REQUEST FOR A LETTER OF AUTHORIZATION FOR THE INCIDENTAL TAKING OF MARINE MAMMALS RESULTING FROM LONG RANGE STRIKE WEAPON SYSTEMS EVALUATION PROGRAM AT THE PACIFIC MISSILE RANGE FACILITY AT KAUAI, HAWAII

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GLOSSARY OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

≤	less than or equal to
>	greater than
°	degrees
° N	degrees North
° S	degrees South
° W	degrees West
86 FWS	86th Fighter Weapons Squadron
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
Air Force	U.S. Air Force
BSURE	Barking Sands Underwater Range Extension
CFR	Code of Federal Regulations
CV	coefficient of variation
D	water depth (meters)
dB	decibels
dB re 1 μPa	decibels referenced to 1 micropascal
dB re 1 μPa @ 1 m	decibels referenced to 1 micropascal at 1 meter
dB re 1 μPa^2·s	decibels referenced to 1 micropascal-squared second
DoD	Department of Defense
DPS	distinct population segment
EA	Environmental Assessment
EA/OEA	Environmental Assessment/Overseas Environmental Assessment
EEZ	Exclusive Economic Zone
ER	Extended Range
ESA	Endangered Species Act of 1973
FTS	flight termination system
GI	gastrointestinal
GPS	Global Positioning System
HARM	High-Speed Anti-Radiation Missile
HICEAS	Hawaiian Islands Cetacean and Ecosystem Assessment
HRC	Hawaii Range Complex
Hz	hertz
IADS	integrated air defense system
IHA	Incidental Harassment Authorization
INS	internal navigation system
JASSM	Joint Air-to-Surface Stand-off Missile
JASSM-ER	Joint Air-to-Surface Stand-Off Missile-Extended Range
JB	Joint Base
JDAM	Joint Direct Attack Munition
kg	kilograms
kHz	kilohertz
km	kilometers
km^2	square kilometers
lb	pounds
LJDAM	Laser Joint Direct Attack Munition
LOA	Letter of Authorization
m	meters
M	animal mass based on species (kilograms)
MALD	Miniature Air Launched Decoy
MALD-J	Miniature Air Launched Decoy–Jamming
MHI	Main Hawaiian Islands
mi^2	square miles

MMPA	Marine Mammal Protection Act
MSL	mean sea level
n/a	not available
N/A	not applicable
NAS	Naval Air Station
NEW	net explosive weight
NM	nautical miles
NM^2	square nautical miles
NMFS	National Marine Fisheries Service
NMSDD	Navy Marine Species Density Database
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NOTMAR	Notice to Mariners
OEA	Overseas Environmental Assessment
Pa	Pascal
Pa·s	pascal-seconds
PBX	plastic bonded explosive
PMRF	Pacific Missile Range Facility
psi·msec	pounds per square inch per millisecond
PTS	permanent threshold shift
SDB	Small Diameter Bomb
SDB-I/II	Small Diameter Bomb-I/II
SEL	sound exposure level
SPL	sound pressure level
TM	telemetry
TNT	2,4,6-trinitrotoluene
TTS	temporary threshold shift
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
W-	Warning Area
WSEP	Weapon Systems Evaluation Program

EXECUTIVE SUMMARY

With this submittal, the Air Force Civil Engineer Center (AFCEC) requests a Letter of Authorization (LOA) for the incidental taking, but not intentional taking (in the form of acoustic-related and/or pressure-related impacts), of marine mammals incidental to air-to-surface missions conducted in the Barking Sands Underwater Range Extension (BSURE) area of the Pacific Missile Range Facility (PMRF), as permitted by the Marine Mammal Protection Act (MMPA) of 1972, as amended. Air-to-surface missions consist of the activities described in the Preferred Alternative of the *Environmental Assessment/Overseas Environmental Assessment (EA/OEA) for the Long Range Strike Weapon Systems Evaluation Program* (WSEP), and presented in Section 1 of this document. The purpose of the Proposed Action is to authorize the Air Force to conduct operational evaluations of Long Range Strike weapons and other munitions as part of Long Range Strike WSEP operations. The need for the Proposed Action is to properly train units to execute requirements within Designed Operational Capability Statements, which describe units' real-world operational expectations in a time of war.

The missions may expose marine mammals in the BSURE area to sound exposure levels associated with Level A harassment and Level B harassment. No mortality is expected. Sound and pressure metrics associated with exploding ordnance were determined to be the only activities with potential for significant impacts to marine species, as analyzed in the associated EA/OEA. Long Range Strike WSEP missions involve the use of multiple types of live and inert munitions (bombs and missiles) scored at the water surface in the BSURE. The ordnance may be delivered by multiple types of aircraft, including bombers and fighter aircraft. Weapon performance will be evaluated by an underwater acoustic hydrophone array system as the weapons strike the water surface. Net explosive weight of the live munitions ranges from 23 to 300 pounds and all detonations will occur at the water surface. Missions will occur annually between 2017 and 2021, primarily during the summer but may occur in the fall as well. All missions will be conducted during daylight hours. The Long Range Strike WSEP impact area is approximately 44 nautical miles (81 kilometers) offshore of Kauai, Hawaii, in a water depth of about 15,240 feet (4,645 meters).

The potential takes outlined in Section 6 represent the maximum expected number of animals that could be affected. Mitigation measures will be employed to decrease the number of animals potentially affected, particularly within the Level A harassment zone. Using the most applicable density estimates for each species, the zone of influence for each detonation event, and the total yearly number of planned events, an estimate of the potential number of animals exposed to acoustic and/or pressure thresholds was analyzed using the most recent criteria and thresholds (NMFS, 2016b; Finneran and Jenkins, 2012). Without mitigation measures in place, marine mammals potentially affected by air-to-surface activities in the BSURE area include a total of 16 species of whales and dolphins. The total number of marine mammals potentially exposed to injurious (permanent threshold shift) Level A harassment is approximately 36 animals from three species combined. A maximum of approximately 382 animals from 15 species combined could potentially be exposed to non-injurious (temporary threshold shift) Level B harassment. Approximately 219 animals from 16 species combined could potentially be exposed to noise corresponding to the Level B behavioral harassment threshold. It is anticipated that mitigation measures, identified in Section 11, will reduce the probability of all forms of take.

The information and analyses provided in this application are presented to fulfill the permit request requirements of Title I, Sections 101(a)(5)(A) and 101(a)(5)(F) of the MMPA.

1.0 DESCRIPTION OF ACTIVITIES

1.1 INTRODUCTION

Due to threats to national security, increased missions involving air-to-surface activities have been directed by the Department of Defense (DoD). Accordingly, the U.S. Air Force (Air Force) seeks the ability to conduct operational evaluations of all phases of Long Range Strike weapons and other munitions within the U.S. Navy's Hawaii Range Complex (HRC). The actions would fulfill the Air Force's requirement to evaluate full-scale maneuvers for such weapons, including scoring capabilities, under operationally realistic scenarios.

In this document, air-to-surface activities refer to the deployment of missiles and bombs from aircraft to the water surface. Depending on the requirements of a given mission, munitions may be inert (containing no explosives or only a "spotting" charge) or live (contain explosive charges). Live munitions may detonate above, at, or slightly below the water surface. The Air Force is preparing an Environmental Assessment/Overseas Environmental Assessment (EA/OEA) to evaluate all components of the proposed activities. The activities described below in Section 1.2, *Mission Description*, represent the preferred alternative of the EA/OEA.

The activities will take place in the Barking Sands Underwater Range Extension (BSURE) area of the Pacific Missile Range Facility (PMRF), offshore of Kauai, Hawaii. Missions are planned to begin in summer 2016 and continue for the following five years. However, the 2016 missions involve only a small number of munitions that have been identified as an immediate need and which will all be tested on the same mission day. Therefore, activities occurring in 2016 have been addressed in a separate request for an Incidental Harassment Authorization (IHA). This Letter of Authorization (LOA) request includes only activities occurring from 2017 to 2021.

The 86th Fighter Weapons Squadron (86 FWS) is the test execution organization under the 53rd Wing for all Weapon Systems Evaluation Program (WSEP) deployments. WSEP objectives are to evaluate air-to-surface and maritime weapon employment data, evaluate tactics, techniques, and procedures in an operationally realistic environment and to determine the impact of tactics, techniques, and procedures on combat Air Force training. The munitions associated with the proposed activities are not part of a typical unit's training allocations, and prior to attending a WSEP evaluation, most pilots and weapon systems officers have only dropped weapons in simulators or used the aircraft's simulation mode. Without WSEP operations, pilots would be using these weapons for the first time in combat. On average, half of the participants in each unit drop an actual weapon for the first time during a WSEP evaluation. Consequently, WSEP is a military readiness activity and is the last opportunity for squadrons to receive operational training and evaluation before they deploy.

This document has been prepared in accordance with the applicable regulations of the Marine Mammal Protection Act of 1972 (MMPA), as amended by the National Defense Authorization Act for Fiscal Year 2004 (Public Law 108-136) and its implementing regulations. The LOA request is based on: (1) the analysis of spatial and temporal distributions of marine mammals in the BSURE area (also referred to as the Study Area), (2) the review of testing activities that have the potential to incidentally take marine mammals, and (3) a technical risk assessment to determine the likelihood of effects. This chapter describes those activities that are likely to result in Level B harassment or Level A harassment under the MMPA.

