranges of 152, 213, 365, and 609.6 meters, respectively.

Based on a parametric evaluation of the effects of charge weight and depth using the Goertner (1982) model, Young (1991) concluded that a conservative safe range for non-injury to a small mammal (representative of a dolphin calf) was approximated by $R=578w^{0.28}$ (*R* is in feet and *w* is in pounds of explosive). O'Keeffe and Young (1984) proposed that a safe range for turtles from an underwater explosion could be expressed by $R = 200\ w^{1/3}$. 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 $R = 560\ w^{1/3}$. Assuming that the U.S. Navy proposes to detonation 5 to 20 lb charges (NEW) during mine neutralization or underwater demolition exercises, the equation proposed by O'Keefe and Young (1984) would produce safe ranges of 104.24 meters (for 5 lb charges) and 165.47 meters (for 20 lb charges). The modified equation proposed by Young (1991) would produce safe ranges of 291.87 meters (for 5 lb charges) and 463.32 meters (for 20 lb charges). The U.S. Navy proposes to use a safe range of 640 meters, which is more than 27 percent greater than the largest of these safe ranges and is greater than the distance at which sea turtles appeared to have been unaffected by the detonations conducted on the Mariana Islands Range Complex. As a result, we would conclude that green sea turtles are not likely to experience physical injury, physiological stress responses, or changes in behavioral states as a result of being exposed to pressure waves associated with underwater detonations on the Mariana Islands Range Complex.

Sea turtles that occur on the Mariana Islands Range Complex might encounter one or more of the parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. Whales also might encounter one or more of these parachutes and become entangled as it sinks to the bottom or once it is on the seafloor. We cannot, however, determine whether such interactions are probable, given the relatively small number of sonobuoys that would be employed in each of the exercises, the relatively large geographic area involved, and the relatively low densities of endangered or threatened marine mammals and sea turtles on the range complex.

HAWKSBILL SEA TURTLE. Because they tend to occur near the coast of islands in the Mariana Islands archipelago, hawksbill sea turtles are not likely to be exposed to stressors associated with air warfare or electronic combat, surface warfare, or joint multi-strike group exercises, which would occur more than 12 nautical miles from land (with the exception of small arms gunnery exercises),

Apra Harbor is a secondary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. This harbor is a secondary site for the amphibious assaults (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Although hawksbill sea turtles are not known to nest in this area, they forage and rest in several areas of the harbor and are likely to be exposed to human disturbance associated with these training activities.

Because of the distance between the locations in which the U.S. Navy is likely to conduct anti-submarine warfare exercises, joint multi-strike group exercises, sinking exercises and operate SURTASS LFA sonar and the coastal locations in which hawksbill sea turtles are most likely to occur, the majority of the hawksbill sea turtles that occur in the Mariana Islands archipelago are not likely to be exposed to active sonar transmissions or the sounds of underwater detonations associated with these training activities. Because they tend to remain in relatively shallow coastal waters where sounds produced by rain, wind, and waves, juvenile, sub-adult, and nesting adult hawksbill sea turtles are not likely to be aware of energy produced by mid-frequency active sonar from these training activities.

However, because the primary site for the floating mine neutralization and underwater demolition exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Agat Bay on Guam where hawksbill sea turtles are likely to forage and rest, these sea turtles would have some risk of being exposed to shock waves and sound fields associated with these training exercises. Nevertheless, because the U.S. Navy proposes to establish 700-yard (640 meters or about 2,100 feet) exclusion zones for sea turtles (and marine mammals) for all mine warfare and mine countermeasure training activities, these sea turtles are not likely to be killed or injured as a result of their exposure to pressure waves produced by these detonations.

As discussed previously, Klima *et. al.* (1988) conducted an experiment in which Kemp’s ridley and loggerhead turtles were placed in cages at four distances from a oil platform to be removed with explosives. The cages were submerged to a depth of 4.52 meters (15 feet) over the 9 meter (30 foot) 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 4.88 meters (16 feet) below the mudline. Loggerhead and Kemp’s ridley turtles at 228.6 meters (750 feet) and 365 meters (1,200 feet), as well as one loggerhead at 914 meters (3,000 feet) were rendered unconscious. The Kemp’s ridley turtle closest to the explosion (range of 228.6 meters) was slightly injured, with an everted cloacal lining; ridleys at ranges of 365 meters, 546 meters, and 914 meters were apparently unharmed. All loggerheads displayed abnormal pink coloration caused by dilated blood vessels at the base of their throats and flippers 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 36.6 meters (120 feet) deep. At least three turtles were noted in the area following the detonations. One turtle at a range of 152 to 213 meters (500 to 700 feet) was killed. A second turtle at a range of 365 meters received minor injuries. A third turtle at 609.6 meters (2,000 feet) was apparently unaffected. At a depth of 18 meters (60 feet), calculated shock wave pressures were 239, 161, 85, and 47 psi at ranges of 152, 213, 365, and 609.6 meters, respectively.

Based on a parametric evaluation of the effects of charge weight and depth using the Goertner (1982) model, Young (1991) concluded that a conservative safe range for non-injury to a small mammal (representative of a dolphin calf) was approximated by $R=578w^{0.28}$ (*R* is in feet and *w* is in pounds of explosive). O’Keeffe and Young (1984) proposed that a safe range for turtles from an underwater explosion could be expressed by $R = 200\ w^{1/3}$. 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 $R = 560\ w^{1/3}$. Assuming that the U.S. Navy proposes to detonate 5 to 20 lb charges (NEW) during mine neutralization or underwater demolition exercises, the equation proposed by O'Keefe and Young (1984) would produce safe ranges of 104.24 meters (for 5 lb charges) and 165.47 meters (for 20 lb charges). The modified equation proposed by Young (1991) would produce safe ranges of 291.87 meters (for 5 lb charges) and 463.32 meters (for 20 lb charges). The U.S. Navy proposes to use a safe range of 640 meters, which is more than 27 percent greater than the largest of these safe ranges and is greater than the distance at which sea turtles appeared to have been unaffected by the detonations conducted on the Mariana Islands Range Complex. As a result, we would conclude that hawksbill sea turtles are not likely to experience physical injury, physiological stress responses, or changes in behavioral states as a result of being exposed to pressure waves associated with underwater detonations on the Mariana Islands Range Complex.

Sea turtles that occur on the Mariana Islands Range Complex might encounter one or more of the parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. Whales also might encounter one or more of these parachutes and become entangled as it sinks to the bottom or once it is on the seafloor. We cannot, however, determine whether such interactions are probable, given the relatively small number of sonobuoys that would be employed in each of the exercises, the relatively large geographic area involved, and the relatively low densities of endangered or threatened marine mammals and sea turtles on the range complex.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

During this consultation, NMFS searched for information on future State, tribal, local, or private actions that were reasonably certain to occur in the action area. Most of the action area includes federal military reserves or is outside of territorial waters of the United States of America, which would preclude the possibility of future state, tribal, or local action that would not require some form of federal funding or authorization. NMFS conducted electronic searches of business journals, trade journals, and newspapers using *First Search*, Google, and other electronic search engines. Those searches produced no evidence of future private action in the action area that would not require federal authorization or funding and is reasonably certain to occur. As a result, NMFS is not aware of any actions of this kind that are likely to occur in the action area during the foreseeable future.

6.0 Integration and Synthesis of Effects

Thus far, we have described the endangered or threatened species that are likely to be exposed to the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex and the probable responses of those endangered or threatened species given that exposure. In this section of our Opinion, we describe the probable consequences of those responses for endangered or threatened individuals, the population(s) those individuals represent, and the species those populations comprise to determine whether the proposed military readiness activities are likely to jeopardize the continued existence of those species by appreciably reducing the reproduction, numbers, or distribution of those species in the wild.

As we discussed in the *Approach to the Assessment* section of this Opinion, we begin our risk analyses by asking whether the probable physical, physiological, behavioral, or social responses of endangered or threatened species are likely to reduce the fitness of endangered or threatened individuals or the growth, annual survival or reproductive success, or lifetime reproductive success of those individuals. If we would not expect listed plants or animals exposed to an action's effects to experience reductions in the current or expected future reproductive success (that is, their fitness), we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (Anderson 2000; Mills and Beatty 1979; Brandon 1978; Stearns 1977, 1992). Therefore, if we conclude that listed plants or animals are not likely to experience reductions in their fitness, we would conclude our assessment because we would not expect the effects of the action to affect the performance of the populations those individuals represent or the species those population comprise. If, however, we conclude that listed plants or animals are likely to experience reductions in their fitness as a result of their exposure to an action, we then determine whether those reductions would reduce the viability of the population or populations the individuals represent and the "species" those populations comprise (in section 7 consultations, the"species" represent the listed entities, which might represent species, subspecies, or distinct populations segments of vertebrate taxa).

As part of our risk analyses, we consider the consequences of exposing endangered or threatened species to the stressors associated with the proposed actions, individually and cumulatively, given that the individuals in the action areas for this consultation are also exposed to other stressors in the action area and elsewhere in their geographic range. These stressors or the response of individual animals to those stressors can produce consequences — or "cumulative impacts" (in the NEPA sense of the term) — that would not occur if animals were only exposed to a single stressor.

As we discuss in the narratives that follow, our analyses led us to conclude that endangered or threatened individuals that are likely to be exposed to the military readiness activities the U.S. Navy proposes to conduct on the Mariana

Islands Range Complex are likely to experience disruptions in their normal behavioral patterns, but they are not likely to be killed, injured, or experience measurable reductions in their current or expected future reproductive success as a result of that exposure.

BLUE WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect blue whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect blue whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; one blue whale might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a blue whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015 we would expect about 197 exposure events involving blue whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 23 instances in which blue whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 139 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when blue whales would be between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 34 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 197 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 8 of the 197 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when blue whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

Blue whale vocalizations include a variety of sounds described as low frequency moans or long pulses in the 10-100 Hz band (Cummings and Thompson 1971; Edds 1982; Thompson and Friedl 1982; McDonald *et al.* 1995; Clark and

Fristrup 1997; Rivers 1997). The most typical signals are very long, patterned sequences of tonal infrasonic sounds in the 15-40 Hz range. Ketten (1997) reports the frequencies of maximum energy between 12 and 18 Hz. Short sequences of rapid calls in the 30-90 Hz band are associated with animals in social groups (see Clark personal observation and McDonald personal communication cited in Ketten 1997). The context for the 30-90 Hz calls suggests that blue whales use these calls to communicate but they do not appear to be related to the reproductive ecology of blue whales. 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.

While we recognize that animal hearing evolved separately from animal vocalizations and, as a result, it may be inappropriate to make inferences about an animal's hearing sensitivity from their vocalizations, we have no data on blue whale hearing. As a result, we assume that blue whale vocalizations are partially representative of their hearing sensitivities. This assumption and the evidence available lead us to conclude that blue whales are not likely to respond to high-frequency sound sources associated with the proposed training activities because of their hearing sensitivities.

For similar reasons, we would not expect the 139 blue whales that find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar ping to devote attentional resources to those sounds, even though received levels might be as high as 140 dB (at 36 kilometers). Although blue whales appear to be able to hear mid-frequency (1 kHz–10 kHz) sounds, this frequency range appears to lie at the periphery of their hearing range and blue whales are less likely to devote attentional resources to stimuli in this frequency range. Similarly, we would not expect the 34 blue whales that find themselves between 15 and 36 kilometers from a sonar transmission to change their behavioral state, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to mid-frequency active sonar, we would expect 19 instances (of the 24 instances in which blue whales might occur within 15 kilometers of a sonar ping) in which blue whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In five of the 24 instances in which blue whales might occur within 15 kilometers of a mid-frequency active sonar ping, we would expect the blue whale to engage in evasive behavior or change their behavioral state. We would also expect the 23 instances in which blue whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the whales to engage in evasive behavior or change their behavioral state. In both cases, this evasive behavior or changes in behavioral state would represent disruptions of the normal behavioral patterns that are essential to the life history of the individual blue whales exhibiting these responses.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect blue whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or that would be expected to produce slight lung injury as a result of their exposure.

As we discussed in our *Exposure Analyses*, we assume that the blue whales the might be exposed to stressors associated with U.S. Navy readiness activities on the Mariana Islands Range Complex are members of the population of blue whales that inhabits the northwest Pacific Ocean. These blue whales would not only be exposed to readiness activities on the range complex considered in this Opinion, they would also be exposed to readiness activities the U.S. Navy conducts off the Japanese archipelago. As a result, the same individuals would be exposed to low- and mid-frequency active sonar associated with anti-submarine warfare and strike warfare exercises associated with those training exercises. Because we do not have the information we would need to complete exposure analyses, we cannot estimate the number of blue whales that might be exposed to mid-frequency active sonar during these training exercises; however, we would expect 10 blue whales to be exposed to low-frequency active sonar each year during readiness activities the SURTASS LFA sonar system conducts offshore of Japan. Because of the geographic distribution of these blue whales, they are probably exposed to active sonar transmissions associated with training activities conducted by Russian naval forces, the People's Republic of China, the Democratic People's Republic of Korea, and the Republic of Korea.

The blue whales that are exposed to the training activities in the Mariana Islands Range Complex might not respond to the acoustic cues generated by Navy vessels, while in other circumstances, they are likely to change their surface times, swimming speed, swimming angle or direction, respiration rates, dive times, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães et al. 2002, Richter et al. 2003, Scheidat et al. 2004, Simmonds 2005, Watkins 1986, Williams et al. 2002). Some blue whales may be less likely to engage in these responses on the Mariana Islands Range Complex if they engage in courtship or reproductive behavior on the Mariana Islands Range Complex because they are less likely to devote attentional resources to sounds associated with U.S. Navy training activities while engaged in those behavioral acts. The blue whales that are likely to be exposed on the Mariana Islands Range Complex would have had prior experience with similar stressors resulting from their exposure in waters off Japan earlier in the year; that experience will make some blue whales more likely to avoid activities associated with the training while others would be less likely to engage in avoidance behavior. Some blue whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship as they engage in avoidance behavior. However, we do not expect these physiological stress responses to reduce the fitness of the blue whales that occur in the Mariana Islands Range Complex.

In conclusion, we expect 28 instances in which individual blue whales might experience disruptions of their normal behavioral patterns each year as a result of their exposure to mid- or low-frequency active sonar associated with the training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex from June 2010 through June 2015. The small number and short duration of these exposure events, however, are not likely to disrupt their behavior patterns to a degree that is likely to reduce the current or expected future reproductive success of the blue whales involved. Therefore, we would not expect the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex to affect the performance of the populations those blue whales represent or the species those population comprise. By extension, we would not expect those military readiness activities to appreciably reduce the blue whales' likelihood of surviving and recovering in the wild.

FIN WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect fin whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect fin whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; two fin whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a fin whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 590 exposure events involving fin whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 69 instances in which fin whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 418 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when fin whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 101 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 197 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 23 of the 590 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when fin whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

As discussed in the *Status of the Species* section of this Opinion, fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981; Watkins *et al.* 1987a; Edds 1988; Thompson *et al.* 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels are as high as 190 dB (Patterson and Hamilton 1964;

Watkins *et al.* 1987a; Thompson *et al.* 1992; McDonald *et al.* 1995). In temperate waters intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald *et al.* 1995). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999).

While we recognize that animal hearing evolved separately from animal vocalizations and, as a result, it may be inappropriate to make inferences about an animal's hearing sensitivity from their vocalizations, we have no data on fin whale hearing. As a result, we assume that fin whale vocalizations are partially representative of their hearing sensitivities. This assumption and the evidence available lead us to conclude that fin whales are not likely to respond to high-frequency sound sources associated with the proposed training activities because of their hearing sensitivities.

Based on in-situ observations of the responses of 122 minke whales, 2,259 fin whales, 833 right whales, and 603 humpback whales exposed to human activities in waters off Cape Cod, whales appeared to respond to acoustic stimuli within their range of hearing. Sounds that were of relatively low amplitude at the whales' location or that had the most energy at frequencies below or above their hearing capacities appeared not to be noticed. The whales appeared to ignore 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 (Watkins 1986). In particular, whales responded negatively to underwater sounds that appeared to be unexpected, too loud, suddenly louder or different or were perceived as being associated with a potential threat (such as the noise of a rapidly approaching ship or outboard on a collision course). Furthermore, whales' assessments of relative movements of a sound source also apparently influenced their reactions (for example, a vessel moving on a parallel course with the whales usually caused less reaction than the same vessel at the same distance that was approaching on a collision course. Whales often ignored continuous sound sequences, such as echosounder signals that gradually increased in amplitude as a vessel slowly approached (perhaps because these sounds were expected).