1.2 MISSION DESCRIPTION

This section describes the Long Range Strike WSEP missions to be conducted by the Air Force in the BSURE area of the PMRF (see Section 2, *Duration and Location of the Activities*, for a description of the

Study Area). The actions include air-to-surface test missions of the Joint Air-to-Surface Stand-off Missile/Joint Air-to-Surface Stand-off Missile-Extended Range (JASSM/JASSM-ER), Small Diameter Bomb-I/II (SDB-I/II), High-speed Anti-Radiation Missile (HARM), Joint Direct Attack Munition/Laser Joint Direct Attack Munition (JDAM/LJDAM), and Miniature Air-Launched Decoy (MALD), including detonations above the water, at the water surface, and slightly below the water surface. The following subsections describe aircraft operations, weapons used, schedule, and typical mission procedures.

Aircraft Operations

Aircraft used for munition releases would include bombers and fighter aircraft. Additional airborne assets, such as the P-3 Orion or the P-8 Poseidon, would be used to relay telemetry (TM) and flight termination system (FTS) streams between the weapon and ground stations. Other support aircraft would be associated with range clearance activities before and during the mission and with air-to-air refueling operations. All weapon delivery aircraft would originate from an out base and fly into military-controlled airspace prior to employment. Due to long transit times between the out base and mission location, air-to-air refueling may be conducted in either Warning Area 188 (W-188) or W-189. Bombers, such as the B-1, would deliver the weapons, conduct air-to-air refueling, and return to their originating base as part of one sortie. However, when fighter aircraft are used, the distance and corresponding transit time to the various potential originating bases would make return flights after each mission day impractical. In these cases, the aircraft would temporarily (less than one week) park overnight at Hickam Air Force Base (AFB) and would return to their home base at the conclusion of each mission set. Multiple weapon-release aircraft would be used during some missions, each potentially releasing multiple munitions. Each Long Range Strike WSEP mission set will occur over a maximum of five consecutive days per year. Approximately 10 Air Force personnel would be on temporary duty to support each mission set. Table 1-1 summarizes example types of aircraft proposed to support Long Range Strike WSEP missions.

Table 1-1. Summary of Example Aircraft Usage During Long Range Strike WSEP Missions

Type	Example Aircraft	Purpose	Potential Outbases
Bombers	B-1, B-2, B-52	Weapon release	Ellsworth AFB; Dyess AFB; Barksdale AFB; Whiteman AFB; Minot AFB
Fighter aircraft	F-15, F-16, F-22, F-35	Weapon release, chase aircraft, range clearance	Mountain Home AFB; Nellis AFB; Hill AFB; JB Hickam-Pearl Harbor; JB Elmendorf-Richardson; JB Langley-Eustis
Refueling tankers	KC-135	Air-to-air refueling	McConnell AFB
Surveillance	P-3, P-8	TM and FTS relays	NAS Point Mugu
Helicopters	S-61N	Range clearance, protected species surveys	PMRF
Cargo aircraft	C-130, C-26	Range clearance, protected species surveys	U.S. Coast Guard; PMRF

AFB = Air Force Base; FTS = flight termination system; JB = Joint Base; NAS = Naval Air Station; PMRF = Pacific Missile Range Facility; TM = telemetry

Aircraft flight maneuver operations and weapon release would be conducted in W-188A. Chase aircraft may be used to evaluate weapon release and to track weapons. Flight operations and weapons delivery would be in accordance with published Air Force directives and weapon operational release parameters, as well as all applicable Navy safety regulations and criteria established specifically for PMRF. Aircraft supporting Long Range Strike WSEP missions would primarily operate at high altitudes, only flying below 3,000 feet for a limited time as needed for escorting non-military vessels outside the hazard area or for monitoring the area for protected marine species (e.g., marine mammals, sea turtles). Protected marine species aerial surveys would be temporary and would focus on an area surrounding the weapon impact point on the water. Post-mission surveys would focus on the area down current of the weapon impact location. A detailed description of protected marine species clearance procedures is included in Section 11. Range clearance procedures for each mission would cover a much larger area for human safety. Weapon release parameters would be conducted as approved by PMRF Range Safety. Daily mission briefs would specify planned release conditions for each mission. Aircraft and weapons would be tracked for time, space, and position information. The 86 FWS test director would coordinate with the PMRF Range Safety Officer, Operations Conductor, Range Facility Control Officer, and other applicable mission control personnel for aircraft control, range clearance, and mission safety. Figure 1-1 shows a photograph taken from a chase aircraft of a JASSM being released and in flight.

Figure 1-1. Joint Air-to-Surface Stand-Off Missile (JASSM) Released

Weapons Descriptions

Joint Air-to-Surface Stand-off Missile/Joint Air-to-Surface Stand-Off Missile-Extended Range (JASSM/JASSM-ER)

The JASSM (Figure 1-2) is a stealthy precision cruise missile designed for launch outside area defenses against hardened, medium-hardened, soft, and area type targets. The JASSM has a range of more than 200 nautical miles (NM) (370 kilometers [km]) and carries a 1,000-pound warhead with approximately 300 pounds of 2,4,6-trinitrotoluene (TNT) equivalent net explosive weight (NEW). The specific explosive used is AFX-757, a type of plastic bonded explosive (PBX). The weapon has the capability to fly a preprogrammed route from launch to a target, using Global Positioning System (GPS) technology and an internal navigation system (INS) combined with a Terminal Area Model when available. Additionally, the weapon has a Common Low Observable Auto-Routing function that gives the weapon the ability to find the route that best utilizes the low observable qualities of the JASSM. In either case, these routes can be modeled prior to weapon release. The JASSM-ER has additional fuel and a different engine for a greater range than the JASSM (500 NM [926 km]) but maintains the same functionality of the JASSM.

Figure 1-2. Joint Air-to-Surface Stand-Off Missile (JASSM)

Small Diameter Bomb-I/Small Diameter Bomb-II (SDB-I/SDB-II)

The SDB I (Figure 1-3) is a 250-pound air-launched GPS-INS guided weapon for fixed soft to hardened targets. SDB II (Figure 1-4) expands the SDB I capability with network enabling and uses a tri-mode sensor infrared, millimeter, and semi-active laser to attack both fixed and movable targets. Both munitions have a range of up to 60 NM (111 km). The SDB-I contains 37 pounds of TNT-equivalent NEW, and the SDB-II contains 23 pounds NEW. The explosive used in both SDB-I and SDB-II is AFX-757.

Figure 1-3. Small Diameter Bomb-I (SDB-I)

Figure 1-4. Small Diameter Bomb-II (SDB-II)

High-speed Anti-Radiation Missile (HARM)

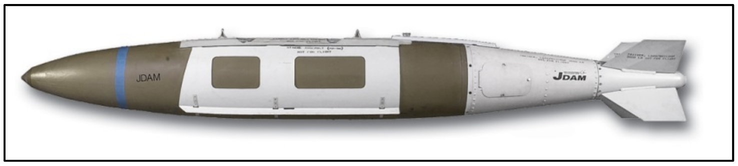
The HARM (Figure 1-5) is a supersonic air-to-surface missile designed to seek and destroy enemy radar-equipped air defense systems. The HARM has a proportional guidance system that homes in on enemy radar emissions through fixed antenna and seeker head in the missile nose. It has a range of up to 80 NM (148 km) and contains 45 pounds of TNT-equivalent NEW. The explosive used is PBXN-107.

Figure 1-5. High-speed Anti-Radiation Missile (HARM)

Joint Direct Attack Munition/Laser Joint Direct Attack Munition (JDAM/LJDAM)

The JDAM (Figure 1-6) is a smart GPS-INS weapon that uses an unguided gravity bomb and adds a guidance and control kit, converting it to a precision-guided munition. The LJDAM variant adds a laser sensor to the JDAM, permitting guidance to a laser designated target. Both JDAM and LJDAM contain 192 pounds of TNT-equivalent NEW with multiple fusing options, with detonations occurring upon impact or with up to a 10-millisecond delay.

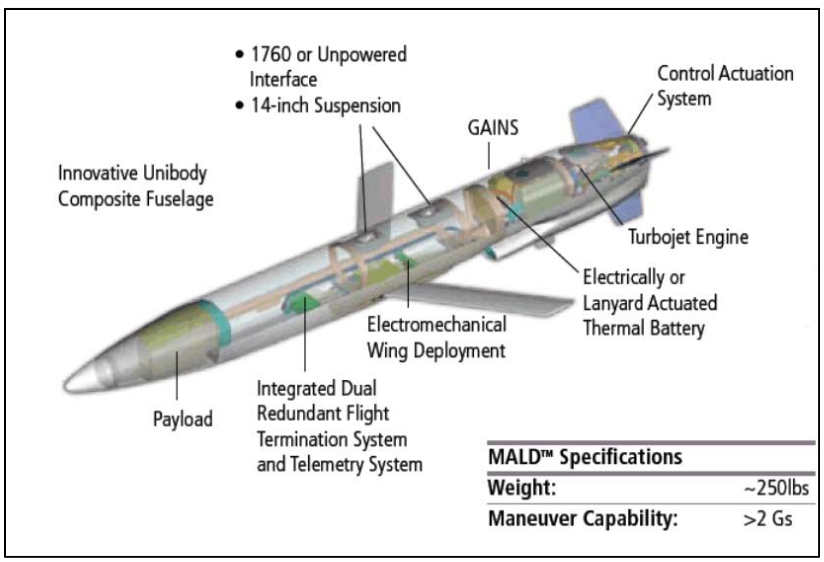
Figure 1-6. Joint Direct Attack Munition (JDAM)



Miniature Air Launched Decoy/Miniature Air Launched Decoy-Jamming (MALD/MALD-J)

The MALD (Figure 1-7) is an air-launched, expendable decoy that will provide the Air Force the capability to simulate, deceive, decoy, and saturate an enemy's threat integrated air defense system (IADS). The MALD production has recently transitioned to include the MALD-J variant, which has the same decoy capability of the MALD plus the addition of jamming IADS. The MALD and MALD-J have ranges up to 500 NM (926 km) to include a 200-NM (370-km) dash with a 30-minute loiter mode. It has no warhead and, therefore, no detonation upon impact with the water surface would occur.

Figure 1-7. Miniature Air Launched Decoy (MALD/MALD-J)



Schedule and General Mission Procedures

The initial phase of the Long Range Strike WSEP operational evaluations is scheduled for September 2016 and will consist of releasing only one live JASSM/JASSM-ER and eight SDBs. Immediate evaluations for JASSM/JASSM-ER and SDB I are needed; therefore, they are the only munitions being proposed for 2016 missions. Weapon release parameters for 2016 mission would involve a B-1 bomber releasing one live JASSM and fighter aircraft, such as F-15, F-16, or F-22, releasing live SDB-I. Up to four SDB-I munitions would be released simultaneously, similar to a ripple effect, each hitting the water surface within a few seconds of each other as a burst; however, the SDB-I releases would occur separately from the JASSM. All releases would occur on the same mission day. As described in Section 1.1, these activities have been addressed in a separate IHA request. This LOA request includes only activities in follow-on years occurring from 2017 to 2021.

Missions conducted in 2017 to 2021 would add deployments of live and inert HARM, JDAM/LJDAM, and MALD/MALD-J munitions, in addition to continued evaluation of JASSM/JASSM-ER and SDB I/II. Releases of live ordnance associated with 2017 – 2021 missions would result in either airbursts, surface detonations, or subsurface detonations (10-foot [3-meter] water depth). Similar to 2016 missions, up to four SDB I/II munitions could be released simultaneously, such that each ordnance would hit the water surface within a few seconds of each other. Aside from the SDB-I/II releases, all other weapons would be released separately, impacting the water surface at different times. There will be a total of five mission days per year during the time frame of 2017 to 2021.

A typical mission day would consist of pre-mission checks, safety review, crew briefings, weather checks, clearing airspace, range clearance, mitigations/monitoring efforts, and other military protocols prior to launch of weapons. Potential delays could be the result of multiple factors including, but not limited to, adverse weather conditions leading to unsafe take-off, landing, and aircraft operations, inability to clear the range of non-mission vessels or aircraft, mechanical issues with mission aircraft or munitions, or presence of protected species in the impact area. These standard operating procedures are usually done in the morning, and live range time may begin in late morning once all checks are complete and approval is granted from range control. The range would be closed to the public for a maximum of four hours per mission day.

Each long range strike weapon would be released in W-188A and would follow a given flight path with programmed GPS waypoints to mark its course in the air. Long range strike weapons would complete their maximum flight range (up to 500-NM distance for JASSM-ER) at an altitude of approximately 18,000 feet mean sea level (MSL) and terminate at a specified location for scoring of the impact. The cruise time would vary among the munitions, but would be about 45 minutes for JASSM/JASSM-ER and 10 minutes for SDB-I/II. The time frame between employments of successive munitions would vary, but releases could be spaced by approximately one hour to account for the JASSM cruise time. The routes and associated safety profiles would be contained within W-188A boundaries. The objective of the route designs is to complete full-scale evasive maneuvers that avoid simulated threats and would, therefore, not consist of a standard “paper clip” or regularly shaped route. The final impact point on the water surface would be programmed into the munitions for weapons scoring and evaluations. The JDAM/LJDAM munitions would also be set to impact at the same point on the water surface.

All missions would be conducted in accordance with applicable flight safety, hazard area, and launch parameter requirements established for PMRF. A weapon hazard region would be established, with the size and shape determined by the maximum distance that a weapon could travel in any direction during its descent. The hazard area is typically adjusted for potential wind speed and direction, resulting in a maximum composite safety footprint for each mission (each footprint boundary is at least 10 NM from the Kauai coastline). This information is used to establish a Launch Exclusion Area and Aircraft Hazard Area. These exclusion areas must be verified to be clear of all non-mission and non-essential vessels and aircraft before live weapons are released. In addition, a buffer area must also be clear on the water surface so that vessels do not enter the exclusion area during the launch window. Prior to weapon release, a range sweep of the hazard area would be conducted by participating mission aircraft or other appropriate aircraft, potentially including S-61N helicopter, C-26 aircraft, fighter aircraft (F-15E, F-16, F-22), or the Coast Guard’s C-130 aircraft.

PMRF has used small water craft docked at the Port Allen public pier to keep nearshore areas clear of tour boats for some mission launch areas. However, for missions with large hazard areas that occur far offshore from Kauai, it would be impractical for these smaller vessels to conduct range clearance activities. The composite safety footprint weapons associated with Long Range Strike WSEP missions is anticipated to be rather large; therefore, it is likely that range clearing activities would be conducted solely by aircraft.

The Range Facility Control Officer is responsible for establishing hazard clearance areas, directing clearance and surveillance assets, and reporting range status to the Operations Conductor. The Control Officer is also responsible for submitting all Notice to Airmen (NOTAMs) and Notice to Mariners (NOTMARs), and for requesting all Federal Aviation Administration airspace clearances. In addition to the human safety measures described above, protected species surveys are carried out before and after missions, as summarized in Section 11.

Table 1-2 summarizes munition and mission information for activities scheduled to occur annually at PMRF from 2017 through 2021.

Table 1-2. Summary of Proposed Testing at Pacific Missile Range Facility from 2017 to 2021

Type of Munition	Live or Inert	NEW (lb)	Type of Aircraft	Detonation Scenario	Number of Proposed Releases				
					2017	2018	2019	2020	2021
JASSM/ JASSM-ER	Live	300	Bomber, Fighter	Surface	6	6	6	6	6
SDB-I	Live	37	Bomber, Fighter	Surface	30	30	30	30	30
SDB-II	Live	23	Bomber, Fighter	Surface	30	30	30	30	30
HARM	Live	45	Fighter	Surface	10	10	10	10	10
JDAM/LJDAM	Live	192	Bomber, Fighter	Subsurface[1]	30	30	30	30	30
MALD/ MALD-J	Inert	N/A	Fighter	N/A	4	4	4	4	4

HARM = High Anti-Radiation Missile; JASSM = Joint Air-to-Surface Standoff Missile; JASSM-ER = Joint Air-to-Surface Standoff Missile – Extended Range; JDAM = Joint Direct Attack Munition; lb = pounds; LJDAM = Laser Joint Direct Attack Munition; MALD = Miniature Air Launched Decoy; MALD-J = Miniature Air Launched Decoy – Jamming; N/A = not applicable (inert); SDB = Small Diameter Bomb

1. Assumes a 10-millisecond time-delayed fuse resulting in detonation occurring at an approximate 10-foot water depth.

2.0 DURATION AND LOCATION OF THE ACTIVITIES

Long Range Strike WSEP missions will occur on weekdays, during daytime hours only. All activities will take place within the PMRF, which is located in Hawaii on and off the western shores of the island of Kauai and includes broad ocean areas to the north, south, and west (Figure 2-1). However, there would be no ground-based or nearshore activities requiring the use of any shoreline areas of Kauai; all aspects and associated impacts from Long Range Strike WSEP missions would occur over open ocean areas. PMRF, as part of the Navy's HRC, is a Major Range and Test Facility Base and, as such, supports the full spectrum of DoD test and evaluation requirements. PMRF is also the world's largest instrumented, multi-environment military testing and training range capable of supporting subsurface, surface, air, and space operations. The PMRF includes 1,020 square nautical miles (NM^2) of instrumented ocean areas at depths between 1,800 feet (549 meters [m]) and 15,000 feet (4,572 m), 42,000 NM^2 of controlled airspace, and a temporary operating area covering 2.1 million NM^2 of ocean area.