Based on this body of evidence, we would not expect fin whales to devote attentional resources to the sounds they receive from sonar pings in the 417 instances in which fin whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). Although fin whales appear to be able to hear mid-frequency (1 kHz–10 kHz) sounds, this frequency range appears to lie at the periphery of their hearing range and fin whales are less likely to devote attentional resources to stimuli in this frequency range. Similarly, we would not expect fin whales to change their behavioral state when exposed to sonar pings in the 101 instances in which they might find themselves between 15 and 36 kilometers from a sonar transmission, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 56 instances (of the 71 instances in which fin whales might occur within 15 kilometers of a sonar ping) in which fin whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 15 of the 71 instances in which fin whales might occur within 15 kilometers of a sonar ping, we would expect the fin whale to engage in evasive behavior or change their behavioral state. We would also expect the 69 instances in which fin whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the fin whales to engage in evasive behavior or change their behavioral state. In both cases, this evasive behavior or changes in behavioral state would represent disruptions of the normal behavioral patterns that are essential to the life history of the individual fin whales exhibiting these responses.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect fin whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or that would be expected to produce slight lung injury as a result of their exposure.

As we discussed, we assume that the fin whales the might be exposed to stressors associated with U.S. Navy readiness activities on the Mariana Islands Range Complex are members of the population of fin whales that inhabits the northwest Pacific Ocean. These fin whales would not only be exposed to readiness activities on the range complex considered in this Opinion, they would also be exposed to readiness activities the U.S. Navy conducts off the Japanese archipelago. As a result, the same individuals would be exposed to low- and mid-frequency active sonar associated with anti-submarine warfare and strike warfare exercises associated with those training exercises. Because we do not have the information we would need to complete exposure analyses, we cannot estimate the number of fin whales that might be exposed to mid-frequency active sonar during these training exercises; however, we would expect 10 fin whales to be exposed to low-frequency active sonar each year during readiness activities the SURTASS LFA sonar system conducts offshore of Japan. Because of the geographic distribution of these fin whales, they are probably exposed to active sonar transmissions associated with training activities conducted by Russian naval forces, the People's Republic of China, the Democratic People's Republic of Korea, and the Republic of Korea.

As we discussed, we assume that the fin whales the might be exposed to stressors associated with U.S. Navy readiness activities on the Mariana Islands Range Complex are members of the population of fin whales that inhabits the northwest Pacific Ocean. These fin whales would not only be exposed to readiness activities on the range complex considered in this Opinion, they would also be exposed to readiness activities the U.S. Navy conducts off the Japanese archipelago. As a result, the same individuals would be exposed to low- and mid-frequency active sonar associated with anti-submarine warfare and strike warfare exercises associated with those training exercises. Because we do not have the information we would need to complete exposure analyses, we cannot estimate the number of fin whales that might be exposed to mid-frequency active sonar during these training exercises; however, we would expect 10 fin whales to be exposed to low-frequency active sonar each year during readiness activities the SURTASS LFA sonar system conducts offshore of Japan. Because of the geographic distribution of these fin whales, they are probably exposed to active sonar transmissions associated with training activities conducted by Russian naval forces, the People's Republic of China, the Democratic People's Republic of Korea, and the Republic of Korea.

The fin whales that are likely to be exposed to the training activities in the Mariana Islands Range Complex might not respond to the acoustic cues generated by Navy vessels, while in other circumstances, they are likely to change their surface times, swimming speed, swimming angle or direction, respiration rates, dive times, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães et al. 2002, Richter et al. 2003, Scheidat et al. 2004, Simmonds 2005, Watkins 1986, Williams et al. 2002). Some fin whales may be less likely to engage in these responses on the Mariana Islands Range Complex if they engage in courtship or reproductive behavior on the Mariana Islands Range Complex because they are less likely to devote attentional resources to sounds associated with U.S. Navy training activities while engaged in those behavioral acts. The fin whales that are likely to be exposed on the Mariana Islands Range Complex would have had prior experience with similar stressors resulting from their exposure in waters off Japan earlier in the year; that experience will make some fin whales more likely to avoid activities associated with the training while others would be less likely to engage in avoidance behavior. Some fin whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship as they engage in avoidance behavior. However, these responses are not likely to reduce the fitness of the fin whales that occur in the Mariana Islands Range Complex.

In conclusion, we expect 84 instances in which individual fin whales might experience disruptions of their normal behavioral patterns each year as a result of their exposure to mid- or low-frequency active sonar associated with the training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex from June 2010 through June 2015. The small number and short duration of these exposure events relative to the time interval over which fin whales occur in waters off the Mariana Islands, however, are not likely to disrupt their behavior patterns to a degree that is likely to reduce the current or expected future reproductive success of the fin whales involved. Therefore, we would not expect the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex to affect the performance of the populations those fin whales represent or the species those population comprise. By extension, we would not expect those military readiness activities to appreciably reduce the fin whales' likelihood of surviving and recovering in the wild.

HUMPBACK WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect humpback whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Like the other baleen whales we consider in this Opinion, we would not expect humpback whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea. As a result humpback whales are not likely to be exposed to training activities that occurred on the range complex from mid-May through mid-November.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; 53 humpback whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a humpback whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 13,571 exposure events involving humpback whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 1,740 instances in which humpback whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 9,604 exposure events would occur at received levels of lower than 140 dB, when humpback whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 2,327 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of these 13,571 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 531 of the 13,571 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when humpback whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

As discussed in the *Status of the Species* section of this Opinion, humpback whales produce a wide variety of sounds. During the winter, breeding season male humpback whales sing long, complex songs, with frequencies in the 25-5000 Hz range and intensities as high as 181 dB (Payne 1970; Winn *et al.* 1970a; Thompson *et al.* 1986). Animals in mating groups produce a variety of sounds (Tyack 1981; Tyack and Whitehead 1983, Silber 1986). Source levels average 155 dB and range from 144 to 174 dB (Thompson *et al.* 1979). The songs appear to have an effective range of approximately 10 to 20 km. Assuming that humpback whale vocalizations are partially representative of their hearing sensitivities, we assume that humpback whales are more likely to hear and devote attentional resources to mid-frequency active sonar than blue, fin, or sei whales.

Humpback whales have been observed 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). However, humpback whales do not appear to be as responsive to anthropogenic sounds on their breeding areas, Humpback whales on breeding areas did not stop singing in response to underwater explosions (Payne and McVay 1971) and breeding humpbacks showed only a slight statistical reaction to playbacks of 60 - 90 Hz sounds with a received level of up to 190 dB (Frankel and Clark 1998). We assume that humpback whales engaged in reproductive activity will focus most or all of their attentional resources on vocalizations, other environmental cues, the process of giving birth to calves, or feeding calves that have just been born.

Based on observations of the responses of fin, humpback, and minke whales to anthropogenic sounds in Cape Cod Bay (discussed in the preceding narrative on fin whales) and the other evidence available to us, we would not expect humpback whales to devote attentional resources to the sounds they receive from sonar pings in the 9,538 instances in which humpback whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). Similarly, we would expect humpback whales to hear sonar pings in the 2,311 instances in which they might find themselves between 15 and 36 kilometers from a sonar ping, although we would not expect these whales to devote attentional resources to those sounds for the reasons we just discussed.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect about 1,306 instances (of the 1,640 instances in which humpback whales might occur within 15 kilometers of a sonar ping) in which humpback whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 334 of the 1,640 instances in which humpback whales might occur within 15 kilometers of a sonar ping, we would expect the humpback whale to engage in evasive behavior or change their behavioral state. We would also expect the 1,740 instances in which humpback whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the humpback whales to engage in evasive behavior or change their behavioral state. In both cases, this evasive behavior or changes in behavioral state would represent disruptions of the normal behavioral patterns that are essential to the life history of the individual humpback whales exhibiting these responses.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or under-water detonations, we would not expect humpback whales to be exposed to underwater detonations at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division). However, we would expect one humpback whale to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 182 dB SEL or 23 psi-ms, which NMFS' Permits Division considers as a threshold for Level B "take" or behavioral harassment.

As we discussed, we assume that the humpback whales that might be exposed to stressors associated with U.S. Navy readiness activities on the Mariana Islands Range Complex are members of the population of humpback whales that inhabits the northwest Pacific Ocean. These humpback whales would not only be exposed to readiness activities on the range complex considered in this Opinion, they would also be exposed to readiness activities the U.S. Navy conducts off the Japanese archipelago. As a result, the same individuals would be exposed to low- and mid-frequency active sonar associated with anti-submarine warfare and strike warfare exercises associated with those training exercises. Because we do not have the information we would need to complete exposure analyses, we cannot estimate the number of humpback whales that might be exposed to mid-frequency active sonar during these training exercises; however, we would not expect humpback whales to be exposed to low-frequency active sonar each year during readiness activities the SURTASS LFA sonar system conducts offshore of Japan. Because of the geographic distribution of these humpback whales, however, they are probably exposed to active sonar transmissions associated with training activities conducted by Russian naval forces, the People's Republic of China, the Democratic People's

Republic of Korea, and the Republic of Korea. Individual whales that migrate to the Hawaiian archipelago during the life cycle might also be exposed to low- and mid-frequency active sonar in the Hawai'ian Islands Range Complex.

The humpback whales that are exposed to the training activities in the Mariana Islands Range Complex might not respond to the acoustic cues generated by Navy vessels, while in other circumstances, they are likely to change their surface times, swimming speed, swimming angle or direction, respiration rates, dive times, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães et al. 2002, Richter et al. 2003, Scheidat et al. 2004, Simmonds 2005, Watkins 1986, Williams et al. 2002). Some humpback whales may be less likely to engage in these responses on the Mariana Islands Range Complex if they engage in courtship or reproductive behavior on the Mariana Islands Range Complex because they are less likely to devote attentional resources to sounds associated with U.S. Navy training activities while engaged in those behavioral acts. The humpback whales that are likely to be exposed on the Mariana Islands Range Complex would have had prior experience with similar stressors resulting from their exposure in waters off Japan earlier in the year; that experience will make some humpback whales more likely to avoid activities associated with the training while others would be less likely to engage in avoidance behavior. Some humpback whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship as they engage in avoidance behavior. However, these responses are not likely to reduce the fitness of the humpback whales that occur in the Mariana Islands Range Complex.

In conclusion, we expect 2,074 instances in which individual humpback whales might experience disruptions of their normal behavioral patterns each year as a result of their exposure to mid- or low-frequency active sonar associated with the training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex from June 2010 through June 2015. Because of the short duration of these exposure events relative to the time interval over which humpback whales occur in waters off the Mariana Islands, however, they are not likely to disrupt the behavior patterns of the individual humpback whales to a degree that is likely to reduce the current or expected future reproductive success of the whales involved. Therefore, we would not expect the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex to affect the performance of the populations those humpback whales represent or the species those population comprise. By extension, we would not expect those military readiness activities to appreciably reduce the humpback whales' likelihood of surviving and recovering in the wild.

SEI WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect sei whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect sei whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; two sei whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a sei whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 570 exposure events involving sei whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 65 instances in which sei whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 404 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when sei whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 98 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of the 570 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 20 of the 570 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when sei whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

As discussed in the *Status of the Species* section of this Opinion, we have almost no information on vocalizations produced by sei whales. 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. That is, we assume 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. Furthermore, we assume that sei whale vocalizations are partially representative of their hearing sensitivities so we assume that sei whales are not likely to respond to high-frequency sound sources associated with the proposed training activities because of their hearing sensitivities.

Based on observations of the responses of fin, humpback, and minke whales to anthropogenic sounds in Cape Cod Bay (discussed in the preceding narrative on fin whales) and the other evidence available to us, we would not expect sei whales to devote attentional resources to the sounds they receive from sonar pings in the 404 instances in which sei whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). We assume that sei whales, like blue and fin whales, hear mid-frequency (1 kHz–10 kHz) sounds although sounds in this frequency range lie at the periphery of their hearing range. As a result, we assume that sei whales are less likely to devote attentional resources to stimuli in this frequency range. Similarly, we would not expect sei whales to change their behavioral state when exposed to sonar pings in the 98 instances in which they might find themselves between 15 and 36 kilometers from a sonar transmission, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 55 instances (of the 69 instances in which sei whales might occur within 15 kilometers of a sonar ping) in which sei whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 14 of the 69 instances in which sei whales might occur within 15 kilometers of a sonar ping, we would expect the sei whale to engage in evasive behavior or change their behavioral state. We would also expect the 65 instances in which sei whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the sei whales to engage in evasive behavior or change their behavioral state. In both cases, this evasive behavior or changes in behavioral state would represent disruptions of the normal behavioral patterns that are essential to the life history of the individual sei whales exhibiting these responses.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or underwater detonations, we would not expect sei whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or that would be expected to produce slight lung injury as a result of their exposure.

As we discussed, we assume that the sei whales the might be exposed to stressors associated with U.S. Navy readiness activities on the Mariana Islands Range Complex are members of the population of sei whales that inhabits the northwest Pacific Ocean. These sei whales would not only be exposed to readiness activities on the range complex considered in this Opinion, they would also be exposed to readiness activities the U.S. Navy conducts off the Japanese archipelago. As a result, the same individuals would be exposed to low- and mid-frequency active sonar associated with anti-submarine warfare and strike warfare exercises associated with those training exercises. Because we do not have the information we would need to complete exposure analyses, we cannot estimate the number of sei whales that might be exposed to mid-frequency active sonar during these training exercises; however, we would expect 11 sei whales to be exposed to low-frequency active sonar each year during readiness activities the SURTASS LFA sonar system conducts offshore of Japan. Because of the geographic distribution of these sei whales, they are probably exposed to active sonar transmissions associated with training activities conducted by Russian naval forces, the People's Republic of China, the Democratic People's Republic of Korea, and the Republic of Korea.

The sei whales that are exposed to the training activities in the Mariana Islands Range Complex might not respond to the acoustic cues generated by Navy vessels, while in other circumstances, they are likely to change their surface times, swimming speed, swimming angle or direction, respiration rates, dive times, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães et al. 2002, Richter et al.

2003, Scheidat et al. 2004, Simmonds 2005, Watkins 1986, Williams et al. 2002). Some sei whales may be less likely to engage in these responses on the Mariana Islands Range Complex if they engage in courtship or reproductive behavior on the Mariana Islands Range Complex because they are less likely to devote attentional resources to sounds associated with U.S. Navy training activities while engaged in those behavioral acts. The sei whales that are likely to be exposed on the Mariana Islands Range Complex would have had prior experience with similar stressors resulting from their exposure in waters off Japan earlier in the year; that experience will make some sei whales more likely to avoid activities associated with the training while others would be less likely to engage in avoidance behavior. Some sei whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship as they engage in avoidance behavior. However, these responses are not likely to reduce the fitness of the sei whales that occur in the Mariana Islands Range Complex.

In conclusion, we expect 79 instances in which individual sei whales might experience disruptions of their normal behavioral patterns each year as a result of their exposure to mid- or low-frequency active sonar associated with the training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex from June 2010 through June 2015. Because of the small number of exposure events relative to the number of sei whales that occur in waters off the Mariana Islands and the short duration of the exposure relative to the time interval over which sei whales occur in those waters, however, they are not likely to disrupt the behavior patterns of the individual sei whales to a degree that is likely to reduce the current or expected future reproductive success of the whales involved. Therefore, we would not expect the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex to affect the performance of the populations those sei whales represent or the species those population comprise. By extension, we would not expect those military readiness activities to appreciably reduce the sei whales' likelihood of surviving and recovering in the wild.

SPERM WHALE. Based on the results of our exposure analyses, each winter over the five-year period between June 2010 and June 2015, we would expect sperm whales to be exposed to vessel traffic associated with U.S. Navy training exercises, low- and mid-frequency active sonar, and pressure waves and sound fields associated with underwater detonations on the Mariana Islands Range Complex. Because of a migratory habit that takes them to foraging areas further north in the North Pacific Ocean off the Kamchatka Peninsula, Aleutian Islands, and in the Bering Sea, we would not expect sperm whales to occur on the Mariana Islands Range Complex during the summer months (mid-May though mid-November) so they are not likely to be exposed to training activities that occurred on the range complex during that time interval.

Assuming that whales that occur within 560 meters (1,968 feet) of Navy vessels moving at speeds greater than 14 knots would have some risk of being struck by the vessel; 60 sperm whales might would occur close enough to a Navy vessel that is underway to have some risk of being struck. Nevertheless, the low frequency of collisions between ships and large whales on the Mariana Range Complex suggests that a collision is not likely to when these whales occurs this close to a Navy vessel. As a result, the evidence available does not lead us to expect a sperm whale to be struck by a Navy vessel on the Mariana Islands Range Complex over the five-year period between June 2010 and June 2015.

Based on the results of our exposure analyses, each year we would expect about 15,186 exposure events involving sperm whales to result from the 184 hours of training the U.S. Navy plans to conduct with AN/SQS-53, the 32 hours of training with AN/SQS-56, the 157 hours of training with AN/AQS-22, and the 6 hours of training with AN/BQQ-10 on the Mariana Islands Range Complex during the winter months (from mid-November through mid-May). During each winter of the five-year period between June 2010 and June 2015, we would also expect about 153 instances in which sperm whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex.

Of the exposure events involving mid-frequency active sonar, about 10,747 exposure events (about 71 percent) would occur at received levels of lower than 140 dB, when sperm whales would occur between 36 and 125 kilometers (between about 22 and 78 miles) from the source of a sonar ping. Another 2,604 of these exposure events (about 17 percent) would occur at received levels between 140 and 150 dB or distances between 15 and 36 kilometers (between about 9.3 and 22.4 miles) from the source of a sonar ping. In total, we would expect about 87 percent of the 570 exposure events to occur at received levels less than 150 dB and distances greater than 15 kilometers from a sonar source. About 534 of the 15,186 exposure events (about 3.6 percent) would occur at received levels between 160 and greater than 190 dB, when sperm whales would occur within 5 kilometers (about 3.1 miles) of the source of a sonar ping.

If exposed to mid-frequency sonar transmissions, sperm whales are likely to hear and respond to those transmissions. The only data on the hearing range of sperm whales are evoked potentials from a stranded neonate (Carder and Ridgway 1990). These data suggest that neonatal sperm whales respond to sounds from 2.5-60 kHz. Sperm whales also produce loud broad-band clicks from about 0.1 to 20 kHz (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995). These clicks were estimated to have source levels at 171 dB re 1 μPa (Levenson 1974). Current evidence suggests that the disproportionately large heads of sperm whales are adaptations that allow them to produce these vocalizations (Norris and Harvey 1972; Cranford 1992; but see Clarke 1979). This suggests that the production of these loud low-frequency clicks is extremely important to the survival of individual sperm whales. The function of these vocalizations is relatively well-studied (Weilgart and Whitehead 1993, 1997; Goold and Jones 1995): long series of monotonous regularly spaced clicks are associated with feeding and are thought to help sperm whales echolocate while the 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, sonar transmissions might temporarily reduce the active space of sperm whale vocalizations. Most of the energy of sperm whales clicks is concentrated at 2 to 4 kHz and 10 to 16 kHz, which overlaps with the mid-frequency sonar. Other studies indicate sperm whales' wide-band clicks contain energy between 0.1 and 20 kHz (Weilgart and Whitehead 1993, Goold and Jones 1995). Ridgway and Carder (2001) measured low-frequency, high amplitude clicks with peak frequencies at 500 Hz to 3 kHz from a neonate sperm whale.

There is some evidence of disruptions of clicking and behavior from sonars (Goold 1999, Watkins and Scheville1975, Watkins *et al.* 1985), pingers (Watkins and Scheville 1975), the Heard Island Feasability Test (Bowles *et al.* 1994), and the Acoustic Thermometry of Ocean Climate (Costa *et al.*1998). Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders (Watkins and

Scheville 1975). Goold (1999) reported six sperm whales that were driven through a narrow channel using ship noise, echosounder, and fishfinder emissions from a flotilla of 10 vessels. Watkins and Scheville (1975) showed that sperm whales interrupted click production in response to pinger (6 to 13 kHz) sounds. They also stopped vocalizing for brief periods when codas were being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

As discussed previously, sperm whales have been reported to have reacted to military sonar, apparently produced by a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins *et al.* 1985). Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 sec pulsed sounds at frequencies similar to those emitted by multi-beam sonar that is used in geophysical surveys (Ridgway *et al.* 1997, Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000, Finneran *et al.* 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.* 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.* 1997, Schlundt *et al.* 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans some-times avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

Published reports identify instances in which sperm whales have responded to an acoustic source and other instances in which they did not appear to respond behaviorally when exposed to seismic surveys. Mate *et al.* (1994) reported an opportunistic observation of the number of sperm whales to have decreased in an area after the start of airgun seismic testing. However, Davis *et al.* (2000) noted that sighting frequency did not differ significantly among the different acoustic levels examined in the northern Gulf of Mexico, contrary to what Mate *et al.* (1994) reported. In one DTAG deployment in the northern Gulf of Mexico on July 28, 2001, researchers documented that the tagged whale moved away from an operating seismic vessel once the seismic pulses were received at the tag at roughly 137 dB re 1 μPa (Johnson and Miller 2002). Sperm whales may also have responded to seismic airgun sounds by ceasing to call during some (but not all) times when seismic pulses were received from an airgun array >300 km away (Bowles *et al.* 1994).

A recent study offshore of northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa peak-to-peak (Madsen *et al.* 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale sounds at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). Recent data from vessel-based monitoring programs in United Kingdom waters suggest that sperm whales in that area may have exhibited some changes in behavior in the presence of operating seismic vessels (Stone 1997, 1998, 2000, 2001, 2003). However, the compilation and analysis of the data led the author to conclude that seismic surveys did not result in observable effects to sperm whales (Stone

2003). The results from these waters seem to show that some sperm whales tolerate seismic surveys.

Sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins and Schevill 1975; Watkins *et al.* 1985). They also stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995).

Preliminary data from an experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico and a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys show that during two controlled exposure experiments in which sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa over octave band with most energy, the whales did not avoid the vessel or change their feeding efficiency (National Science Foundation 2003). Although the sample size is small (4 whales in 2 experiments), the results are consistent with those off northern Norway.

Other studies identify instances in which sperm whales did not respond to anthropogenic sounds. Sperm whales did not alter their vocal activity when exposed to levels of 173 dB re 1 μPa from impulsive sounds produced by 1 g TNT detonators (Madsen and Mohl 2000). Richardson *et al.* (1995) citing a personal communication with J. Gordon suggested that sperm whales in the Mediterranean Sea continued calling when exposed to frequent and strong military sonar signals. When Andre *et al.* (1997) exposed sperm whales to a variety of sounds to determine what sounds may be used to scare whales out of the path of vessels, sperm whales were observed to have startle reactions to 10 kHz pulses (180 db re 1 μPa at the source), but not to the other sources played to them.

These studies suggest that the behavioral responses of sperm whales to anthropogenic sounds are highly variable, but do not appear to result in the death or injury of individual whales or result in reductions in the fitness of individuals involved. Responses of sperm whales to anthropogenic sounds probably depend on the age and sex of animals being exposed, as well as other factors. There is evidence that many individuals respond to certain sound sources, provided the received level is high enough to evoke a response, while other individuals do not.

Based on observations of the responses of fin, humpback, and minke whales to anthropogenic sounds in Cape Cod Bay (discussed in the narrative on fin whales) and the other evidence available to us, we would not expect sperm whales to devote attentional resources to the sounds they receive from sonar pings in the 10,734 instances in which sperm whales might find themselves between 36 and 125 kilometers from the source of a mid-frequency active sonar, even though received levels might be as high as 140 dB (at 36 kilometers). Similarly, we would not expect sperm whales to change their behavioral state when exposed to sonar pings in the 2,601 instances in which they might find themselves between 15 and 36 kilometers from a sonar transmission, despite being exposed to received levels ranging from 140 and 150 dB; these whales might engage in low-level avoidance behavior or short-term vigilance behavior.

Based on our review of the relative frequency of physical, physiological, and behavioral responses of cetaceans that have been exposed to active sonar, we would expect 1,461 instances (of the 1,835 instances in which sperm whales might occur within 15 kilometers of a sonar ping) in which sperm whales either ignore the stimulus, change their location to avoid continued exposure to the sound, make vocal adjustments to calls or other vocalizations (for example, increasing the amplitude or repetition rates of their vocalizations or the timing of their vocalization), or engage in minor changes in their behavior. In 374 of the 1.835 instances in which sperm whales might occur within 15 kilometers of a sonar ping, we would expect the sperm whale to engage in evasive behavior or change their behavioral state. We would also expect the 153 instances in which sperm whales might be exposed to SURTASS LFA sonar transmissions at received levels between 120 and 180 dB on the Mariana Range Complex to cause the sperm whales to engage in evasive behavior or change their behavioral state. In both cases, this evasive behavior or changes in behavioral state would represent disruptions of the normal behavioral patterns that are essential to the life history of the individual sperm whales exhibiting these responses.

Because of the mitigation measures the U.S. Navy plans to employ before engaging in sinking exercises or under-water detonations, we would not expect sperm whales to be exposed to underwater detonations at received levels that would be expected to cause them experience them to experience 50 percent tympanic membrane rupture or at received levels that would be expected to produce slight lung injury as a result of their exposure (these two received levels are considered thresholds for Level A "take" or injury by NMFS' Permits Division). However, we would expect three sperm whales to be exposed to underwater detonations on the Mariana Islands Range Complex at received levels greater than or equal to 182 dB SEL or 23 psi-ms, which NMFS' Permits Division considers as a threshold for Level B "take" or behavioral harassment.

As we discussed, we assume that the sperm whales the might be exposed to stressors associated with U.S. Navy readiness activities on the Mariana Islands Range Complex are members of the population of sperm whales that inhabits the northwest Pacific Ocean. These sperm whales would not only be exposed to readiness activities on the range complex considered in this Opinion, they would also be exposed to readiness activities the U.S. Navy conducts off the Japanese archipelago, as well as training activities conducted by Russian naval forces, the People's Republic of China, the Democratic People's Republic of Korea, and the Republic of Korea. As a result, the same individuals would be exposed to low- and mid-frequency active sonar associated with anti-submarine warfare and strike warfare exercises associated with those training exercises. Because we do not have the information we would need to complete exposure analyses, we cannot estimate the number of sperm whales that might be exposed to mid-frequency active sonar during these training exercises; however, we would expect 10 instances in which sperm whales might be exposed to low-frequency active sonar at received levels that might change their behavioral state.

The sperm whales that are exposed to the training activities in the Mariana Islands Range Complex might not respond to the acoustic cues generated by Navy vessels, while in other circumstances, they are likely to change their surface times, swimming speed, swimming angle or direction, respiration rates, dive times, and social interactions (Amaral and Carlson 2005; Au and Green 2000, Cockeron 1995, Erbe 2002, Félix 2001, Magalhães et al. 2002, Richter et al. 2003, Scheidat et al. 2004, Simmonds 2005, Watkins 1986, Williams et al. 2002). Some sperm whales may be less likely to engage in these responses on the Mariana Islands Range Complex if they engage in courtship or reproductive behavior on the Mariana Islands Range Complex because they are less likely to devote attentional resources to sounds associated with U.S. Navy training activities while engaged in those behavioral acts. The sperm whales that are likely to be exposed on the Mariana Islands Range Complex would have had prior experience with similar stressors resulting from their exposure in waters off Japan earlier in the year; that experience will make some sperm whales more likely to avoid activities associated with the training while others would be less likely to engage in avoidance behavior. Some sperm whales might experience physiological stress (but not "distress") responses if they attempt to avoid one ship and encounter a second ship as they engage in avoidance behavior. However, these responses are not likely to reduce the fitness of the sperm whales that occur in the Mariana Islands Range Complex.

In conclusion, we expect 527 instances in which individual sperm whales might experience disruptions of their normal behavioral patterns each year as a result of their exposure to mid- or low-frequency active sonar associated with the training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex from June 2010 through June 2015. Because of the small number of exposure events relative to the number of sperm whales that occur in waters off the Mariana Islands and the short duration of the exposure relative to the time interval over which sperm whales occur in those waters, however, they are not likely to disrupt the behavior patterns of the individual sperm whales to a degree that is likely to reduce the current or expected future reproductive success of the whales involved. Therefore, we would not expect the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex to affect the performance of the populations those sperm whales represent or the species those population comprise. By extension, we would not expect those military readiness activities to appreciably reduce the sperm whales' likelihood of surviving and recovering in the wild.

GREEN SEA TURTLES. Because they tend to occur near the coast of islands in the Mariana Islands archipelago, green sea turtles are not likely to be exposed to stressors associated with air warfare or electronic combat, surface warfare, or joint multi-strike group exercises, which would occur more than 12 nautical miles from land (with the exception of small arms gunnery exercises),

The primary site for the amphibious assault (Marine Air Ground Task Force) exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Unai Chulu Beach on the island of Tinian where green sea turtles are likely to nest. This beach is a secondary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Adult green sea turtles that might arrive on this beach to nest would be potentially exposed to human disturbance associated with these training activities; any nests that might occur on this beach during such an exercise has some probably of being trampled or destroyed.

Apra Harbor is a primary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. This harbor is a secondary site for the amphibious assaults (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Although green sea turtles are not known to nest in this area, they forage and rest in several areas of the harbor and are likely to be exposed to human disturbance associated with these training activities.

Because of the distance between the locations in which the U.S. Navy is likely to conduct anti-submarine warfare exercises, joint multi-strike group exercises, sinking exercises and operate SURTASS LFA sonar and the coastal locations in which green sea turtles are most likely to occur, the majority of the green sea turtles that occur in the Mariana Islands archipelago are not likely to be exposed to active sonar transmissions or the sounds of underwater detonations associated with these training activities. Because they tend to remain in relatively shallow coastal waters where sounds produced by rain, wind, and waves, juvenile, sub-adult, and nesting adult green sea turtles are not likely to be aware of energy produced by mid-frequency active sonar from these training activities.

However, because the primary site for the floating mine neutralization and underwater demolition exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Agat Bay on Guam where green sea turtles are likely to forage and rest, these sea turtles would have some risk of being exposed to pressure waves and sound fields associated with these training exercises. Nevertheless, because the U.S. Navy proposes to establish 700-yard (640 meters or about 2,100 feet) exclusion zones for sea turtles (and marine mammals) for all mine warfare and mine countermeasure training activities, green sea turtles are not likely to be exposed to pressure waves at pressures that are likely to cause them physical trauma or other injury.

Klima *et. al.* (1988) conducted an experiment in which Kemp's ridley and loggerhead turtles were placed in cages at four distances from a oil platform to be removed with explosives. The cages were submerged to a depth of 4.52 meters (15 feet) over the 9 meter (30 foot) 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 4.88 meters (16 feet) below the mudline. Loggerhead and Kemp's ridley turtles at 228.6 meters (750 feet) and 365 meters (1,200 feet), as well as one loggerhead at 914 meters (3,000 feet) were rendered unconscious. The Kemp's ridley turtle closest to the explosion (range of 228.6 meters) was slightly injured, with an everted cloacal lining; ridleys at ranges of 365 meters, 546 meters, and 914 meters 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 36.6 meters (120 feet) deep. At least three turtles were noted in the area following the detonations. One turtle at a range of 152 to 213 meters (500 to 700 feet) was killed. A second turtle at a range of 365 meters received minor injuries. A third turtle at 609.6 meters (2,000 feet) was apparently unaffected. At a depth of 18 meters (60 feet), calculated shock wave pressures were 239, 161, 85, and 47 psi at ranges of 152, 213, 365, and 609.6 meters, respectively.

Based on a parametric evaluation of the effects of charge weight and depth using the Goertner (1982) model, Young (1991) concluded that a conservative safe range for non-injury to a small mammal (representative of a dolphin calf) was approximated by $R=578w^{0.28}$ (*R* is in feet and *w* is in pounds of explosive). O'Keeffe and Young (1984) proposed that a safe range for turtles from an underwater explosion could be expressed by $R = 200\ w^{1/3}$. 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 $R = 560\ w^{1/3}$. Assuming that the U.S. Navy proposes to detonation 5 to 20 lb charges (NEW) during mine neutralization or underwater demolition exercises, the equation proposed by O'Keefe and Young (1984) would produce safe ranges of 104.24 meters (for 5 lb charges) and 165.47 meters (for 20 lb charges). The modified equation proposed by Young (1991) would produce safe ranges of 291.87 meters (for 5 lb charges) and 463.32 meters (for 20 lb charges). The U.S. Navy proposes to use a safe range of 640 meters, which is more than 27 percent greater than the largest of these safe ranges and is greater than the distance at which sea turtles appeared to have been unaffected by the detonations conducted at Panama City. As a result, we would conclude that green sea turtles are not likely to experience physical injury, physiological stress responses, or changes in behavioral states as a result of being exposed to pressure waves associated with underwater detonations on the Mariana Islands Range Complex.

Green sea turtles that occur on the Mariana Islands Range Complex might encounter one or more of the parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. 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 green sea turtles on the open-water areas of the range complex.