Within the PMRF, activities would occur in the BSURE area, which lies in W-188A. The specific impact location within the BSURE area, which is the central point around which all missions are expected to occur, is shown on Figure 2-2. The BSURE consists of about 900 NM^2 of instrumented underwater ranges, encompassing the deepwater portion of the PMRF and providing over 80 percent of PMRF's underwater scoring capability. The BSURE facilitates training, tactics, development, and test and evaluation for air, surface, and subsurface weapons systems in deep water. It provides a full spectrum of range support, including radar, underwater instrumentation, telemetry, electronic warfare, remote target command and control, communications, data display and processing, and target/weapon launching and recovery facilities. The underwater tracking system begins 9 NM (17 km) from the north shore of Kauai and extends out to 40 NM (74 km) from shore. Long Range Strike WSEP missions would employ live weapons with long flight paths requiring large amounts of airspace and conclude with weapon impact and surface detonations within the BSURE instrumented range. Missions would be conducted primarily in the summer months (June through August) but may occasionally occur in the fall (September through November) beginning 2017 through 2021.

Figure 2-1. Regional Location of Long Range Strike WSEP Activities

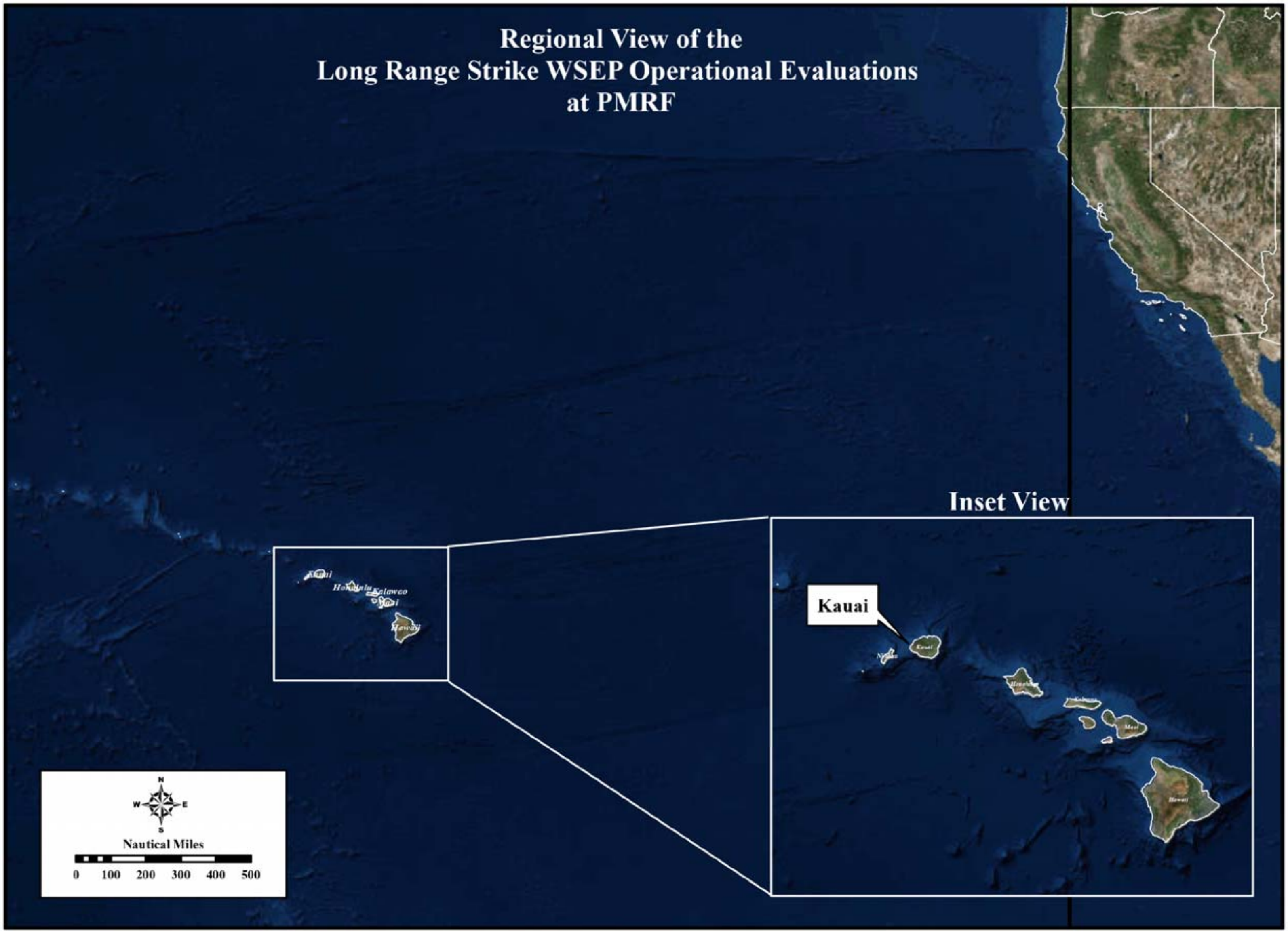
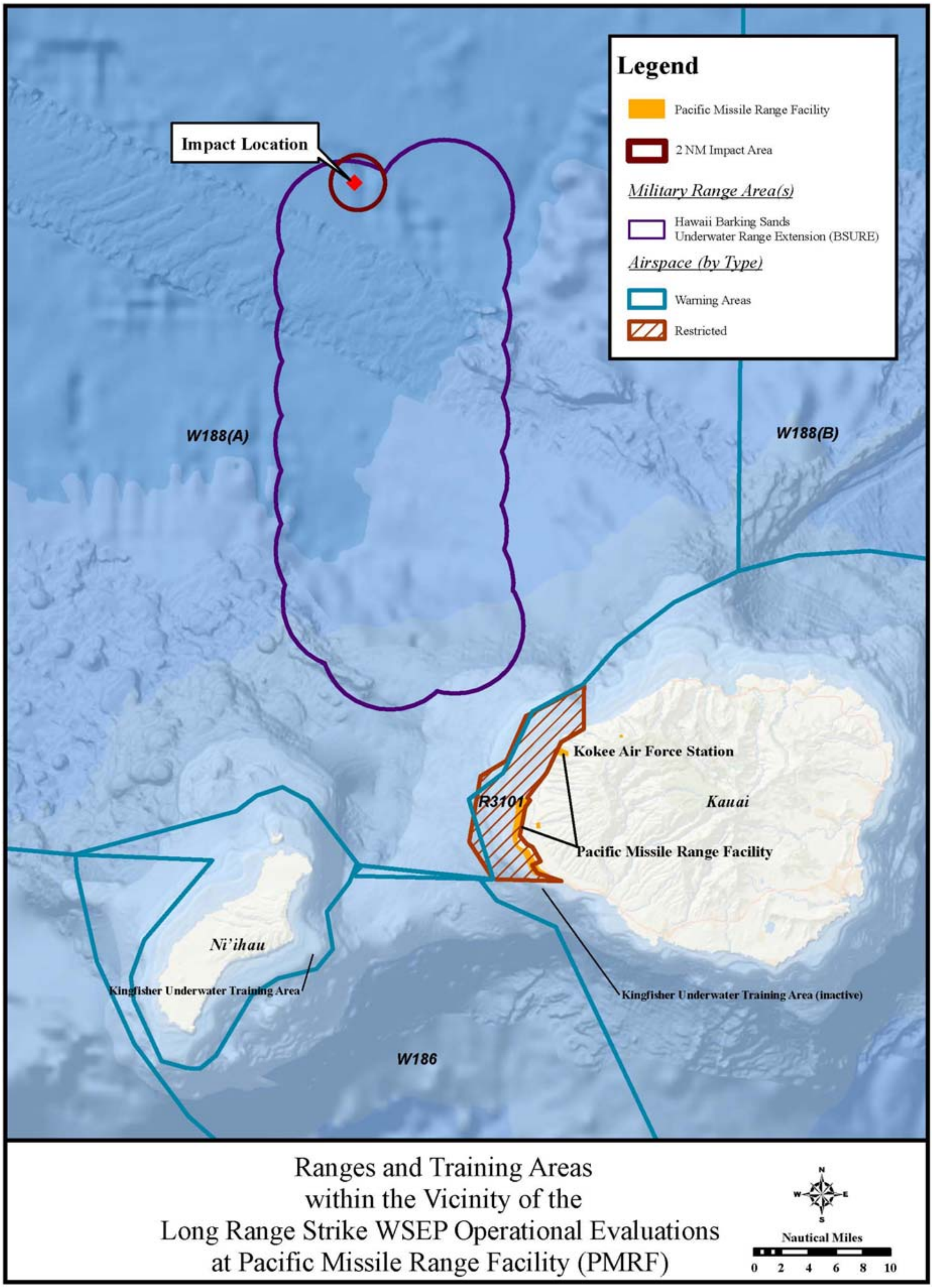


Figure 2-2. Pacific Missile Range Facility on Kauai, Hawaii



3.0 MARINE MAMMAL SPECIES AND NUMBERS

This section identifies marine mammal species and stocks potentially found in the PMRF (including the BSURE area), provides general information on marine mammal behavior, hearing and vocalization, and threats, and provides a density estimate for each species. Marine mammals are a diverse group of approximately 130 species that rely wholly or substantially on the sea for important life functions and include cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, sea lions, and walruses), sirenians (manatees, dugongs, and sea cows), marine otters, and polar bears. Of these animal groups, whales, dolphins, and one pinniped occur in the Study Area. Although most marine mammal species live wholly or predominantly in the marine habitat, some spend time in terrestrial habitats (e.g., seals) or freshwater environments (e.g., freshwater dolphins). All marine mammals in the United States are protected under the MMPA; some species are additionally protected under the Endangered Species Act of 1973 (ESA). Marine mammals may be designated under the ESA as endangered, threatened, candidate, or proposed species. Under the MMPA, species may be designated as depleted, which is defined as a species or stock that is (1) below its optimum sustainable population or (2) designated as endangered or threatened under the ESA. Marine mammal species protected under the ESA are evaluated separately in an associated Biological Assessment.

Cetaceans may be categorized as odontocetes or mysticetes. Odontocetes, which range in size from about 1 m to over 18 m, have teeth that are used to capture and consume individual prey. Mysticetes, which are also known as baleen whales, range in size from about 10 m to over 30 m. Instead of teeth, mysticetes have baleen (a fibrous structure made of keratin) in their mouth, which is used to filter the large numbers of small prey that are engulfed, sucked, or skimmed from the water or ocean floor sediments. Cetaceans inhabit virtually every marine environment, from coastal waters to the open ocean. Their distribution is primarily influenced by prey availability, which depends on factors such as ocean current patterns, bottom relief, and sea surface temperature, among others. Most of the large cetaceans are migratory, but many small cetaceans do not migrate in the strictest sense. Instead, they may undergo seasonal dispersal, or shifts in density. Pinnipeds generally spend a large portion of time on land at haulout sites used for resting and moulting, and at rookeries used for breeding and nursing young, and return to the water to forage. The only pinniped species that occurs regularly in Hawaii is the Hawaiian monk seal (*Neomonachus schauinslandi*). In the Main Hawaiian Islands, they are generally solitary and have no established rookeries.

Marine mammals with potential occurrence in the BSURE area are shown in Table 3-1.

Table 3-1. Marine Mammals with Potential Occurrence in the Study Area

Common Name	Scientific Name
Mysticetes (baleen whales)	
Humpback whale	*Megaptera novaeangliae*
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Sei whale	*Balaenoptera borealis*
Bryde’s whale	*Balaenoptera brydei/edeni*
Minke whale	*Balaenoptera acutorostrata*
Odontocetes (toothed whales and dolphins)	
Sperm whale	*Physeter macrocephalus*
Pygmy sperm whale	*Kogia breviceps*
Dwarf sperm whale	*Kogia sima*
Killer whale	*Orcinus orca*
False killer whale	*Pseudorca crassidens*
Pygmy killer whale	*Feresa attenuata*

Table 3-1. Marine Mammals with Potential Occurrence in the Study Area, Cont'd

Common Name	Scientific Name
Short-finned pilot whale	*Globicephala macrorhynchus*
Melon-headed whale	*Peponocephala electra*
Bottlenose dolphin	*Tursiops truncatus*
Pantropical spotted dolphin	*Stenella attenuata*
Striped dolphin	*Stenella coeruleoalba*
Spinner dolphin	*Stenella longirostris*
Rough-toothed dolphin	*Steno bredanensis*
Fraser's dolphin	*Lagenodelphis hosei*
Risso's dolphin	*Grampus griseus*
Cuvier's beaked whale	*Ziphius cavirostris*
Blainville's beaked whale	*Mesoplodon densirostris*
Longman's beaked whale	*Indopacetus pacificus*
Pinnipeds	
Hawaiian monk seal	*Neomonachus schauinslandi*

General Behavior

Many species of marine mammals, particularly odontocetes, are highly social animals that spend much of their lives living in groups or schools ranging from several individuals to several thousand individuals. Aggregations of baleen whales may form during particular breeding or foraging seasons, although they do not appear to persist over time as a social unit. All marine mammals dive beneath the water surface, primarily for the purpose of foraging. Dive frequency and the time spent during dives vary among species and within individuals of the same species. Some species that forage on deep-water prey can make dives lasting over an hour. Other species spend the majority of their lives close to the surface and make relatively shallow dives. The diving behavior of a particular species or individual has implications regarding the ability to detect them during mitigation and monitoring activities. In addition, their distribution through the water column is an important consideration when conducting acoustic exposure analyses.

Vocalization and Hearing

All marine mammals that have been studied can produce sounds and use sounds to forage, orient, detect and respond to predators, and socially interact with others. Measurements of marine mammal sound production and hearing capabilities provide some basis for assessment of whether exposure to a particular sound source may affect a marine mammal. Marine mammal hearing abilities are quantified using live animals either via behavioral audiometry or electrophysiology. Behavioral audiograms are plots of animals' exhibited hearing threshold versus frequency, and are obtained from captive, trained live animals. Behavioral audiograms are difficult to obtain because many species are too large, too rare, and too difficult to acquire and maintain for experiments in captivity. Electrophysiological audiometry measures small electrical voltages produced by neural activity when the auditory system is stimulated by sound. The technique is relatively fast, does not require a conscious response, and is routinely used to assess the hearing of newborn humans. Understanding of a species' hearing ability may be based on the behavioral audiogram of only a single individual or small group of animals. In addition, captive animals may be exposed to local ambient sounds and other environmental factors that may impact their hearing abilities and may not accurately reflect the hearing abilities of free-swimming animals (Houser, Finneran, et al., 2010). For animals not available in captive or stranded settings (including large whales and rare species), estimates of hearing capabilities are made based on physiological structures, vocal characteristics, and extrapolations from related species.

Direct measurement of hearing sensitivity exists for only about 25 of the nearly 130 species of marine mammals. Table 3-2 provides a summary of sound production and general hearing capabilities for marine mammals with potential occurrence in the Study Area. For purposes of the analyses in this document, marine mammals are arranged into the following functional hearing groups based on their generalized hearing sensitivities: high-frequency cetaceans, mid-frequency cetaceans, low-frequency cetaceans (mysticetes), and phocid pinnipeds (true seals). Summaries of the functional hearing groups applicable to this document are provided below. For a detailed discussion of all marine mammal functional hearing groups and their derivation, see Finneran and Jenkins (2012).

Table 3-2. Hearing and Vocalization Ranges for Marine Mammal Functional Hearing Groups and Species Potentially Occurring within the Study Area

Functional Hearing Group	Species Potentially Present in the Study Area	Sound Production		General Hearing Ability Frequency Range
		Frequency Range	Source Level (dB re 1 µPa @ 1 m)	
High-Frequency Cetaceans	Kogia Species (Dwarf Sperm Whale and Pygmy Sperm Whale)	100 Hz to 200 kHz	120 to 205	200 Hz to 180 kHz
Mid-Frequency Cetaceans	Sperm Whale, Beaked Whales (*Indopacetus*, *Mesoplodon*, and *Ziphius* species), Bottlenose Dolphin, Fraser's Dolphin, Killer Whale, False Killer Whale, Pygmy Killer Whale, Melon-headed Whale, Short-finned Pilot Whale, Risso's Dolphin, Rough-toothed Dolphin, Spinner Dolphin, Pantropical Spotted Dolphin, Striped Dolphin	100 Hz to >100kHz	118 to 236	150 Hz to 160 kHz
Low-Frequency Cetaceans	Blue Whale, Bryde's Whale, Fin Whale, Humpback Whale, Minke Whale, Sei Whale	10 Hz to 20 kHz	129 to 195	7 Hz to 22 kHz
Phocidae	Hawaiian monk seal	100 Hz to 12 kHz	103 to 180	In water: 75 Hz to 75 kHz

> = greater than; dB re 1 µPa @ 1 m = decibels referenced to 1 microPascal at 1 meter; Hz = hertz; kHz = kilohertz

High-Frequency Cetaceans. Marine mammals within the high-frequency cetacean functional hearing group are all odontocetes (toothed whales) and includes eight species and subspecies of porpoises (family: Phocoenidae); dwarf and pygmy sperm whales (family: Kogiidae); six species and subspecies of river dolphins; and four species of Cephalorhynchus. The only high-frequency cetaceans found in the Study Area are dwarf sperm whale and pygmy sperm whale. Functional hearing in high-frequency cetaceans occurs between approximately 200 hertz (Hz) and 180 kilohertz (kHz) (Southall et al., 2007).

Sounds produced by high-frequency cetaceans range from approximately 100 Hz to 200 kHz with source levels of 120 to 205 decibels (dB) referenced to (re) 1 micro (µ) Pascal (Pa) at 1 m (Madsen et al., 2005; Richardson et al., 1995; Verboom and Kastelein, 2003; Villadsgaard et al., 2007). Recordings of sounds produced by dwarf and pygmy sperm whales consist almost entirely of the click/pulse type (Marten, 2000). High-frequency cetaceans also generate specialized clicks used in biosonar (echolocation) at frequencies above 100 kHz that are used to detect, localize, and characterize underwater objects such as prey (Richardson et al., 1995).

An electrophysiological audiometry measurement on a stranded pygmy sperm whale indicated best sensitivity between 90 to 150 kHz (Ridgway and Carder, 2001).