Nevertheless, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex each year from June 2010 through June 2015 are not likely to interact with sufficient number of adult or sub-adult green sea turtles, if they interact with green sea turtles at all, to reduce the viability of the nesting aggregations those green 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 sea turtles surviving and recovering in the wild by reducing their reproduction, numbers, or distribution.

HAWKSBILL SEA TURTLE. Because they tend to occur near the coast of islands in the Mariana Islands archipelago, hawksbill sea turtles are not likely to be exposed to stressors associated with air warfare or electronic combat, surface warfare, or joint multi-strike group exercises, which would occur more than 12 nautical miles from land (with the exception of small arms gunnery exercises),

Apra Harbor is a secondary site for the amphibious raids (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. This harbor is a secondary site for the amphibious assaults (Marine Air Ground Task Force) the U.S. Navy proposes to conduct on the Mariana Islands Range Complex. Although hawksbill sea turtles are not known to nest in this area, they forage and rest in several areas of the harbor and are likely to be exposed to human disturbance associated with these training activities.

Because of the distance between the locations in which the U.S. Navy is likely to conduct anti-submarine warfare exercises, joint multi-strike group exercises, sinking exercises and operate SURTASS LFA sonar and the coastal locations in which hawksbill sea turtles are most likely to occur, the majority of the hawksbill sea turtles that occur in the Mariana Islands archipelago are not likely to be exposed to active sonar transmissions or the sounds of underwater detonations associated with these training activities. Because they tend to remain in relatively shallow coastal waters where sounds produced by rain, wind, and waves, juvenile, sub-adult, and nesting adult hawksbill sea turtles are not likely to be aware of energy produced by mid-frequency active sonar from these training activities.

However, because the primary site for the floating mine neutralization and underwater demolition exercises the U.S. Navy proposes to conduct on the Mariana Islands Range Complex is Agat Bay on Guam where hawksbill sea turtles are likely to forage and rest, these sea turtles would have some risk of being exposed to shock waves and sound fields associated with these training exercises. Nevertheless, because the U.S. Navy proposes to establish 700-yard (640 meters or about 2,100 feet) exclusion zones for sea turtles (and marine mammals) for all mine warfare and mine countermeasure training activities, hawksbill sea turtles are not likely to be exposed to pressure waves at pressures that are likely to cause them physical trauma or other injury.

Klima *et. al.* (1988) conducted an experiment in which Kemp's ridley and loggerhead turtles were placed in cages at four distances from a oil platform to be removed with explosives. The cages were submerged to a depth of 4.52 meters (15 feet) over the 9 meter (30 foot) 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 4.88 meters (16 feet) below the mudline. Loggerhead and Kemp's ridley turtles at 228.6 meters (750 feet) and 365 meters (1,200 feet), as well as one loggerhead at 914 meters (3,000 feet) were rendered unconscious. The Kemp's ridley turtle closest to the explosion (range of 228.6 meters) was slightly injured, with an everted cloacal lining; ridleys at ranges of 365 meters, 546 meters, and 914 meters 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 36.6 meters (120 feet) deep. At least three turtles were noted in the area following the detonations. One turtle at a range of 152 to 213 meters (500 to 700 feet) was killed. A second turtle at a range of 365 meters received minor injuries. A third turtle at 609.6 meters (2,000 feet) was apparently unaffected. At a depth of 18 meters (60 feet), calculated shock wave pressures were 239, 161, 85, and 47 psi at ranges of 152, 213, 365, and 609.6 meters, respectively.

Based on a parametric evaluation of the effects of charge weight and depth using the Goertner (1982) model, Young (1991) concluded that a conservative safe range for non-injury to a small mammal (representative of a dolphin calf) was approximated by $R=578w^{0.28}$ (*R* is in feet and *w* is in pounds of explosive). O'Keeffe and Young (1984) proposed that a safe range for turtles from an underwater explosion could be expressed by $R = 200\ w^{1/3}$. 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 $R = 560\ w^{1/3}$. Assuming that the U.S. Navy proposes to detonation 5 to 20 lb charges (NEW) during mine neutralization or underwater demolition exercises, the equation proposed by O'Keefe and Young (1984) would produce safe ranges of 104.24 meters (for 5 lb charges) and 165.47 meters (for 20 lb charges). The modified equation proposed by Young (1991) would produce safe ranges of 291.87 meters (for 5 lb charges) and 463.32 meters (for 20 lb charges). The U.S. Navy proposes to use a safe range of 640 meters, which is more than 27 percent greater than the largest of these safe ranges and is greater than the distance at which sea turtles appeared to have been unaffected by the detonations conducted at Panama City. As a result, we would conclude that hawksbill sea turtles are not likely to experience physical injury, physiological stress responses, or changes in behavioral states as a result of being exposed to pressure waves associated with underwater detonations on the Mariana Islands Range Complex.

Hawksbill sea turtles that occur on the Mariana Islands Range Complex might encounter one or more of the parachutes after they have been jettisoned from these sonobuoys and could become entangled as a result. 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 hawksbill sea turtles on the open-water areas of the range complex.

Nevertheless, we conclude that training exercises and other activities the U.S. Navy plans to conduct in the Mariana Islands Range Complex each year from June 2010 through June 2015 are not likely to interact with sufficient number of adult or sub-adult hawksbill sea turtles, if they interact with hawksbill sea turtles at all, to reduce the viability of the nesting aggregations those hawksbill 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 hawksbill sea turtles surviving and recovering in the wild by reducing their reproduction, numbers, or distribution.

7.0 CONCLUSION

After reviewing the current status of blue whales, fin whales, humpback whales, sei whales, sperm whales, green sea turtles, and hawksbill sea turtles, the environmental baseline for the action area, the effects of the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex each year for a five-year period beginning in June 2010 and for which the Permits Division's proposal to promulgate MMPA regulations, and the cumulative effects, it is NMFS' biological opinion that the Navy's proposed activities are likely to adversely affect but are not likely to jeopardize the continued existence of these threatened and endangered species under NMFS jurisdiction.

Because critical habitat that has been designated for endangered or threatened species does not occur in the action area, it is not likely to be adversely affected by the military readiness activities the U.S. Navy proposes to conduct on the Mariana Islands Range Complex.

8.0 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibits the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2) of the ESA, taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of an Incidental Take Statement.

The National Marine Fisheries Service is not including a statement that would exempt the take of endangered or threatened species incidental to the military readiness activities the U.S. Navy proposes to conduct on the Mariana Island Range Complex from the prohibitions of section 9 of the ESA in this Opinion. There are two reasons for this. First, the incidental take of marine mammals has not been authorized pursuant to section 101(a)(5) of the Marine Mammal Protection Act of 1972, as amended; the National Marine Fisheries Service's Permits, Conservation, and Education Division plans to issue annual Letters of Authorization that would authorize the U.S. Navy to "take" marine mammals pursuant to the MMPA. The National Marine Fisheries Service generally treats those Letters of Authorization as actions for the purposes of section 7(a)(2) of the ESA; therefore, we complete section 7 consultations on the issuance of those Letters of Authorization, and may issue biological opinions at the conclusion of those consultations that would include incidental take statements for the endangered and threatened marine mammals, as appropriate.

Second, the military readiness activities and MMPA regulations described in this Opinion and that we concluded are not likely to jeopardize the continued existence of endangered or threatened species and are not likely to result in the destruction or adverse modification of critical habitat that has been designated for those species represent the maximum number, frequency, duration, and intensity that would occur in any of the five years between June 2010 and June 2015. In any particular year, however, the U.S. Navy might alter the number, timing, frequency, duration, location, and intensity of the activities they plan to conduct on the Mariana Islands Range Complex or the measures they plan to employ to mitigate the effects of their training on living marine resources. For example, in the past, such changes have reduced the number of endangered or threatened species that we would expect to be "taken" as a result. Deferring the issuance of an incidental take statement until we complete formal consultation on annual letters of authorization also allow us to insure that our incidental take statements reflect the amount or extent of take that we actually expect to occur in any particular year and to insure that any terms and conditions we include in incidental take statements address the needs of all endangered or threatened species that might be "taken" as a result of U.S. Navy military readiness activities and MMPA authorizations.

9.0 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

The following conservation recommendations would provide information for future consultations involving the issuance of marine mammal permits that may affect endangered whales as well as reduce harassment related to research activities:

1. *Cumulative Impact Analysis.* The U.S. Navy should work with NMFS Endangered Species Division and other relevant stakeholders (the Marine Mammal Commission, International Whaling Commission, and the marine mammal research community) to develop a method for assessing the cumulative impacts of anthropogenic noise on cetaceans, pinnipeds, sea turtles, and other marine animals. This includes the cumulative impacts on the distribution, abundance, and the physiological, behavioral and social ecology of these species.

In order to keep NMFS Endangered Species Division informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Permits, Conservation and Education Division of the Office of Protected Resources should notify the Endangered Species Division of any conservation recommendations they implement in their final action.

10.0 REINITIATION NOTICE

This concludes formal consultation on military readiness activities the U.S. Navy's Pacific Fleet plans to conduct on the Mariana Islands Range Complex and the National Marine Fisheries Service's Permits, Conservation, and Education Division's proposal to promulgate regulations that would allow them to authorize the U.S. Navy to "take" marine mammals incidental to this training. As provided in 50 CFR 402.16, reinitiation of formal consultation is normally 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, Action Agencies are normally required to reinitiate section 7 consultation immediately. However, because this Biological Opinion did not exempt any "take" of endangered or threatened species, any "take" of endangered or threatened species that might result from the proposed training activities will be considered in subsequent biological opinions that accompany any Letters of Authorization the National Marine Fisheries Service issues on the proposed training activities.

11 Literature Cited

Adler-Fenchel, H.S. 1980. Acoustically derived estimate of the size distribution for a sample of sperm whales (*Physeter catodon*) in the Western North Atlantic. Canadian Journal of Fisheries and Aquatic Sciences 37:2358-2361.

Advanced Research Projects Agency, and NOAA, National Marine Fisheries Service. 1995. Final Environmental Impact Statement/Environmental Impact Report for the Kauai Acoustic Thermometry of Ocean Climate Project and its associated Marine Mammal Research Program, Vols. I and II. Advanced Research Projects Agency, Arlington, Virginia; NOAA, National Marine Fisheries Service, Silver Spring, Maryland.

Agler, B.A., R.L. Schooley, S.E. Frohock, S.K. Katona, and I.E. Seipt. 1993. Reproduction of photographically identified fin whales, *Balaenoptera physalus*, from the Gulf of Maine. Journal of Mammology 74:577-587.

Aguayo L.A. 1974. Baleen whales off continental Chile. Pages 209-217. In: W.E. Schevill (editor) The whale problem: a status report. Harvard University Press, Cambridge, Massachusetts.

Aguilar, A., and C. Lockyer. 1987. Growth, physical maturity, and mortality of fin whales (*Balaenoptera physalus*) inhabiting the temperate waters of the northeast Atlantic. Canadian Journal of Zoology 65:253-264.

Aicken, W., E. Clements, E. Harland, S. Healy, G. Smith, P. Ward, C. MacLeod, and C. Pierpont. 2005. STUFT2 Trial: Environmental protection data analysis report. Unpublished reported prepared by QuinetiQ Limited for the United Kingdom Ministry of Defense. QuinetiQ Limited, Hampshire, United Kingdom.

Allen, K.R. 1980. Conservation and management of whales. University of Washington Press, Seattle; Washington.

Anderson, J. J. 2000. A vitality-based model relating stressors and environmental properties to organism survival. Ecological Monographs 70:445-470.

Andrews, R.C. 1916. The sei whale (*Balaenoptera borealis* Lesson). Memoirs of the American Museum of Natural History New Series 1(6):291-388.

Angliss, R. P., and R. B. Outlaw. 2007. Alaska marine mammal stock assessments, 2006. NOAA Technical Memorandum NMFS-ASFC-168, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, Washington.

Anisman, H., and Z. Merali. 1999. Understanding stress: characteristics and caveats. Alcholol Research & Health **23**:241-249.

Anonymous. 2001. Report of the workshop on status and trends of Western North Atlantic right whales. Journal of Cetacean Research and Management Supplement 2:61 - 87.

Anonymous. 2001. Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. Journal of Cetacean Research and Management Supplement 2:1 - 60.

Ashford, J.R. and A.R. Martin. Interactions between cetaceans and longline fishery operations around South Georgia. Marine Mammal Science 12(3):452-457.

Atkins, N., and S. L. Swartz (eds.). 1989. Proceedings of the workshop to review and evaluate whale watching programs and management needs. November 14-16, 1988, Monterey, California. Center for Marine Conservation., Washington D.C.

Au, W. W. L. 1997. Some hot topics in animal bioacoustics. The Journal of the Acoustical Society of America 101:10.

Au, W. W. L., A. Frankel, D. A. Helweg, and D. H. Cato. 2001. Against the humpback whale sonar hypothesis. IEEE Journal of Oceanic Engineering 26:5.

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

Au, W. W. L., and K. J. Benoit-Bird. 2003. Automatic gain control in the echolocation system of dolphins. Nature 423:861-863.

Au, W. W. L., and P. E. Nachtigall. 1997. Acoustics of echolocating dolphins and small whales. Marine Behaviour and Physiology 29:36.

Au, W. W. L., L. N. Andersen, A. R. Rasmussen, H. L. Roitblat, and P. E. Nachtigall. 1995. Neural network modeling of a dolphin's sonar discrimination capabilities. The Journal of the Acoustical Society of America 98:8.

Au, W., and M. Green. 2000. Acoustic interaction of humpback whales and whale-watching boats. Marine Environmental Research 49:469-481.

Au, W.W.L., P. Nachtigall, and J.L. Pawloski. 1997. Acoustic effects of the ATOC signal (75 Hz, 195 dB) on dolphins and whales. Journal of the Acoustical Society of America 101:2973-2977.

Backus, R.H. and W.E. Schevill. 1966. Physeter clicks. p.510-528 In: K.S. Norris (editor) Whales, Dolphins, and Porpoises. University of California Press; Berkeley, California.

Baker, C.S. L.M. Herman, B.G. Bays and G.B. Bauer. 1983. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1982 season. Report submitted to the National Marine Mammal Laboratory, Seattle, Washington.

Balcomb, K.C. 1987. The whales of Hawai'i, including all species of marine mammals in Hawai'ian and adjacent waters. Marine Mammal Fund Publication; San Francisco, California.

Bannister, J.L. and E. Mitchell. 1980. North Pacific sperm whale stock identity: distributional evidence from Maury and Townsend charts. Reports of the International Whaling Commission Special Issue No. 2: 219-223

Barlow, J. 1994. Abundance of large whales in California coastal waters: a comparison of ship surveys in 1979/80 and in 1991. Report of the International Whaling Commission 44. 399-406.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall 1991. Fishery Bulletin 93: 1-14.

Barlow, J., K. A. Forney, P. S. Hill, R. L. Brownell, Jr., J. V. Carretta, D. P. DeMaster, F. Julian, M. S. Lowry, T. Ragen, and R. R. Reeves. 1997. U.S. Pacific marine mammal stock assessment: 1996. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-248. Southwest Fisheries Science Center; La Jolla, California.

Barlow, J., R.L. Brownell, D.P. DeMaster, K.A. Forney, M.S. Lowry, S. Osmek, T.J. Ragen, R.R. Reeves, and R.J. Small. 1995. U.S. Pacific marine mammal stock assessments 1995. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-219. La Jolla, California.

Barthol, S.M., J. Musick, and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). Copeia 1999(3): 836-840.

Bauer, G.B. 1986. The behavior of humpback whales in Hawai'i and modification of behavior induced by human interventions. Unpublished doctoral dissertation; University of Hawai'i, Honolulu.

Bauer, G.B. and L.M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawai'i. Report Submitted to NMFS Southwest Region, Western Pacific Program Office; Honolulu, Hawai'i.

Beach, D.W., and M.T. Weinrich. 1989. Watching the whales: Is an educational adventure for humans turning out to be another threat for endangered species? Oceanus 32(1):84-88.

Beale, C. M., and P. Monaghan. 2004. Human disturbance: people as predation-free predators? Journal of Applied Ecology 41:335-343.

Blumstein, D. T., and A. Bouskila. 1996. Assessment and decision making in animals: a mechanistic model underlying behavioral flexibility can prevent ambiguity. Oikos **77**:569-576.

Botteldooren, D., B. De Coensel, B. Berglund, and M. E. Nilsson. 2008. Modeling the role of attention in the assessment of environmental noise annoyance. *in* 9th International Congress on Noise as a Public Health Problem, July 21-25 2008, Mashantucket, Connecticut.

Bowles, A.E., M. Smultea, B. Wursig, D.P. DeMaster, D. Palka. 1994. Abundance of marine mammals exposed to transmissions from the Heard Island Feasibility Test. Journal of the Acoustical Society of America 96(4):2469-2482.

Bregman, A. S. 1990. Auditory scene analysis. The perceptual organization of sound. The MIT Press, Cambridge, Massachusetts.

Buck, J.R., and P.L. Tyack. 2000. Response of gray whales to low-frequency sound. Journal of the Acoustical Society of America 107 (5): 2744.

Carder, D.A. and S.H. Ridgway. 1990. Auditory brainstem response in a neonatal sperm whale Physeter spp. Journal of the Acoustical Society of America Supplement 1:88.

Carretta, J.V., and K.A. Forney. 1993. Report on two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter aircraft: March 9- April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS-SWFSC-185; La Jolla, California.

Caswell, H. 1980. On the equivalence of maximizing reproductive value and maximizing fitness. Ecology 6:19-24.

Caswell, H. 1982. Optimal life histories and the maximization of reproductive value: a general theorem for complex life cycles. Ecology 63:1218-1222.

Caswell, H. 2001, Matrix population models. Sunderland, Massachusetts, Sinauer Publishers, Inc.

Cato, D.H. and R.C. McCauley. 2001. Ocean ambient noise from anthropogenic and natural sources in the context of marine mammal acoustics. Journal of the Acoustical Society of America 110: 2751.

Charif, R.A., D.K. Mellinger, K.J. Dunsmore, and C.W. Clark. Submitted. Source levels and depths of fin whale (*Balaenoptera physalus*) vocalizations from the eastern North Pacific.

Cherfas, J. 1989. The Hunting of the Whale. Viking Penguin Inc.; New York, New York.

Clapham, P. J., S. B. Young, and R. L. Brownell, Jr. 1999. Baleen whales: Conservation issues and the status of the most endangered populations. Mammal Review 29:35-60.

Clapham, P.J. and D.K. Mattila. 1993. Reaction of humpback whales to skin biopsy sampling on a West Indies breeding ground. Marine Mammal Science, 9(4):382-391.

Clapham, P.J., and R.L. Brownell, Jr. 1996. Potential for interspecific competition in baleen whales. Reports of the International Whaling Commission 46:361-367.

Clark, C.W. and K.M. Firstrup. 2001. Baleen whale responses to low-frequency human-made underwater sounds. Journal of the Acoustical Society of America 110: 2751.

Clark, C.W. and K.M. Fristrup. 1997. Whales '95: A combined visual and acoustic survey of blue and fin whales off southern California. Reports of the International Whaling Commission 47: 583-600.

Clark, C.W., C.J. Gagnon and D.K. Mellinger. 1993. Whales '93: Application of the Navy IUSS for low-frequency marine mammal research. Invited paper, abstract published in Tenth Biennial conference on the Biology of Marine Mammals abstracts, 11-15 November 1993, Galveston, Texas. (Abstract)

Clark, C.W., Tyack P., Ellison W.T. 1998. Low-frequency sound scientific research program. Phase I: Responses of blue and fin whales to SURTASS LFA, southern California Bight. Quick Look Report. Marine Acoustics Inc.; Washington, D.C.

Clarke, J.T. and S.A. Norman. 2005. Results and evaluation of the US Navy shock trial environmental mitigation of marine mammals and sea turtles. Journal of Cetacean Research and Management 7: 43 – 50.

Clarke, M.R. 1976. Observation on sperm whale diving. Journal of the Marine Biology Association UK 56: 809-810.

Clarke, M.R. 1979. The head of the sperm whale. Scientific American 240(1): 106-117.

Clarke, R. 1956. Sperm whales of the Azores. Discovery Reports 28, 237-298.

Conner, R.C. and R.S. Smolker. 1985. Habituated dolphins (*Tursiops* sp.) in western Australia. Journal of Mammalogy 66(2):398-400.

Cox, T. M., T. J. Ragen, A. J. Read, E. Vos, R. W. Baird, K. C. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D. D'Spain, A. Fernandez, J. J. Finneran, R. L. Gentry, W. Gerth, F. M. D. Gulland, J. Hildebrand, D. Houser, T. Hullar, P. D. Jepson, D. R. Ketten, C. D. MacLeod, P. Miller, S. Moore, D. C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, P. L. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management **7**:177 - 187.

Cranford, T.W. 1992. Directional asymmetry in the Odontocete forehead. American Zoologist 32(5): 140A.

Croll, D.A., B.R. Tershy, A. Acevedo, and P. Levin. 1999. Marine vertebrates and low frequency sound. Unpublished technical report for the U.S. Navy's Environmental Impact Statement on Low Frequency Active Sonar. Marine Mammal and Seabird Ecology Group, Institute of Marine Sciences, University of California, Santa Cruz; Santa Cruz, California.

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

Cudahy, E., and W.T. Ellison. 2001. A review of the potential for in vivo tissue damage by exposure to underwater sound. Unpublished report prepared for National Marine Fisheries Service, Office of Protected Resources. Silver Spring, Maryland.

Cummings, W.C. and P.O. Thompson. 1971. Underwater sounds from the blue whale *Balaenoptera musculus*. Journal of the Acoustical Society of America50(4):1193-1198.

Cummings, W.C. and P.O. Thompson. 1977. Long 20-Hz sounds from blue whales in the northeast Pacific. Abstracts of the Second Conference on the Biology of Marine Mammals, San Diego, USA, December 1977.

Cummings, W.C. and P.O. Thompson. 1994. Characteristics and seasons of blue and finback whale sounds along the U.S. west coast as recorded at SOSUS stations. Journal of the Acoustical Society of America 95: 2853.

Curtis, K.R., B.M. Howe, and J.A. Mercer. 1999. Low-frequency ambient sound in the North Pacific: long time series observations. Journal of the Acoustical Society of America 106: 3189-3200.

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

Daan, S., C. Deerenberg, and C. Dijkstra. 1996. Increased daily work precipitates natural death in the kestrel. The Journal of Animal Ecology **65**:539 - 544.

de Kloet, E. R. 2003. Hormones, brain, and stress. Endocrine Regulations **37**:51-68.

Donovan, G. P. 1984. Blue whales off Peru, December 1982, with special reference to pygmy blue whales. Reports of the International Whaling Commission 34: 473-476.

Donovan, G.P. 1991. A review of IWC stock boundaries. Reports of the International Whaling Commission, Special Issue 13:39- 68.

Ecolarge and Government of Australia. 2006. Pacific Islands whale watch tourism: 2006. An economic valuation. Unpublished paper submitted to the International Whaling Commission IWC/58/7. International Whaling Commission, Cambridge, United Kingdom.

Edds, P. L. 1988. Characteristics of finback *Balaenoptera physalus* vocalizations in the St. Lawrence Estuary. Bioacoustics 1: 131-149.

Edds, P.L. 1982. Vocalizations of the blue whale Balaenoptera musculus, in the St. Lawrence River. J.ournal of Mammalogy 63(2):345-347.

Edds, P.L. and J.A.F. MacFarlane. 1987. Occurrence and general behavior of balaenopterid cetaceans summering in the St. Lawrence Estuary, Canada. Canadian Journal of Zoology 65(6):1363-1376.

Edds-Walton, P.L. 1997. Acoustic communication signals of mysticete whales. Bioacoustics 8: 47-60.

Erbe, C. 2000. Detection of whale calls in noise: Performance comparison between a beluga whale, human listeners and a neural network. Journal of the Acoustical Society of America108:297-303.

European Cetacean Society. 2003. Program for the Seventeenth Annual Conference: Marine Mammals and Sound. Las Palmas De Gran Canaria, Spain; 9 – 13 March 2003.

Félix, F. 2001. Observed changes of behavior in humpback whales during whalewatching encounters off Ecuador. 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada.

Fernandez, A. 2004. Pathological findings in stranded beaked whales during the naval military manoeuvers near the Canary Islands. Pages 37-40. European Cetacean Society Newsletter.

Fernandez, A., J. F. Edwards, F. Rodriguez, A. Espinosa de los Monteros, P. Herraez, P. Castro, J. R. Jaber, V. Martin, and M. Arbelo. 2005. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family *Ziphiidae*) exposed to anthropogenic sonar signals. Veterinary Pathology 42:12.

Fernandez, A., J. F. Edwards, F. Rodriguez, A. Espinosa de los Monteros, P. Herraez, P. Castro, J. R. Jaber, V. Martin, and M. Arbelo. 2005. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family *Ziphiidae*) exposed to anthropogenic sonar signals. Veterinary Pathology 42:446 - 457.

Fernandez, A., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada *et al*. 2004. Pathology: Whales, sonar and decompression sickness (reply). Nature 428:n.

Fernandez, A., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herraez, A. M. Pocknell, F. Rodriguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and P. D. Jepson. 2004. Beaked whales, sonar and decompression sickness. Nature 428:U1 - 2.

Ferrero, R. C., J. Hodder, and J. Cesarone. 1994. Recent strandings of rough-toothed dolphins (*Steno bredanensis*) on the Oregon and Washington coasts. Marine Mammal Science 10:114-115.

Finneran, J. J. 2003. Whole-lung resonance in a bottlenose dolphin (*Tursiops truncatus*) and white whale (*Delphinapterus leucas*). The Journal of the Acoustical Society of America 114:7.

Finneran, J. J., and M. C. Hastings. 2000. A mathematical analysis of the peripheral auditory system mechanics in the goldfish (*Carassius auratus*). The Journal of the Acoustical Society of America 108:14.

Finneran, J. J., C. E. Schlundt, D. A. Carder, and S. H. Ridgway. 2002. Auditory filter shapes for the bottlenose dolphin (*Tursiops truncatus*) and the white whale (*Delphinapterus leucas*) derived with notched noise. The Journal of the Acoustical Society of America 112:7.

Finneran, J. J., C. E. Schlundt, R. Dear, D. A. Carder, and S. H. Ridgway. 2000. Masked temporary threshold shift (MTTS) in odontocetes after exposure to single underwater impulses from a seismic watergun. The Journal of the Acoustical Society of America 108:2515.

Finneran, J. J., D. A. Carder, C. E. Schlundt, and S. H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. The Journal of the Acoustical Society of America 118:10.

Forney, K. A., J. Barlow, M. M. Muto, M. Lowry, J. Baker, G. Cameron, J. Mobley, C. Stinchcomb, and J. V. Carretta. 2000. U.S. Pacific Marine Mammal Stock Assessmemts: 2000 DRAFT. NOAA Technical Memorandum. Southwest Fisheries Science Center; La Jolla, California.

Forney, K. A., M. M. Muto, and J. Baker. 1999. U.S. Pacific marine mammal stock assessment: 1999. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-282, Southwest Fisheries Science Center; La Jolla, California.

Frankel, A. S. and C. W. Clark. 1998. Results of low-frequency playback of M-sequence noise to humpback whales, *Megaptera novaeangliae*, in Hawai'i. Canadian Journal of Zoology 76:521-535.

Frankel, A. S., and C.W. Clark. 2000. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. Journal of the Acoustical Society of America 108(4).

Frankel, A. S., C. W. Clark, L. M. Herman, C. M. Gabriele, M. A. Hoffhines, T. R. Freeman, and B. K. Patterson. 1989. Acoustic Location and tracking of wintering humpback whales (*Megaptera novaeangliae*) off South Kohala, Hawai'i. In Proceedings of the Eighth Biennial Conference on the Biology of Marine Mammals

Frankel, A.S. 1994. Acoustic and visual tracking reveals distribution, song variability and social roles of humpback whales in Hawai'ian waters. Unpublished doctoral dissertation, University of Hawai'i. University Microfilms, Inc.

Frankel, A.S., J. Mobley, L. Herman. 1995. Estimation of auditory response thresholds in humpback whales using biologically meaningful sounds. Pages 55-70. In: R.A. Kastelein, J.A. Thomas, P.E. Nachtigall (editors) Sensory Systems of Aquatic Mammals. De Spil Publication, Woerden, Netherlands.

Frid, A. 2003. Dall's sheep responses to overflights by helicopter and fixed-wing aircraft. Biological Conservation 110:387-399.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:1 - 11.

Fristrup, K.M., L.T. Hatch, and C.W. Clark. 2003. Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts. Journal of the Acoustical Society of America 113(6): 3411-3424

Gagnon, C. J. and C. W. Clark. 1993. The use of U.S. Navy IUSS passive sonar to monitor the movement of blue whales. Abstracts of the 10th Biennial Conference on the Biology of Marine Mammals, Galveston, Texas. November 1993.

Gambell, R. 1976. World whale stocks. Mammal Review 6 (1): 41-53.

Gambell, R. 1985. Sei whale *Balaenoptera borealis* (Lesson, 1828). Pages 193-240. In: S.H. Ridgway and R. Harrison (editors). Handbook of marine mammals. Vol. 3: The sirenians and baleen whales. Adacemic Press; London, United Kingdom.

Gauthier, J and R. Sears. 1999. Behavioral response of four species of balaenopterid whales to biopsy sampling. Marine Mammal Science. 15(1): 85-101.

Giese, M. 1996. Effects of human activity on adelie penguin Pygoscelis adeliae breeding success. Biological Conservation 75:157.

Gill, J. A., and W. J. Sutherland. 2000. Predicting the consequences of human disturbance from behavioral decisions, Pages 51 - 64 *in* L. M. Gosling, and W. J. Sutherland, eds. Behavior and conservation. Cambridge, United Kingdom, Cambridge University Press.

Gill, J. A., K. Norris, and W. J. Sutherland. 2001. Why behavioral responses may not reflect the population consequences of human disturbance. Biological Conservation 97:265-268.

Gisiner, R. C. 1998. Workshop on the effects of anthropogenic noise in the marine environment. U.S. Navy, Office of Naval Research, Marine Mammal Research Program, Washington, D.C.

Goddard, P.C. and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. Marine Mammal Science 14(2):344-349.

Goold, J.C. and S.E. Jones. 1995. Time and frequency domain characteristics of sperm whale clicks. Journal of the Acoustical Society of America 98: 1279-1291.

Gordon, J.C.D. 1987. Behaviour and ecology of sperm whales off Sri Lanka. Ph.D. dissertation, University of Cambridge, Cambridge, England.

Gosho, M.E., D.W. Rice, and J.M. Breiwick. 1984. Sperm whale interactions with longline vessels in Alaska waters during 1997. Unpublished report available Alaska Fisheries Science Center; Seattle, Washington.

Gotelli, N. J. 2001, A primer of ecology. Sunderland, Massachusetts, Sinauer Associates, Inc.

Government Printing Office. 1987. Endangered fish and wildlife; approaching humpback whales in Hawai'ian waters. Federal Register 52 (225, 23 Nov.):44912-44915.

Grimm, G., and J. Farley. 2008. Sea turtle nesting activity on Navy lands, Guam 2007-2008. U.S. Navy, Pacific Fleet, Marianas Environmental, Guam.

Guam Division of Aquatic and Wildlife Resources. 2000. Job progress report, sea turtle recovery program. October 1, 1999 to September 30, 2000. Guam Department of Agriculture, Division of Aquatic and Wildlife Resources, Mangilao, Guam.

Hain, J.H.W., M.J. Ratnaswamy, R.D. Kenney, and H.E. Winn. 1992. The fin whale, *Balaenoptera physalus*, in waters of the northeastern United States continental shelf. Reports of the International Whaling Commission 42: 653-669.

Harris, C. M., editor. 1998. Handbook of acoustical measurements and noise control. Acoustical Society of America, Woodbury, New York.

Hazel, J., I. R. Lawler, and M. Hamann. 2009. Diving at the shallow end: green turtle behavior in near-shore foraging habitat. Journal of Experimental Marine Biology and Ecology **371**:84-92.

Herman, J. P., and W. E. Cullinan. 1997. Neurocircuitry of stress: central control of hypothalamo-pituitary-adrenocortical axis. Trends in Neuroscience **20**:78-84.

Herman, L. M., C. S. Baker, P. H. Forestell and R. C. Antinoja. 1980. Right whale *Balaena glacialis* - sightings near Hawai'i: a clue to the wintering grounds? 2:271-275.

Hildebrand, J. A. 2004. Impacts of anthropogenic sound on cetaceans. Unpublished paper submitted to the International Whaling Commission Scientific Committee SC/56/E13. International Whaling Commission, Cambridge, United Kingdom.

Hildebrand, J. A. 2005. Annex K: Report of the standing working group on environmental concerns. Appendix 3. Introduction to acoustics. Journal of Cetacean Research and Management 7:284 - 286.

Hill, P.S. and D.P. DeMaster. 1999. Pacific Marine Mammal Stock Assessments, 1999. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-110. Alaska Fisheries Science Center; Auke Bay, Alaska.