Mid-Frequency Cetaceans. Marine mammals within the mid-frequency cetacean functional hearing group are all odontocetes, and include the sperm whale (family: Phystereidae); 32 species and subspecies of dolphins (family: Delpinidae); the beluga and narwhal (family: Monodontidae); and 19 species of beaked and bottlenose whales (family: Ziphiidae). The following members of the mid-frequency cetacean group are present or have a reasonable likelihood of being present in the Study Area: sperm whale, killer whale, false killer whale, pygmy killer whale, short-finned pilot whale, melon-headed whale, common bottlenose dolphin, pantropical spotted dolphin, striped dolphin, spinner dolphin, rough-toothed dolphin, Fraser's dolphin, Risso's dolphin, and beaked whales (*Berardius, Indopacetus, Mesoplodon*, and *Ziphius* species). Functional hearing in mid-frequency cetaceans is conservatively estimated to be between approximately 150 Hz and 160 kHz (Southall et al., 2007).

Hearing studies on cetaceans have focused primarily on odontocete species, and hearing sensitivity has been directly measured for a number of mid-frequency cetaceans, including Atlantic white-sided dolphins (*Lagenorhynchus acutus*) (Houser, Dankiewicz-Talmadge, et al., 2010), common dolphins (*Delphinus* spp.) (Houser, Dankiewicz-Talmadge, et al., 2010), Atlantic bottlenose dolphins (Johnson, 1967), belugas (White et al., 1977; Finneran et al., 2005), Indo-Pacific bottlenose dolphins (Houser, Dankiewicz-Talmadge, et al., 2010), Black Sea bottlenose dolphins (Popov et al., 2007), striped dolphins (Kastelein et al., 2003), white-beaked dolphins (Nachtigall et al., 2008), Risso's dolphins (Nachtigall et al., 2005), belugas (*Delphinapterus leucas*) (Finneran et al., 2005; White et al., 1977), false killer whales (Yuen et al., 2005), killer whales (Szymanski et al., 1999), Gervais' beaked whales (Finneran and Schlundt, 2009), and Blainville's beaked whales (Pacini et al., 2011). All audiograms exhibit the same general U-shape, with a wide nominal hearing range between approximately 150 Hz and 160 kHz.

In general, odontocetes produce sounds across the widest band of frequencies. Their social vocalizations range from a few hundreds of Hz to tens of kHz (Southall et al., 2007) with source levels in the range of 100–170 dB re 1 μPa (see Richardson et al., 1995). As mentioned earlier, they also generate specialized clicks used in echolocation at frequencies above 100 kHz that are used to detect, localize and characterize underwater objects such as prey (Au, 1993). Echolocation clicks have source levels that can be as high as 229 dB re 1 μPa peak-to-peak (Au et al., 1974).

Low-Frequency Cetaceans. Marine mammals within the low-frequency functional hearing group are all mysticetes. This group is comprised of 13 species and subspecies of mysticete whales in six genera: *Eubalaena, Balaena, Caperea*, *Eschrichtius, Megaptera*, and *Balaenoptera*. The following members of the low-frequency cetacean group are present or have a reasonable likelihood of being present in the Study Area: humpback, blue, fin, sei, Bryde's, and minke whales. Functional hearing in low-frequency cetaceans is conservatively estimated to be between approximately 7 Hz and 22 kHz (Southall et al., 2007).

Because of animal size and availability of live specimens, direct measurements of mysticete whale hearing are unavailable, although there was one effort to measure hearing thresholds in a stranded grey whale (Ridgway and Carder, 2001). Because hearing ability has not been directly measured in these species, it is inferred from vocalizations, ear structure, and field observations. Vocalizations are audible somewhere in the frequency range of production, but the exact range cannot be inferred (Southall et al., 2007).

Mysticete cetaceans produce low-frequency sounds that range in the tens of Hz to several kHz that most likely serve social functions such as reproduction, but may have an orientation function as well (Green et al., 1994). Humpback whales are the notable exception within the mysticetes, with some calls exceeding 10 kHz. These sounds can be generally categorized as low-frequency moans; bursts or pulses; or more complex songs (Edds-Walton, 1997; Ketten, 1997). Source levels of most mysticete sounds range from 150–190 dB re 1 μPa (see Richardson et al., 1995).

Phocid Pinnepeds. The only phocid (true seal) present in the Study Area is the Hawaiian monk seal. Hearing in phocids has been tested in the following species: gray seals (Ridgway et al., 1975); harbor seals (Richardson et al., 1995; Terhune and Turnbull, 1995; Kastak and Schusterman, 1998; Wolski et al., 2003; Southall et al., 2007; Kastelein et al., 2012); harp seals (Terhune and Ronald, 1971; Terhune and Ronald, 1972); Hawaiian monk seals (Thomas et al., 1990); northern elephant seal (Kastak and Schusterman, 1998; Kastak and Schusterman, 1999); and ringed seals (Terhune and Ronald, 1975; Terhune and Ronald, 1976). Phocid hearing limits are estimated to be 75 Hz–30 kHz in air and 75 Hz–75 kHz in water (Kastak and Schusterman, 1999; Kastelein et al., 2009 Møhl, 1968; Reichmuth, 2008; Terhune and Ronald, 1971; Terhune and Ronald, 1972).

General Threats

Marine mammal populations can be influenced by various factors and human activities. These factors can affect marine mammal populations directly (e.g., hunting and whale watching), or indirectly (e.g., reduced prey availability or lowered reproductive success). Marine mammals may also be influenced by natural phenomena such as storms and other extreme weather patterns, and climate change. Generally, not much is known about how large storms and other weather patterns affect marine mammals, other than that mass strandings (when two or more marine mammals become beached or stuck in shallow water) sometimes coincide with hurricanes, typhoons, and other tropical storms (Marsh, 1989; Rosel and Watts, 2008). Climate change can potentially affect marine mammal species directly through habitat loss (especially for species that depend on ice or terrestrial areas) and indirectly via impacts on prey, changing prey distributions and locations, and changes in water temperature.

Mass die offs of some marine mammal species have been linked to toxic algal blooms. In such cases, the mammals consume prey that has consumed toxic plankton. All marine mammals have parasites that, under normal circumstances, probably do little overall harm, but that under certain conditions can cause health problems or even death (Jepson et al., 2005; Bull et al., 2006; Fauquier et al., 2009). Disease affects some individuals (especially older animals), and occasionally disease epidemics can injure or kill a large percentage of a population (Paniz-Mondolfi and Sander-Hoffmann, 2009; Keck et al., 2010). Recently the first case of morbillivirus in the central Pacific was documented for a stranded Longman's beaked whale at Maui (West et al., 2012).

Human impacts on marine mammals have received much attention in recent decades and include hunting (both commercial and native practices), fisheries interactions (such as gear entanglement or shootings by fishers), bycatch (accidental or incidental catch), indirect effects of fisheries through takes of prey species, ship strikes, noise pollution, chemical pollution, and general habitat deterioration or destruction. Direct hunting, as in whaling and sealing operations, provided the original impetus for marine mammal management efforts and has driven much of the early research on cetaceans and pinnipeds (Twiss and Reeves, 1999). In 1994, the MMPA was amended to formally address bycatch. Cetacean bycatch subsequently declined by 85 percent between 1994 and 2006. However, fishery bycatch is likely the most impactful problem presently and may account for the deaths of more marine mammals than any other cause (Northridge, 2008; Read, 2008; Hamer et al., 2010; Geijer and Read, 2013). For example, bycatch has significantly contributed to the decline of the Hawaiian population of false killer whales (Boggs et al., 2010).

Ship strikes are an issue of increasing concern for most marine mammals, particularly baleen whale species. There were nine reported ship collisions with humpback whales in the Hawaiian Islands in 2006 (none involved Navy vessels), as recorded by the National Marine Fisheries Service (NMFS) Pacific Islands Region Marine Mammal Response Network Activity Updates (NMFS, 2007a). Overall, from 2007 to 2012 in Hawaii, there were 39 vessel collisions involving humpback whales (Bradford and Lyman, 2015). None of these strikes involved Navy vessels. A humpback carcass was discovered on the shore of southwest Molokai in 2010 with indications that the death resulted from trauma consistent with a ship strike (NMFS, 2010a). Chemical pollution is also of concern, although for the most part, its effects on marine mammals are not well understood (Aguilar de Soto et al., 2008). Chemical pollutants found in pesticides flow into the marine environment from human use on land and are absorbed into the bodies of marine mammals, accumulating in their blubber or internal organs, or are transferred to the young from its mother's milk (Fair et al., 2010). Marine mammals that live closer to the source of pollutants and those that feed on higher-level organisms have increased potential to accumulate toxins (Moon et al., 2010). The buildup of human-made persistent compounds in marine mammals not only increases their likelihood of contracting diseases or developing tumors, but also compromises the function of their reproductive systems (Fair et al., 2010). Oil and other chemical spills are a specific type of ocean contamination that can have damaging effects on some marine mammal species (see Matkin et al., 2008).