Hohn, A. A., D. S. Rotstein, C. A. Harms, and B. L. Southall. 2006. Report on marine mammal unusual mortality event UME0501Sp Multispecies mass stranding of pilot whales (*Globicephala macrorhynchus*), minke whale (*Balaenoptera acutiorostrata*), and dwarf sperm whales (*Kogia sima*) in North Carolina on 15 - 16 January 2005. NOAA Technical Memorandum NMFS-SEFSC-537. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida.

Holberton, R. L., B. Helmuth, and J. C. Wingfield. 1996. The corticosterone stress response in gentoo and king penguins during the non-fasting period. The Condor 98:4.

Hood, L. C., P. D. Boersma, and J. C. Wingfield. 1998. The adrenocortical response to stress in incubating magellanic penguins (Spheniscus magellanicus). The Auk 115:9.

Horwood, J. 1987. The sei whale: population biology, ecology and management. Croom Helm; Beckenham, Kent, United Kingdom.

Hudspeth, A. J. 1997. How hearing happens. Neuron **19**:947-950.

I-Jiunn, C. 2009. Changes in diving behavior during the internesting period by green turtles. Journal of Experimental Marine Biology and Ecology **381**:18-24.

International Whaling Commission (IWC). 1980. Report of the sub-committee on protected species and aboriginal whaling. Reports of the International Whaling Commission 30:103-111.

International Whaling Commission (IWC). 2005. Annex K. Report of the standing working group on environmental concerns. Journal of Cetacean Research and Management 7 (Supplement):267 - 281.

International Whaling Commission [IWC]. 1998. Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. International Whaling Commission special workshop held 19-25 March 1998, in Cape Town, South Africa. SC/50/REP 4.

Jahoda, M., C. L. Lafortuna, N. Biassoni, C. Almirante, A. Azzelino, S. Panigada, M. Zanardelli et al. 2003. Mediterranean fin whale's (*Balaenoptera physalus*) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. Marine Mammal Science 19:15.

Jansen, G. 1998. Chapter 25. Physiological effects of noise. Pages 25.21 - 25.19 in C. M. Harris, editor. Handbook of acoustical measurements and noise control. Acoustical Society of America, Woodbury, New York.

Jaquet, N. 1996. How spatial and temporal scales influence understanding of sperm whale distribution. Mammal Review 26:51.

Jaquet, N., and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. Marine ecology progress series 135:10.

Jasny, M., J. Reynolds, C. Horowitz, and A. Wetzler. 2005. Sounding the depths II: The rising toll of sonar, shipping and industrial ocean noise on marine life. Natural Resources Defense Council, New York, New York.

Jensen, A. S., and G. K. Silber. 2003. Large whale ship strike database. NOAA Technical Memorandum NMFS-F/OPR 25, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland.

Jepson, P. D., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada *et al*. 2003. Gas-bubble lesions in stranded cetaceans. Nature 425:575-576.

Jepson, P. D., R. Deaville, I. A. P. Patterson, A. M. Pocknell, H. M. Ross, J. R. Baker, F. E. Howie, R. J. Reid, A. Colloff, and A. A. Cunningham. 2005. Acute and chronic gas bubble lesions in cetaceans stranded in the United Kingdom. Veterinary Pathology 42:291-305.

Jessop, T. S., A. D. Tucker, C. J. Limpus, and J. M. Whittier. 2003. Interactions between ecology, demography, capture stress, and profiles of corticosterone and glucose in a free-living population of Australian freshwater crocodiles. General and Comparative Endocrinology 132:10.

Johnson, P.A. and B.W. Johnson. 1980. Hawai'ian monk seal observations on French Frigate Shoals, 1980. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-50. National Marine Fisheries Service, Southwest Fisheries Science Center; La Jolla California.

Jones, D. M., and D. E. Broadbent. 1998. Chapter 24. Human peformance and noise. Pages 24.21 - 24.24 in C. M. Harris, editor. Handbook of acoustical measurements and noise control. Acoustical Society of America, Woodbury, New York.

Kastak, D., R.J. Schusterman, B.L. Southall, and C. Reichmuth. 2000. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of the Acoustical Society of America 106(2):1142-1148.

Kasuya, T. 1991. Density dependent growth in North Pacific sperm whales. Marine Mammal Science 7(3):230-257.

Kawakami, T. 1980. A review of sperm whale food. Scientific Report of the Whales Research Institute Tokyo 32:199-218.

Kawamura, A. 1982. Food habits and prey distributions of three rorqual species in the North Pacific Ocean. Scientific Reports of the Whales Research Institute, Tokyo 34:59-91.

Ketten, D. R. 2005. Annex K: Report of the standing working group on environmental concerns. Appendix 4. Marine mammal auditory systems: a summary of audiometric and anatomical data and implications for underwater acoustic impacts. Journal of Cetacean Research and Management 7:286 - 289.

Ketten, D.R. 1994. Functional analyses of whale ears: adaptations for underwater hearing. IEEE Proceedings on Underwater Acoustics 1: 264-270.

Ketten, D.R. 1997. Structure and function in whale ears. Bioacoustics 8: 103-135.

Ketten, D.R. 1998. Marine mammal auditory systems: a summary of audiometric and anatomical data and its implications for underwater acoustic impacts. NOAA Technical Memorandum NMFS: NOAA-TM-NMFS-SWFSC-256.

Korte, S. M., J. M. Koolhaas, J. C. Wingfield, and B. S. McEwen. 2005. The Darwinian concept of stress: benefits of allostasis and costs of allostatic load and the trade-offs in health and disease. Neuroscience and Biobehavioral Reviews 29:3 - 38.

Krausman, P. R., L. K. Harris, C. L. Blasch, K. K. G. Koenen, and J. Francine. 2004. Effects of military operations on behavior and hearing of endangered Sonoran pronghorn. Wildlife Monographs:1-41.

Lafferty, K. D., and R. D. Holt. 2003. How should environmental stress affect the population dynamics of disease? Ecology Letters 6:654-664.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet, and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science 17:35-75.

Lambertsen, R. H. B. A. Kohn, J. P. Sundberg, and C. D. Buergelt. 1987. Genital papillomatosis in sperm whale bulls. Journal of Wildlife Diseases. 23(3):361-367.

Landis, C.J. 1965. Research: A new high pressure research animal? Undersea Technology 6:21.

Landis, W. G., G.B. Matthews, R.A. Matthews, A. Sergeant. 1994. Application of multivariate techniques to endpoint determination, selection and evaluation in ecological risk assessment. Environmental Toxicology and Chemistry 13: 1917.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent arctic waters: a guide to their identification. NOAA Technical Report National Marine Fisheries Service Circular 444.

Lenhardt, M.L. 1994. Auditory behavior of the loggerhead sea turtle (*Caretta caretta*). Page 89. In: K.A. Bjorndahl, A.B. Bolten, D.A. Johnson, and P.J. Eliazar (compilers), Proceedings of the 14th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-351.

Levenson, C. 1974. Source level and bistatic target strength of the sperm whale (*Physeter catodon*) measured from an oceanographic aircraft. Journal of the Acoustical Society of America 55: 1100-1103.

Lipton, J., H. Galbraith, J. Burger, D. Wartenberg. 1993. A paradigm for ecological risk assessment. Environmental Management 17: 1-5.

Ljungblad DK, Clark CW, Shimada H (in press) Sounds attributed to pygmy blue whales (*Balaenoptera musculus brevicauda*) recorded south of the Madagascar Plateau in December 1996 as compared to sounds attributed to "true" blue whales (*Balaenoptera musculus*) recorded off Antarctica in January 1997.

Lockyer, C. 1978. The history and behavior of a solitary wild, but sociable bottlenose dolphin (*Tursiops truncatus*) on the west coast of England and Wales. Journal of Natural History 12:513-528.

Lockyer, C. 1981. Growth and energy budgets of large baleen whales from the Southern Hemisphere. Mammals in the Seas. Vol. 3. Food and Agricultural Organization Fisheries Series 5: 379-487.

Lockyer, C. 1984. Review of baleen whale (Mysticeti) reproduction and implications for management. Reports of the International Whaling Commission, Special Issue 6: 27-50.

Loughlin, T.R., D.J. Rugh, and C.H. Fiscus. 1984. Northern sea lion distribution and abundance: 1956-80. Journal of Wildlife Management 48: 729-740.

Lowell, R.B. J.M. Culp, and M.G. Dube. 2000. A weight of evidence approach to northern river risk assessment: integrating the effects of multiple stressors. Environmental Toxicology and Chemistry 19: 1182-1190.

MacArthur, R.A., R.H. Johnson and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: A physiological approach to the study of wildlife harassment. Canadian Journal of Zoology 57(10):2010-2021.

Mackintosh, N.A. 1942. The southern stocks of whalebone whales. Discovery Reports 22:197-300.

Mackintosh, N.A. 1965. The stocks of whales. Fishing News (Books) Ltd., London.

Mackintosh, N.A. and J.F.G. Wheeler. 1929. Southern blue and fin whales. Discovery Reports 1: 257-540.

MacLeod, C. D., and A. D'Amico. 2006. A review of beaked whale behavior and ecology in relation to assessing and mitigating impacts of anthropogenic noise. Journal of Cetacean Research and Management **7**:211 - 221.

MacLeod, C. D., G. J. Pierce, and M. B. Santos. 2004. Geographic and temporal variations in strandings of beaked whales (Ziphiidae) on the coasts of the UK and the Republic of Ireland from 1800-2002. Journal of Cetacean Research and Management **6**:79 - 86.

Magalhaes, S., R. Prieto, M. A. Silva, J. Goncalves, M. Afonso-Dias, and R. S. Santos. 2002. Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. Aquatic Mammals 28:267-274.

Malme, C. I., P. R. Miles, C. W. Clark, P. Tyack, and J. E. Bird. 1983. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior: Final Report for the Period of 7 June 1982 - 31 July 1983. Prepared for U.S. Department of the Interior Minerals Management Service, Alaska OCS Office by Bolt Beranek and Newman Inc. Cambridge: Bolt Beranek and Newman Inc., 1983.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J. E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 586. Rep. from Bolt, Beranek, & Newman, Inc. Cambridge, Massachusetts, for U.S. Minerals Management Service, Anchorage, Alaska.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. Report No. 5851, Unpublished report prepared by Bolt, Beranek and Newman Inc., Cambridge, USA, for U.S. Minerals Management Service, Alaska OCS Office, Anchorage, Alaska.

Marshall, G. J. 1998. Crittercam: an animal-borne imaging and data logging system. Marine Technology Science Journal. 32(1):11-17.

Masaki, Y. 1976. Biological studies on the North Pacific sei whale. Bulletin of the Far Seas Fisheries Research Laboratory (Shimizu) 14:1-104.

Masaki, Y. 1977. The separation of the stock units of sei whales in the North Pacific. Reports of the International Whaling Commission Special Issue No. 1: 71-79.

Mate, B.R., K.M. Stafford and D.K. Ljungblad. 1994. A change in sperm *whale (Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. Journal of the Acoustical Society of America 96(2):3268-3269.

Maury, M.F. 1852. Whale chart of the world, (The wind and current charts), Series F, Washington, D.C.

Maury, M.F. 1853. A chart showing the favourite reports of the sperm and right whales by M.F. Maury, L.L.D. Lieutenant, U.S. Navy. Constructed from Maury's whale chart of the world by Robert H. Wayman, Lieutenant, U.S. Navy by Authority of the Commo. Bureau of Ordinance and Hydrography; Washington, D.C.

Maybaum, H.L. 1989. Effects of 3.3 kHz sonar system on humpback whales *Megaptera novaeangliae*, in Hawai'ian waters. Eos.71(2):92.

Mayo, C.A., and M. K. Marx. 1990. Surface foraging behavior of the North Atlantic right whale (*Eubalaena glacialis*) and associated zooplankton characteristics. Canadian Journal of Zoology 68: 2214-2220.

McCall Howard, M.P. 1999. Sperm whales *Physeter macrocephalus* in the Gully, Nova Scotia: Population, distribution, and response to seismic surveying. Unpublished Thesis prepared for a Batchelor of Science Degree. Dalhousie University, Halifax, Nova Scotia.

McCarty, L. S., and M. Power. 1997. Environmental risk assessment within a decision-making framework. Environmental Toxicology and Chemistry 16:122.

McCauley, R. D., and D. H. Cato. 2001. The underwater noise of vessels in the Hervey Bay (Queensland) whale watch fleet and its impact on humpback whales. Journal of the Acoustical Society of America 109:2455.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M-N Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid. Report R99-15. Centre for Marine Science and Technology, Curtin University of Technology, Western Australia.

McDonald, M. A., J. A. Hildebrand, and S. C. Webb. 1995. Blue and fin whales observed on a seafloor array in the northeast Pacific. Journal of the Acoustical Society of America 98:712-721.

McDonald, M.A. and Fox, C.G. 1999. Passive acoustic methods applied to fin whale population density estimation. Journal of the Acoustical Society of America 105(5): 2643-2651

McEwen, B. S., and J. C. Wingfield. 2003. The concept of allostasis in biology and biomedicine. Hormones and Behavior 43:2 - 15.

McEwen, B. S., and T. Seeman. 2000. Overview - protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. Annals of the New York Academy of Sciences 896:18.

Meredith, G.N. and R.R. Campbell. 1988. Status of the fin whale, *Balaenoptera physalus*, in Canada. Canadian Field-Naturalist 102: 351-368.

Miller, P.J.O., N. Biassoni, A. Samuels and P.L. Tyack. 2000. Whales songs lengthen in response to sonar. Nature 405, 903

Mills, S. K., and J. H. Beatty. 1979. The propensity interpretation of fitness. Philosophy of Science 46:263-286.

Miyashita, T., H. Kato, and T. Kasuya. 1995. Worldwide map of cetacean distribution based on Japanese sighting data (Volume 1). National Research Institute of Far Seas Fisheries, Shimizu, Shizuoka, Japan.

Miyashita, T., T. Kishiro, N. Higashi, F. Sato, K. Mori, and H. Kato. 1996. Winter distribution of cetaceans in the Western North Pacific inferred from sighting cruises 1993-1995. Report of the International Whaling Commission **46**:437-441.

Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984. The blue whale, *Balaenoptera musculus*. Marine Fisheries Review 46(4):15-19.

Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984b. The fin whale, *Balaenoptera physalu*s. Marine Fisheries Review 46(4):20-24.

Mizue, K. 1951. Food of whales (in the adjacent waters of Japan). Scientific Reports of the Whales Research Institute 5:81-90.

Moberg, G. P. 1985. Biological response to stress: key to assessment of animal well-being? Pages 27 - 49 in G. P. Moberg, editor. Animal stress. American Physiological Society, Bethesda, Maryland.

Moberg, G. P. 2000. Biological response to stress: implications for animal welfare. Pages 1 - 21 in G. P. Moberg, and J. A. Mench, editors. The biology of animal stress. Basic principles and implications for animal welfare. Oxford University Press, Oxford, United Kingdom.

Mobley, J. R., L. M. Herman, A. S. Frankel. 1988. Responses of wintering Humpback whales (*Megaptera novaeangliae*) to playback of recordings of winter and summer vocalizations and of synthetic sounds. Behavioural Ecology and Sociobiology 23: 211-223

Mobley, J. R., M. Smultea, T. Norris, and D. Weller. 1996. Fin whale sighting north of Kauai, Hawai'i. Pacific Science 50: 230-233.

Mobley, J. R., R. A. Grotefendt, P. H. Forestell, and A. S. Frankel. 1999a. Results of Aerial surveys of marine mammals in the major Hawai'ian Islands (1993-1998): Report to the Acoustic Thermometry of Ocean Climate Marine Mammal Research Program. Cornell University Bioacoustics Research Program, Ithaca, New York.

Mohl, B. 2001. Sound transmission in the nose of the sperm whale *Physeter catodon*. A post mortem study. Journal of Comparative Physiology A Sensory Neural and Behavioral Physiology 187:335-340.

Mohl, B., M. Wahlberg, P. T. Madsen, A. Heerfordt, and A. Lund. 2003. The monopulsed nature of sperm whale clicks. The Journal of the Acoustical Society of America 114:12.

Mohl, B., M. Wahlberg, P. T. Madsen, L. A. Miller, and A. Surlykke. 2000. Sperm whale clicks: Directionality and source level revisited. Journal of the Acoustical Society of America 107:638.

Mohl, *et al*. 2000. Sperm whale clicks: Directionality and source level revisted. Journal of the Acoustical Society of America 107 (1), January 2000, pp. 638 -645.

Moore, K. E., W. A. Watkins, and P. L. Tyack. 1993. Pattern similarity in shared codas from sperm whales (*Physeter catodon*). Marine Mammal Science 9:1-9.

Mortimer, J. A. 2008. The state of the world's hawksbills. The State of the World's Sea Turtles Report **3**:10-11.