Habitat deterioration and loss is a major factor for almost all coastal and inshore species of marine mammals, especially those that live in rivers or estuaries, and it may include such factors as depleting a habitat's prey base and the complete loss of habitat (Kemp, 1996; Smith et al., 2009; Ayres et al., 2012). In some locations, especially where urban or industrial activities or commercial shipping is intense, anthropogenic noise is also being increasingly considered as a potential habitat level stressor. Noise is of particular concern to marine mammals because many species use sound as a primary sense for navigating, finding prey, avoiding predators, and communicating with other individuals. Noise may cause marine mammals to leave a habitat, impair their ability to communicate, or cause stress (Hildebrand, 2009; Tyack et al., 2011; Rolland et al., 2012; Erbe et al., 2012). Noise can cause behavioral disturbances, mask other sounds (including their own vocalizations), may result in injury and in some cases, may result in behaviors that ultimately lead to death (National Research Council, 2003; National Research Council, 2005; Nowacek et al., 2007; Würsig and Richardson, 2009; Southall et al., 2009; Tyack, 2009a). Anthropogenic noise is generated from a variety of sources including commercial shipping, oil and gas activities, commercial and recreational fishing, recreational boating and whale watching, offshore power generation, research (including sound from air guns, sonar, and telemetry), and military training and testing activities. Vessel noise in particular is a large contributor to noise in the ocean. Commercial shipping's contribution to ambient noise in the ocean has increased by as much as 12 dB over the last few decades (McDonald et al., 2008; Hildebrand, 2009).

Marine mammals as a whole are subject to the various influences and factors described above. If additional specific threats to individual species within the Study Area are known, those threats are described in the species accounts in Section 4, *Affected Species Status and Distribution*.

Density Estimates

For purposes of impacts analysis, the number of marine mammals potentially affected may be considered in terms of density, which is the number of animals present in the area affected by a given surface detonation. A significant amount of effort is required to collect and analyze survey data sufficient for producing useable marine species density estimates for large areas such as the HRC and is typically beyond the scope of any single organization. As a result, there is often no single source of density available for every area, species, and season of interest; density data are often compiled from multiple sources. The density estimates used for acoustic analysis in this document are from the U.S. Navy's Marine Species Density Database for the Pacific region, which includes the HRC (U.S. Department of the Navy, 2016). The Navy database includes a compilation of the best available density data from several primary sources and published works including survey data from NMFS within the U.S. Exclusive Economic Zone (EEZ) off the coast of Hawaii (hereafter referred to as the Hawaiian Islands EEZ). NMFS publishes annual stock assessment reports for various regions of U.S. waters, which cover all stocks of marine mammals within those waters (for abundance and distribution information on species potentially occurring within the Study Area, see Muto et al. [2016] and Carretta et al. [2016]). Other researchers often publish density data or research covering a particular marine mammal species or geographic area, which is integrated into the stock assessment reports.

For most marine mammal species, abundance is estimated using line-transect methods that derive densities based on sighting data collected during systematic ship or aerial surveys. Habitat-based models may also be used to model density as a function of environmental variables. Each source of data may use different methods to estimate density, and uncertainty in the estimate can be directly related to the method applied. Uncertainty in published density estimation is typically large because of the low number of sightings collected during surveys. Uncertainty characterization is an important consideration in marine mammal density estimation and some methods inherently result in greater uncertainty than others. Therefore, in selecting the best density value for a species, area, and time, it is important to select the data source that used a method providing the least uncertainty and the best estimate for the geographic area. A discussion of methods that provide the best estimate with the least uncertainty under different scenarios is provided in the Navy's density database technical report (U.S. Department of the Navy, 2016). For this LOA request, the Navy provided their most recent information on the type of model used to estimate density, along with the sources of uncertainty (expressed as a coefficient of variation), for each marine mammal species in the Hawaii region as part of their latest updates to the Navy Marine Species Density Database (NMSDD) since 2014. At the time of writing this LOA Request, the technical report for the updated NMSDD had not been finalized, so the source documents for the coefficient of variation values are based on the draft version of the NMSDD technical report referenced above. The most recent information is provided in Table 3-3.

Table 3-3. Marine Mammal Density Models and Uncertainty Values for the Hawaii Region

Species	Coefficient of Variation	Source	Model Type
Humpback whale	Main: 0.15 Outer strata and transit boxes: 0.30	Main Hawaii Islands inner stratum: Mobley, Spitz, et al. (2001) Outer strata and transit boxes: Calambokidis et al. (2008)	Main Hawaii Islands: line-transect Outer EEZ: mark-recapture
Blue whale	1.09	Bradford et al. (in review)	Multiple-covariate line-transect
Fin whale	1.05	Bradford et al. (in review)	Multiple-covariate line-transect
Sei whale	0.90	Bradford et al. (in review)	Multiple-covariate line-transect
Bryde's whale	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Minke whale	n/a	n/a	Acoustically derived from hydrophones using correction factors (Martin et al., 2015)
Sperm whale	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Pygmy sperm whale	1.12	Barlow (2006)	Multiple-covariate line-transect
Dwarf sperm whale	0.74	Barlow (2006)	Multiple-covariate line-transect
Killer whale	0.96	Bradford et al. (in review)	Multiple-covariate line-transect
False killer whale (Main Hawaiian Islands insular stock)	0.20	Oleson et al. (2010)	Population Viability Analysis
False killer whale (all other stocks)	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Pygmy killer whale	0.53	Bradford et al. (in review)	Multiple-covariate line-transect

Table 3-3. Marine Mammal Density Models and Uncertainty Values for the Hawaii Region, Cont'd

Species	Coefficient of Variation	Source	Model Type
Short-finned pilot whale	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Melon-headed whale	0.20	Aschettino (2010)	Mark-recapture
Bottlenose dolphin	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Pantropical spotted dolphin	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Striped dolphin	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Spinner dolphin	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Rough-toothed dolphin	Spatially-explicit	Forney et al. (2015)	Habitat-based density model
Fraser's dolphin	0.66	Bradford et al. (in review)	Multiple-covariate line-transect
Risso's dolphin	0.43	Bradford et al. (in review)	Multiple-covariate line-transect
Cuvier's beaked whale	0.69	Bradford et al. (in review)	Multiple-covariate line-transect
Blainville's beaked whale	1.13	Bradford et al. (in review)	Multiple-covariate line-transect
Longman's beaked whale	0.66	Bradford et al. (in review)	Multiple-covariate line-transect
Hawaiian monk seal	n/a	n/a	Navy derived

n/a = not available; EEZ = Exclusive Economic Zone

The NMSDD is considered the most relevant information source available for the Hawaii area and has been used in impacts analysis of previous military actions conducted near the Study Area. For some species, density estimates are uniform throughout the Hawaii region. For others, densities are provided in multiple smaller blocks. In these cases, the Air Force used density estimates corresponding to the block containing the Long Range Strike WSEP impact location and calculated zones of impact based on acoustic modeling results (refer to Section 6.3 Detonation Effects). The resulting marine mammal seasonal density estimates used in this document are shown in Table 3-4. Long Range Strike WSEP missions are generally planned to occur in summer (June to August), but may experience schedule slips resulting in missions occurring in the fall (September to November. To account for this, fall density estimates are used for all species. As shown in Table 3-4, summer and fall densities are the same for all species, except for most baleen whales. Using the fall densities for this analysis considers seasonal occurrence of baleen whales in the BSURE area in the instances when missions are conducted in the fall.

Table 3-4. Marine Mammal Density Estimates

Species	Density Estimate (animals per square kilometer)			
	Fall	Spring	Summer	Winter
Humpback whale	0.02110	0.02110	0	0.02110
Blue whale	0.00005	0.00005	0	0.00005
Fin whale	0.00006	0.00006	0	0.00006
Sei whale	0.00016	0.00016	0	0.00016
Bryde's whale	0.00010	0.00010	0.00010	0.00010
Minke whale	0.00423	0.00423	0	0.00423
Sperm whale	0.00156	0.00156	0.00156	0.00156
Pygmy sperm whale	0.00291	0.00291	0.00291	0.00291
Dwarf sperm whale	0.00714	0.00714	0.00714	0.00714
Killer whale	0.00006	0.00006	0.00006	0.00006
False killer whale (Main Hawaiian Islands insular stock)	0.00080	0.00080	0.00080	0.00080

Table 3-4. Marine Mammal Density Estimates, Cont'd

Species	Density Estimate (animals per square kilometer)			
	Fall	Spring	Summer	Winter
False killer whale (all other stocks)	0.00071	0.00071	0.00071	0.00071
Pygmy killer whale	0.00440	0.00440	0.00440	0.00440
Short-finned pilot whale	0.00919	0.00919	0.00919	0.00919
Melon-headed whale	0.00200	0.00200	0.00200	0.00200
Bottlenose dolphin	0.00316	0.00316	0.00316	0.00316
Pantropical spotted dolphin	0.00623	0.00623	0.00623	0.00623
Striped dolphin	0.00335	0.00335	0.00335	0.00335
Spinner dolphin	0.00204	0.00204	0.00204	0.00204
Rough-toothed dolphin	0.00470	0.00470	0.00470	0.00470
Fraser's dolphin	0.021	0.021	0.021	0.021
Risso's dolphin	0.00470	0.00470	0.00470	0.00470
Cuvier's beaked whale	0.00030	0.00030	0.00030	0.00030
Blainville's beaked whale	0.00086	0.00086	0.00086	0.00086
Longman's beaked whale	0.00310	0.00310	0.00310	0.00310
Hawaiian monk seal	0.00003	0.00003	0.00003	0.00003

4.0 AFFECTED SPECIES STATUS AND DISTRIBUTION

This section provides information on the marine mammal species with potential occurrence in the Study Area. Information is provided for individual species and for stocks when applicable. The MMPA defines a marine mammal "stock" as "a group of marine mammals of the same species or smaller taxon in a common spatial arrangement that interbreed when mature." For MMPA management purposes, a stock is considered an isolated population or group of individuals within a whole species that is found in the same area. However, due to lack of sufficient information, NMFS' recognized management stocks may include groups of multiple species, such as with two *Kogia* species. Marine mammal species may also be managed according to distinct population segments (DPS). A DPS is a population or group of populations that is discrete from other populations of the species and which is significant in relation to the species as a whole.