Mullins, J., H. Whitehead, and L.S. Weilgart. 1988. Behavior and vocalizations of two single sperm whales, *Physeter macrocephalus* off Nova Scotia. Canadian Journal of Fisheries and Aquatic Sciences 45(10):1736-1743.

Mullner, A., K. Eduard Linsenmair, and M. Wikelski. 2004. Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). Biological Conservation 118:549-558.

Myrberg, A.A., Jr. 1978. Ocean noise and behavior of marine animals: Relationships and implications. Pages 169-208. In: J.L. Fletcher and R.G. Busnel (eds.) Effects of Noise on Wildlife. Academic Press; New York, New York.

Nachtigall, P. E., A. Y. Supin, J. Pawloski, and W. W. L. Au. 2004. Temporary threshold shifts after noise exposure in the bottlenose dolphin (*Tursiops truncatus*) measured using evoked auditory potentials. Marine Mammal Science 20:15.

Nachtigall, P. E., J. L. Pawloski, and W. W. L. Au. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). The Journal of the Acoustical Society of America 113:5.

Nachtigall, P. E., M. M. L. Yuen, T. A. Mooney, and K. A. Taylor. 2005. Hearing measurements from a stranded infant Risso's dolphin, *Grampus griseus*. The Journal of Experimental Biology 208:4181.

Nasu, K. 1974. Movement of baleen whales in relation to hydrographic conditions in the northern part of the North Pacific Ocean and the Bering Sea. Pages 345-361 *in* D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Institute of Marine Science, University of Alaska; Fairbanks, Alaska.

National Marine Fisheries Service (NMFS). 1992. Environmental assessment of the effects of biopsy darting and associated approaches on humpback whales (*Megaptera novaeangliae*) and right whales (*Eubalaena glacialis*) in the North Atlantic. U.S. Department of Commerce, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service (NMFS). 1994. An assessment of whale watching in the United States. Prepared for the International Whaling Commission by U.S. Department of Commerce, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1998. Draft recovery plan for the fin whale *Balaenoptera physalus* and sei whale *Balaenoptera borealis*. Prepared by R.R. Reeves, G.K. Silber, and P. Michael Payne for the National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 1998. Recovery plan for the blue whale (*Balaenoptera musculus*). Prepared by R.R. Reeves, P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber for the National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2001. Final biological opinion on the U.S. Navy's North Pacific Acoustic Laboratory Sound Source. Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2002. Final biological opinion on the U.S. Navy's Surveillance Towed Array Sensor System Low Frequency Active Sonar (SURTASS LFA). Office of Protected Resources, Endangered Species Division, Silver Spring, Maryland.

National Research Council [NRC]. 1994. Low-frequency sound and marine mammals, current knowledge and research needs. National Academy Press; Washington, D.C.

National Research Council [NRC]. 1996b. Marine mammals and low frequency sound: Progress since 1994 - an interim report. National Academy Press; Washington, D.C.

National Research Council [NRC]. 2000. Marine mammals and low frequency sound: Progress since 1994. National Academy Press; Washington, D.C.

National Research Council [NRC]. 2003. Ocean noise and marine mammals. National Academy Press; Washington, D.C.

National Research Council 2005. Marine mammal populations and ocean noise : determining when noise causes biologically significant effects. National Academies Press, Washington, D.C.

Nemoto T. 1964. School of baleen whales in the feeding areas. Scientific Reports of the Whales Research Institute 18: 89-110.

Nemoto, T. 1957. Foods of baleen whales in the northern Pacific. Scientific Reports of the Whales Research Institute 12:33-89.

Nemoto, T. 1970. Feeding pattern of baleen whales in the oceans. Pages 241-252 *in* Steele, J.H. (ed.), Marine Food Chains. University of California Press, Berkeley, California.

Nemoto, T. 1978. Humpback whales observed within the continental shelf waters of the Bering Sea. Scientific Reports of the Whales Research Institute, Tokyo 39:245-247.

Nemoto, T., and A. Kawamura. 1977. Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. Reports of the International Whaling Commission, Special Issue 1:80-87.

Newman, M. C., D. R. Ownby, L. C. A. Mezin, D. C. Powell, T. R. L. Christensen, S. B. Lerberg, and B. A. Anderson. 2000. Applying species-sensitivity distributions in ecological risk assessment: assumptions of distribution type and sufficient numbers of species. Environmental Toxicology and Chemistry 19:508.

Nishiwaki, M. 1952. On the age determination of Mystacoceti, chiefly blue and fin whales. Scientific Reports of the Whales Research Institute 7: 87-119.

Nishiwaki, M. 1966. Distribution and migration of the larger cetaceans in the North Pacific as shown by Japanese whaling results. Pages 171-191 *in* Norris, K.S., (ed.), Whales, Dolphins and Porpoises. University of California Press, Berkeley.

Norris KS, Harvey GW (1972) A theory for the function of the spermaceti organ of the sperm whale (Physeter catodon L.). In: Galler SR, Schmidt-Koenig K, Jacobs GJ, Belleville RE (eds) Animal Orientation and Navigation. pp 397-417. NASA Special Publications, Washington.

Norton, S. B., D. J. Rodier, J. H. Gentile, W. H. Van Der Schalie, and W. P. Wood. 1992. The framework for ecological risk assessment at the EPA. Environmental Toxicology and Chemistry 11:1663.

Notarbartolo-di-Sciara, G., M. Zanardelli, M. Jahoda, S. Panigada, and S. Airoldi. 2003. The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. Mammal Review 33:105-150.

Nowacek, D. P., M. P. Johnson, and P. L. Tyack. 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. Proceedings of the Royal Society Biological Sciences Series B 271:227-231.

O'Hara, J. and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, Caretta caretta, to low frequency sound. Copeia 1990(2):564-567.

O'Hara, T.M., M.M. Krahn, D. Boyd, P.R. Becker, and L.M. Philo. 1999. Organochlorine contaminant levels in Eskimo harvested bowhead whales of arctic Alaska. Journal of Wildlife Diseases 35(4): 741-52.

O'Shea, T.J. and R.L.J. Brownell. 1994. Organochlorine and metal contaminants in baleen whales: A review and evaluation of conservation implications. Science of the Total Environment 154 (2-3): 179-200.

Ohsumi, S., and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. Reports of the International Whaling Commission 24:114-126.

Panigada, S., G. Pesante, M. Zanardelli, F. Capoulade, A. Gannier, and M. T. Weinrich. 2006. Mediterranean fin whales at risk from fatal ship strikes. Marine Pollution Bulletin 52:1287-1298.

Parrish, F. A., M.P. Craig, K. Abernathy, G.J. Marshall and B.M. Buhleier. Hawai'ian monk seals (*Monachus Shauinslandi*) foraging in deepwater coral beds, another endangered species using old growth "Trees?" (May 23, 2000) (unpublished manuscript, on file with the NMFS).

Patterson, B. and G. R. Hamilton. 1964. Repetitive 20 cycle per second biological hydroacoustic signals at Bermuda. In: Tavolga, W.N. (ed.) Marine bioacoustics.

Payne, R. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. Annals of the New York Academy of Sciences 188:0110-141.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999. The great whales: history and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. Marine Fisheries Review 61: 1-74.

Piantadosi, C. A., and E. D. Thalmann. 2004. Pathology: Whales, sonar and decompression sickness. Nature 428:n.

Piatt, J. F. and D. A. Methven. 1992. Threshold foraging behavior of baleen whales. Marine Ecology Progress Series 84:205-210.

Piatt, J. F., D. A. Methven, A. E. Burger, R. L. McLagan, V. Mercer and E. Creelman. 1989. Baleen whales and their prey in a coastal environment. Canadian Journal of Zoology 67:1523-1530.

Pryor, K. 1990. Non-acoustic communication in small cetaceans: glance, touch, position, gesture, and bubbles. In: J.A. Thomas and R.A. Kastelein (eds.), Sensory Abilities in Cetaceans - Laboratory and Field Evidence. p.537-544. NATO ASI Series, Plenum Press, New York.

Randall, R. H., R. T. Tsuda, R. S. Jones, M. J. Gawel, J. A. Chase, and R. Rechebei. 1975. Marine biological survey of the Cocos Barrier Reef and enclosed lagoon. Technical Report No. 17, Reported prepared by the University of Guam Marine Laboratory for the U.S. Army Corps of Engineers, Mangilao Guam.

Ray, G. C., E. Mitchell, D. Wartzok, V. Koxicki, and R. Maiefski. 1978. Radio tracking of a fin whale (*Balaenoptera physalus*). Science 202: 521-524.

Reeves, R. R. 1992. Whale responses to anthropogenic sounds: a literature review. New Zealand Department of Conservation, Wellington, New Zealand.

Reeves, R.R. and Whitehead, H. 1997. Status of the sperm whale, *Physeter macrocephalus*, in Canada. Canadian Field-Naturalist 111(2): 293-307

Reeves, R.R., B.D. Smith, E.A. Crespo, G. Notarbartolo di Sciara. 2002. Dolphins, whales and porpoises. 2002 – 2010 Conservation action plan for the world's cetaceans. The World Conservation Union, Cetacean Specialist Group. IUCN; Gland, Switzerland and Cambridge, United Kingdom.

Relyea, R. A. 2003. Predator cues and pestcides: A double dose of danger for amphibians. Ecological Applications 13:7.

Relyea, R. A. 2004. Synergistic impacts of malathion and predatory stress on six species of North American tadpoles. Environmental Toxicology and Chemistry 23:5.

Relyea, R. A. 2005. The lethal impacts of roundup and predatory stress on six species of North American tadpoles. Archives of Environmental Contamination and Toxicology 48:7.

Relyea, R. A., and N. Mills. 2001. Predator-induced stress makes the pesticide carbaryl more deadly to gray treefrog tadpoles (*Hyla versicolor*). Proceedings of the National Academy of Sciences of the United States of America 98:6.

Reneerkens, J., R. I. G. Morrison, M. Ramenofsky, T. Piersma, and J. C. Wingfield. 2002. Baseline and stress-induced levels of corticosterone during different life cycle substages in a shorebird on the high arctic breeding grounds. Physiological and Biochemical Zoology 75:200-208.

Rice, D. W. 1989. Sperm whale, *Physeter macrocephalus* (Linneaus, 1758). In: S.H. Ridgway and R. Harrison (editors). Handbook of marine mammals. Vol. 4. River dolphins and the larger toothed whales.

Rice, D.W. 1974. Whales and whale research in the eastern North Pacific . Pages 170-195 *in* Schevill, W.E. (ed.), The Whale Problem: A Status Report. Harvard University Press, Cambridge, Massachusetts.

Rice, D.W. 1977. Synopsis of biological data on the sei whale and Bryde's whale in the eastern North Pacific. Reports of the International Whaling Commission, Special Issue No. 1:92-97.

Rice, D.W. 1986. Sperm whales. Pages 94-101 *in* D. Haley (ed.), Marine Mammals of the Eastern North pacific and Arctic Waters, 2nd ed. Pacific Search Press, Seattle, Washington.

Richardson W.J., C.R. Greene Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press; San Diego, California.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme and D. H. Thompson. 1991. Effects of noise on marine mammals. OCS Study MMS-90-0093; LGL Rep. TA834-1. Unpublished report prepared by LGL Ecological Research Associates, Inc. for U.S. Minerals Management Service, Atlantic OCS Reg., Herndon, Virginia. NTIS PB91-168914.

Richardson, W.J., C.R. Greene, Jr., W.R. Koski and M.A. Smultea. 1991a. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska -- 1990 phase. OCS Study MMS 91-0037; LGL Rep. TA848-5. Unpublished eport prepared by LGL Ltd., for U.S. Minerals Management Service, Herndon, Virginia. NTIS PB92-170430.

Romero, L. M. 2004. Physiological stress in ecology: lessons from biomedical research. Trends in Ecology and Evolution 19:249-255.

Romero, L. M., and M. Wikelski. 2001. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. Proceedings of the National Academy of Sciences of the United States of America 98:5.

Romero, L. M., and M. Wikelski. 2002. Exposure to tourism reduces stress-induced corticosterone levels in Galapagos marine iguanas. Biological conservation 108:371-374.

Sapolsky, R. M., L. M. Romero, and A. U. Munck. 2000. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews 21:55 – 89.

Sergeant, D. E. 1977. Stocks of fin whales, *Balaenoptera physalus*, in the North Atlantic Ocean. Reports of the International Whaling Commission 27: 460-473.

Shallenberger, E. E. 1978. Activities possibly affecting the welfare of humpback whales. Pages 81-85 In: K.S. Norris and R.R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawai'i. Unpublished report prepared by Sea Life Inc., for the U.S. Marine Mammal Commission, Bethesda, Maryland. MMC-77/03. NTIS PB-280794

Shane, S.H., R.S. Wells, and B. Wursig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. Marine Mammal Science 2(1):34-63.

Sharpe F.A., L.M. Dill. 1997. The behavior of Pacific herring schools in response to artificial humpback whale bubbles. Canadian Journal of Zoology 75: 725-730

Sigurjonsson, J. and T. Gunnlaugsson. 1990. Recent trends in abundance of blue whales (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeangliae*) off west and southwest Iceland with a note on occurrence of other cetacean species. Report of the International Whaling Commission 40: 557-551.

Sih, A., A. M. Bell, and J. L. Kerby. 2004. Two stressors are far deadlier than one. Trends in Ecology and Evolution 19:274-276.

Silber, G. K. 1986. The relationship of social vocalizations to surface behavior and aggression in the Hawai'ian humpback whale (*Megaptera novaeangliae*). Canadian Journal of Zoology 64:2075-2080.

Silber, G. K., S. Bettridge, and D. Cottingham. 2009. Report of a workshop to identify and assess technologies to reduce ship strikes of large whales. Providence, Rhode Island 8 - 10 July 2008. NOAA Technical Memorandum NMFS-F/OPR 42, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland.

Sleptsov, M.M. 1955. Biology of whales and the whaling fishery in Far Eastern seas. >Pishch. Prom.', Moscow [In Russian] (Transl. with comments and conclusions only by Fish. Res. Board Can., Transl. Ser. 118, 6 pp.)

Slijper E. 1962. Whales. Basic Books; New York, New York.

Smultea, M.A. 1989. Habitat utilization patterns of humpback whales off West Hawai'i. Unpublished report prepared for the Marine Mammal Commission, Contract No. T6223925-9. Bethesda, Maryland.

Southall, B. L., R. Braun, F. M. D. Gulland, A. D. Heard, R. W. Baird, S. M. Wilkin, and T. K. Rowles. 2006. Hawai'ian melon-headed whale (*Peponacephala electra*) mass stranding event of July 3 - 4, 2004. NOAA Technical Memorandum NMFS-OPR-31. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland.

Southall, B. L., R. J. Schusterman, and D. Kastak. 2000. Masking in three pinnipeds: Underwater, low-frequency critical ratios. Journal of the Acoustical Society of America 108:1322.

Spaulding, G.C. 1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Fisheries Research Board of Canada, Bulletin No. 146.

Spero, D. 1981. Vocalizations and associated behavior of northern right whales *Eubalaena glacialis*. Abstracts of the Fourth Biennial Conference on the Biology of Marine Mammals, San Francisco, USA, December 1981.

SRS-Parsons Joint Venture. 2007. Marine mammal and sea turtle survey and density estimates for Guam and the Commonwealth of the Northern Mariana Islands. Final report prepared by SRS-Parsons Joint Venture, Geo-Marine, Inc., and Biowaves, Inc. for Naval Facilities Engineering Command Pacific, Newport Beach, California.

St. Aubin, D.J. and J.R. Geraci. 1988. Capture and handling stress suppresses circulating levels of thyroxine (T4) and triiodothyronine (T3) in beluga whales Delphinapterus leucas. Physiological Zoology 61(2): 170-175.

Stark, J. D., J. E. Banks, and R. Vargas. 2004. How risky is risk assessment: The role that life history strategies play in susceptibility of species to stress. Proceedings of the National Academy of Sciences of the United States of America 101:732-736.

Stearns, S. C. 1992. The evolution of life histories. New York, New York, Oxford University Press.

Stojkovich, J. O. 1977. Survey and species inventory of representative pristine marine communities on Guam. Technical Report No. 40, Reported prepared by the University of Guam Marine Laboratory for Government of Guam, Bureau of Planning, Coastal Management Section, Mangilao, Guam.

Stone, C.J. 1997. Cetacean observations during seismic surveys in 1996. Joint Nature Conservation Committee, Rep. 228, Aberdeen, Scotland.

Stone, C.J. 1998. Cetacean observations during seismic surveys in 1997. Joint Nature Conservation Committee Rep. 278, Aberdeen, Scotland.

Stone, C.J. 2000. Cetacean observations during seismic surveys in 1998. Joint Nature Con-ser-vancy, Aberdeen, Scotland.

Stone, C.J. 2001. Marine mammal observations during seismic surveys in 1999. JNCC Report 316. Joint Nature Conservation Committee Rep. 316, Aberdeen, Scotland.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters, 1998-2000 JNCC Report No. 323.

Taylor, B., J. Barlow, R. Pitman, L. Ballance, T. Klinger, D. DeMaster, J. Hildebrand, J. Urban, D. Palacios, and J Mead. 2004. A call for research to assess risk of acoustic impact on beaked whale populations. Unpublised paper submitted to the International Whaling Commission, Scientific Committee SC/56/E36. Cambridge, United Kingdom.

Thomas, J. A., R. A. Kastelein and F. T. Awbrey. 1990. Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. Zoo Biology 9(5): 393-402.

Thomas, J.A., P. Moore, R. Withrow and M. Stoermer. 1990b. Underwater audiogram of a Hawai'ian monk seal (*Monachus schauinslandi*). Journal of the Acoustical Society of America 87(1): 417-420.

Thompson P.O., L.T. Findley, O. Vidal, W.C. Cummings. 1996. Underwater sounds of blue whales, *Balaenoptera physalus*, in the Gulf of California, Mexico. Marine Mammal Science 288-293.

Thompson P.O., W.C. Cummings, S.J. Ha. 1986. Sounds, source levels, and associated behavior of humpback whales, southeast Alaska. Journal of the Acoustical Society of America 80: 735-740.

Thompson T. J., H. E. Winn, and P. J. Perkins. 1979. Mysticete sounds. Pages 403-431. In: H.E. Winn and B.L. Olla (editors). Behavior of Marine Animals. Vol. 3. Cetaceans. Plenum Press; New York, New York.

Thompson, P.O. and W.A. Friedl. 1982. A long term study of low frequency sounds from several species of whales off Oahu, Hawai'i. Cetology 45: 1-19.

Thompson, P.O., L.T. Findley, and O. Vidal. 1992. 20-Hz pulses and other vocalizations of fin whales, Balaenoptera physalus, in the Gulf of California, Mexico. Journal of the Acoustical Society of America 92: 3051-3057.

Thomson, C.A. and J.R. Geraci. 1986. Cortisol, aldosterone, and leucocytes in the stress response of bottlenose dolphins, *Tursiops truncatus*. Canadian Journal of Fisheries and Aquatic Sciences 43(5): 1010-1016

Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. Reports of the International Whaling Commission Special Issue No. 1:98-106.

Todd S., P. Stevick, J. Lien, F. Marques, D. Ketten. 1996. Behavioural effects of exposure to underwater explosions in humpback whales *Megaptera novaeangliae*. Canadian Journal of Zoology 74: 1661-1672.

Tomich, P.Q. 1986. Mammals in Hawai'i. A synopsis and notational bibliography. Second edition. Bishop Museum Press; Honolulu, Hawai'i.

Tomilin, A. G. 1957. Cetacea. In: Heptner, V. G. (ed.). Mammals of the USSR and adjacent countries. Vol. 9. Israel Program for Scientific Translations, Jerusalem, 1967.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica (N.Y.) 19:1-50.

Trimper, P. G., N. M. Standen, L. M. Lye, D. Lemon, T. E. Chubbs, and G. W. Humphries. 1998. Effects of low-level jet aircraft noise on the behaviour of nesting osprey. The Journal of Applied Ecology 35:9.

Turl, C.W. 1980. Literature review on: I. Underwater noise from offshore oil operations and II. Underwater hearing and sound productions of marine mammals. Naval Ocean Systems Center Report, San Diego, California.

Tyack P. and H. Whitehead. 1983. Male competition in large groups of wintering humpback whales. Behaviour 83: 132-154.

Tyack, P. 1981. Interactions between singing Hawai'ian humpback whales and conspecifics nearby. Behavioural Ecology and Sociobiology 8: 105-116.

Tyack, P.L. 2000. Functional aspects of cetacean communication. Pages 270-307. In: J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead (eds.) Cetacean societies: field studies of dolphins and whales. The University of Chicago Press; Chicago, Illinois.

Tyack, P.L. and C.W. Clark. 1997. Long range acoustic propagation of whale vocalizations. In: Taborsky M, Taborsky B (eds) Advances in Ethology, 32. pp 28. Contributions to the XXV International Ethological Conference, Vienna.

U.S. Department of Commerce. 1983. Draft management plan and environmental impact statement for the proposed Hawai'i Humpback Whale National Marine Sanctuary. NOAA, Office of Ocean and Coastal Resource management, Sanctuary Programs Division, and Hawai'i Department of Planning and Economic Development, Washington, D.C.

U.S. Department of the Navy [Navy]. 1999a. Biological Assessment for the Employment of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. Washington, D.C.

U.S. Department of the Navy [Navy]. 1999b. Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Technical Report 1: Low Frequency Sound Scientific Research Program Technical Report (Responses of four species of whales to sounds of SURTASS LFA sonar transmissions). U.S. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2001a. Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. U.S. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2001b. Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Action (SURTASS LFA) Sonar. Technical Report 2: Acoustic Modeling Results. U.S. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy [Navy]. 2008. Mariana Islands Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). Department of the Navy, U.S. Pacific Fleet, Pearl Harbor, Hawaii.

U.S. Department of the Navy [Navy]. 2009. Draft Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS): Guam and CNMI Military Relocation. Relocating Marines from Okinawa, Visiting Aircraft Carrier Berthing, and Army Air and Missile Defense Task Force. Department of the Navy, U.S. Pacific Fleet, Pearl Harbor, Hawaii.

U.S. Department of the Navy Pacific Fleet. 2007a. Consultation package: Exercise Valiant Shield 2007. U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii.

U.S. Department of the Navy Pacific Fleet. 2007b. Mariana Islands sea turtle and cetacean survey report for cruises from 13 January - 13 April 2007. U.S. Navy, Pacific Fleet, Naval Facilities Engineering Command, Pacific, Honolulu, Hawaii.

U.S. Department of the Navy Pacific Fleet. 2007c. Final comprehensive report for the operation of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar onboard the R/V *Cory Chouest* and USNS IMPECCABLE (T-AGOS 23) unde the National Marine Fisheries Service Regulations 50 CFR 216 Subpart Q. U.S. Navy, Chief of Naval Operations, Washington, D.C.

U.S. Department of the Navy Third Fleet. 2002. Programmatic Environmental Assessment for the Rim of the Pacific training exercises. U.S. Navy, Pacific Fleet, Pearl Harbor, Hawai'i.

U.S. Department of the Navy Third Fleet. 2004. 2004 Supplement to the Programmatic Environmental Assessment for the Rim of the Pacific training exercises. U.S. Navy, Pacific Fleet, Pearl Harbor, Hawai'i.

U.S. Department of the Navy Third Fleet. 2005. Request for incidental take harassment authorization for the incidental harassment of marine mammals resulting from raining events conducted during the Riim of the Pacific (USWEX) exercise. U.S. Navy, Pacific Fleet, Pearl Harbor, Hawai'i.

U.S. Department of the Navy Third Fleet. 2006a. 2006 Supplement to the Programmatic Environmental Assessment for the Rim of the Pacific training exercises. U.S. Navy, Pacific Fleet, Pearl Harbor, Hawai'i.

U.S. Department of the Navy Third Fleet. 2006b. Undersea Warfare exercise (USWEX) draft programmatic environmental assessment and overseas environmental assessment. U.S. Navy, Pacific Fleet, Pearl Harbor, Hawai'i.

U.S. Department of the Navy Third Fleet. 2006c. 2006 Rim of the Pacific Exercise After Action Report: analysis of the effectiveness of the mitigation and monitoring measures as required under the Marine Mammal Protection Act (mmpa) incidental harassment authorization and National Defense Exemption from the requirements of the mmpa for mid-frequency active sonar mitigation measures. U.S. Department of the Navy, Chief of Naval Operations; Washington, D.C.

U.S. Department of the Navy. 2005. Operation of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar onboard the *R/V Cory Chouest* and USNS *Impeccable* (T-AGOS 23) under the National Marine Fisheries Service Letters of Authorization of 13 August 2004. Annual Report No. 3.

Unpublished report prepared by the U.S. Department of the Navy, Chief of Navy Operations for the National Marine Fisheries Service, Office of Protected Resources. Silver Spring, Maryland.

U.S. Environmental Protection Agency [EPA]. 1998. Guidelines for ecological risk assessment. Federal Register 63(93); 26846-26924.

U.S. Fish and Wildlife Service, and National Marine Fisheries Service. 1998a. Recovery plan for the U.S. Pacific population of the green turtle (*Chelonia mydas*). U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, National Marine Fisheries Service, Silver Spring, Maryland, and Portland, Oregon.

U.S. Fish and Wildlife Service, and National Marine Fisheries Service. 1998b. Recovery plan for the U.S. Pacific population of the hawksbill turtle (*Eretmochelys imbricata*). U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, National Marine Fisheries Service, Silver Spring, Maryland, and Portland, Oregon.

U.S. Fish and Wildlife Service, and National Marine Fisheries Service. 1998c. Recovery plan for the U.S. Pacific population of the olive ridley turtle (*Lepidochelys olivacea*). U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, National Marine Fisheries Service, Silver Spring, Maryland, and Portland, Oregon.

U.S. National Marine Fisheries Service. 2002. Biological opinion on the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

U.S. National Marine Fisheries Service. 2003. Biological opinion on annual letter of authorization for the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

U.S. National Marine Fisheries Service. 2004. Biological opinion on annual letter of authorization for the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

U.S. National Marine Fisheries Service. 2005. Biological opinion on annual letter of authorization for the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

U.S. National Marine Fisheries Service. 2006. Biological opinion on annual letter of authorization for the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources; Silver Spring, Maryland.

U.S. National Marine Fisheries Service. 2007. Letter of concurrence to the U.S. Navy on the proposed ammunition wharf expansion (Kilo Wharf) in Apra Harbor, Guam. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Regional Office; Honolulu, Hawai'i.

Vogt, S. 2009. Wildlife surveys on military leased lands, Tinian, Commonwealth of the Northern Mariana Islands. Fiscal years 2006 and 2007 report for 61755NR410. Report prepared for the U.S. Navy, Pacific Fleet, Honolulu, Hawaii.

von Ziegesar, O. 1984. A survey of the humpback whales in southeastern Prince William Sound, Alaska: 1980, 1981, and 1983. Report to the Sate of Alaska, Alaska Council on Science and Technology.

Wada, S. 1980. Japanese whaling and whale sighting in the North Pacific 1978 season. Reports of the International Whaling Commission 30:415-424.

Wade, P.R., and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the Eastern Tropical Pacific. Reports of the International Whaling Commission 43:477-493.

Walsh, M. T., R. Y. Ewing, D. K. Odell, and G. D. Bossart. 2001. Mass strandings of cetaceans. Pages 83 - 96 in L. Dierauf, and F. M. D. Gulland, editors. Marine mammal medicine. CRC Press, Boca Raton, Florida.

Watkins W.A., W.E. Schevill. 1972. Sound source location by arrival-times on a non-rigid three-dimensional hydrophone array. Deep-Sea Research 19: 691-706.

Watkins, W. A. 1977. Acoustic behavior of sperm whales. Oceanus. 2:50-58.

Watkins, W. A., K. E. Moore, D. Wartzok, and J. H. Johnson. 1981. Radio tracking of finback *(Balaenoptera physalu*s) and humpback *(Megaptera novaeanglia*e) whales in Prince William Sound, Alaska. Deep-Sea Research 28A(6):577-588.

Watkins, W. A., P. Tyack, K. E. Moore, and J. E. Bird. 1987. The 20-Hz signals of finback whales (*Balaenoptera physalus*). Journal of the Acoustical Society of America 82(6): 1901-1912.

Watkins, W.A. 1980. Acoustics and the behavior of sperm whales. Pages 283-290. In: R.G. Busnel and J.F. Fish (editors). Animal Sonar Systems. Plenum Press; New York, New York.

Watkins, W.A. 1981. Activities and underwater sounds of fin whales. Scientific Reports of the International Whaling Commission 33: 83-117.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Marine Mammal Science 2(4): 251-262.

Watkins, W.A. and W.E. Schevill. 1975. Sperm whales (*Physter catodon*) react to pingers. Deep-Sea Research 22: 123-129.

Watkins, W.A. and W.E. Schevill. 1977. Spatial distribution of *Physeter catodon* (sperm whales) underwater. Deep-Sea Research 24:693-699.

Watkins, W.A. and Wartzok, D. 1985. Sensory biophysics of marine mammals. Marine Mammal Science 1(3): 219-260.

Watkins, W.A., K.E. Moore, and P. Tyack. 1985. Codas shared by Caribbean sperm whales. In: Abstracts of the Sixth Biennial Conference on the Biology of Marine Mammals, November 1985; Vancouver, British Columbia.

Watkins, W.A., K.E. Moore, and P. Tyack. 1985. Sperm whale acoustic behaviors in the southeast Caribbean. Cetology 49:1-15.

Watkins, W.A., M.A. Dahr, K.M. Fristrup and T.J. Howald 1993. Sperm whales tagged with transponders and tracked underwater by sonar. Marine Mammal Science 9(1):55-67.

Watkins, W.A., P. Tyack, K.E. Moore, and J.E. Bird. 1987. The 20 Hz signals of finback whales (*Balaenoptera physalus*). Journal of the Acoustical Society of America 82(6): 1901-1912.

Weilgart, L. and H. Whitehead. 1997. Group-specific dialects and geographical variation in coda repertoire in South Pacific sperm whales. Behavioural Ecology and Sociobiology 40: 277-285.

Weilgart, L.S. and H. Whitehead. 1988. Distinctive vocalizations from mature male sperm whales (*Physeter macrocephalus*). Canadian Journal of Zoology 66:1931-1937.

Weinrich, M.T., R.H. Lambertsen, C.R. Belt, M.R. Schilling, H.J. Iken and S.E. Syrjala. 1992. Behavioural reactions of humpback whales *Megaptera novaeangliae* to biopsy procedures. Fisheries Bulletin 90(3): 588-598.

Weinrich, M.T., R.H. Lambertsen, C.S. Baker, M.R. Schilling and C.R. Belt. 1991. Behavioural responses of humpback whales (*Megaptera novaeangliae*) in the southern Gulf of Maine to biopsy sampling. Reports of the International Whaling Commission (Special Issue 13): 91-97.

Wentsel, R. S. 1994. Risk assessment and environmental policy. Environmental Toxicology and Chemistry 13:1381.

Whitehead, H. 1996. Babysitting, dive synchrony, and indications of alloparental care in sperm whales. Behavioural Ecology and Sociobiology 38: 237-244.

Whitehead, H. 2002. Sperm whale (*Physeter macrocephalus*). Pages 1165 - 1172 in W. F. Perrin, B. Wursig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, Inc., San Diego, California.

Whitehead, H. 2003, Sperm whales. Chicago, Illinois, University of Chicago Press.

Whitehead, H., J. Gordon, E. A. Mathews and K. R. Richard. 1990. Obtaining skin samples from living sperm whales. Marine Mammal Science 6(4):316-326.

Wiles, G. J., A. B. Amerson Jr., and B. J. R. E. 1989. Notes on the herpetofauna of Tinian, Mariana Islands. Micronesica **22**:107-118.

Wiles, G. J., C. F. Aguon, and G. W. Davis. 1995. The status and distribution of endangered animals and plants in northern Guam. Micronesica **28**:31-49.

Wilkinson, D. M. 1991. Program review of the Marine Mammal Stranding Network. Unpublished report prepared for the Assistant Administrator for Fisheries. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland.

Wingfield, J. C., K. M. O'Reilly, and L. B. Astheimer. 1995. Modulation of the adrenocortical responses to acute stress in Arctic birds: A possible ecological basis. American Zoologist 35:10.

Winn, H.E, P.J. Perkins, L. Winn. 1970. Sounds and behavior of the northern bottlenosed whale. Pages 53-59. In: Proceedings of the 7th Annual Conference on the Biology, Sonar and Diving of Mammals. Stanford Research Institute; Menlo Park, California.

Winn, H.E., C.A. Price, and P.W. Sorensen. 1986. The distributional biology of the right whale (*Eubalaena glacialis*) in the western North Atlantic. Reports of the International Whaling Commission Special Issue No. 10:129- 138.

Yochem, P. K. and S. Leatherwood. 1985. Blue whale *Balaenoptera musculus* (Linnaeus, 1758). In: S.H Ridgway and R. Harrison (editors) Handbook of marine mammals. Volume 3. The sirenians and baleen whales. Academic Press, Inc.; London, United Kingdom.