Up to 25 marine mammal species may occur in the Study Area, including 6 mysticetes (baleen whales), 18 odontocetes (dolphins and toothed whales), and 1 pinniped. Multiple stocks are designated in the Hawaii region for some of these species, resulting in a total of 40 stocks managed by NMFS or the U.S. Fish and Wildlife Service (USFWS) in the Hawaiian Islands EEZ. Many of the stock boundaries are based on water depth or distance from shore. Therefore, due to the Long Range Strike WSEP impact site location, not all stocks coincide with the mission area. Certain stocks of melon-headed whale, bottlenose dolphin, pantropical spotted dolphin, and spinner dolphin are excluded based on these criteria. Three false killer whale stocks occur in the vicinity of the Hawaiian Islands and one of these, the Main Hawaiian Islands Insular stock, is listed as endangered under the ESA. The offshore boundary for this stock is delineated at a maximum distance of 39 NM (72 km) offshore. For 2017–2021 missions, the behavioral harassment threshold range extends into this stock boundary by less than 2 km. No other threshold ranges extend into the stock boundary. Therefore, the Main Hawaiian Islands Insular stock is included in the evaluation of potential behavioral effects in this document. The remaining two false killer whale stocks (Northwestern Hawaiian Islands and Hawaii Pelagic) are evaluated for potential impacts associated with all detonation-related pressure and energy criteria.

Species for which some stocks in the Hawaii region are excluded from consideration, and the rationale for inclusion or exclusion, is provided in Table 4-1. All species and stocks occurring in the Hawaii region are shown in Table 4-2. Information on status, distribution, abundance, and ecology of each species is presented in the following subsections. The North Pacific right whale (*Eubalaena japonica*) is not included in the table or in impacts analyses provided later in this document. This species is considered "vagrant" in the area, as the Hawaii region is currently outside the typical geographic range (Reilly et al., 2008). The most recent known sightings in the Hawaii region occurred in 1996 and 1979 (Salden and Mickelsen, 1999; Herman et al., 1980; Rowntree et al., 1980).

In some instances in this section, references are made to various regions of the Pacific Ocean delineated by the National Oceanic and Atmospheric Administration (NOAA)/NMFS Science Centers. The Eastern North Pacific is the area in the Pacific Ocean that is east of 140 degrees (°) west (W) longitude and north of the equator. Similarly the Central North Pacific is the area north of the equator and between the International Date Line (180° W longitude) and 140° W longitude. The Eastern Tropical Pacific is the area roughly extending from the U.S.-Mexico Border west to Hawaii and south to Peru.

Table 4-1. Occurrence of Marine Mammal Species with Multiple Designated Stocks

Species	Stock[1]	Stock Boundary Designation	Occurrence in Mission Area (44 NM/81 km offshore, water depth 4,645 m)	
			Present	Not Present
False killer whale (*Pseudorca crassidens*)	Main Hawaiian Islands Insular	Animals inhabiting waters within 72 km (39 NM) of the Main Hawaiian Islands	X[2]	
	Northwestern Hawaiian Islands	Animals inhabiting waters within a 93-km (50-NM) radius of the Northwestern Hawaiian Islands, or the boundary of the Papahānaumokuākea Marine National Monument, with the radial boundary extended to the southeast to encompass Kauai and Niihau	X	
	Hawaii Pelagic	Animals inhabiting waters greater than 11 km (6 NM) from the Main Hawaiian Islands (there is no inner boundary within the Northwestern Hawaiian Islands)	X	
Melon-headed whale (*Peponocephala electra*)	Hawaiian Islands	Animals inhabiting waters throughout the U.S. EEZ of the Hawaiian Islands	X	
	Kohala Resident	Animals off the Kohala Peninsula and west coast of Hawaii Island and in less than 2,500-m water depth		X
Bottlenose dolphin (*Tursiops truncatus*)	Hawaii Pelagic	Animals inhabiting waters throughout the U.S. EEZ of the Hawaiian Islands	X	
	Kauai and Niihau Oahu 4-Island Hawaii Island	Animals occurring from the shoreline of the respective islands to 1,000-m water depth		X
Pantropical spotted dolphin (*Stenella attenuata*)	Hawaii Pelagic	Animals inhabiting waters throughout the U.S. EEZ of the Hawaiian Islands, outside of the insular stock areas	X	
	Oahu	Animals occurring from the shoreline of the respective islands to 20 km offshore		X
	4-Island			
	Hawaii Island	Animals occurring from the shoreline to 65 kilometers offshore of Hawaii Island		X
Spinner dolphin (*Stenella longirostris*)	Hawaii Pelagic	Animals inhabiting waters throughout the U.S. EEZ of the Hawaiian Islands, outside of island-associated stock boundaries	X	
	Hawaii Island	Animals occurring within 10 NM (19 km) of shore of the respective islands		X
	Oahu and 4-Island			
	Kauai and Niihau			
	Midway Atoll/Kure			
	Pearl and Hermes Reef			

EEZ = Exclusive Economic Zone; km = kilometer; m = meter; NM = nautical mile
[1]Stock designations and boundaries were obtained from Carretta et al., 2016.
[2]Evaluated for potential behavioral harassment effects only.

Table 4-2. Status of Marine Mammals in the Study Area

Common Name	Scientific Name	Stock	Stock Abundance (CV)[4]	Study Area Abundance (CV)[4]	Occurrence	ESA/MMPA Status
Mysticetes (baleen whales)						
Humpback whale[1]	*Megaptera novaeangliae*	Central North Pacific	10,103 (N/A)	4,491 (N/A)	Seasonal; throughout known breeding grounds during winter and spring (most common November through April)	Endangered/Depleted
Blue whale[2]	*Balaenoptera musculus*	Central North Pacific	81 (summer/fall) (1.14)	81 (summer/fall) (1.14)	Seasonal; infrequent winter migrant; few sightings, mainly fall and winter; considered rare	Endangered/Depleted
Fin whale[2]	*Balaenoptera physalus*	Hawaii	58 (summer/fall) (1.12)	58 (summer/fall) (1.12)	Seasonal, mainly fall and winter; considered rare	Endangered/Depleted
Sei whale[2]	*Balaenoptera borealis*	Hawaii	178 (summer/fall) (0.90)	178 (summer/fall) (0.90)	Rare; limited sightings of seasonal migrants that feed at higher latitudes	Endangered/Depleted
Bryde's whale[2]	*Balaenoptera brydei/edeni*	Hawaii	798 (0.28)	798 (0.28)	Uncommon; distributed throughout the Hawaiian EEZ	N/A
Minke whale[2]	*Balaenoptera acutorostrata*	Hawaii	No data	No data	Regular but seasonal (October-April)	N/A
Odontocetes (toothed whales and dolphins)						
Sperm whale[2]	*Physeter macrocephalus*	Hawaii	3,354 (0.34)	3,354 (0.34)	Widely distributed year-round; more likely in waters > 1,000 m depth, most often > 2,000 m	Endangered/Depleted
Pygmy sperm whale[2]	*Kogia breviceps*	Hawaii	No data	No data	Stranding numbers suggest this species is more common than previous survey sightings indicated	N/A

Common Name	Scientific Name	Stock	Stock Abundance (CV)[4]	Study Area Abundance (CV)[4]	Occurrence	ESA/MMPA Status
Dwarf sperm whale[2]	*Kogia sima*	Hawaii	No data	No data	Stranding numbers suggest this species is more common than previous survey sightings indicated	N/A
Killer whale[2]	*Orcinus orca*	Hawaii	101 (1.00)	101 (1.00)	Uncommon; infrequent sightings	N/A
False killer whale Hawaiian Islands Stock Complex[3]	*Pseudorca crassidens*	Main Hawaiian Islands Insular	151 (0.20)	151 (0.20)	Regular	Endangered/Depleted
		Hawaii Pelagic	1,540 (0.66)	1,540 (0.66)	Regular	N/A
		Northwestern Hawaiian Islands	617 (1.11)	617 (1.11)	Regular	N/A
Pygmy killer whale[2]	*Feresa attenuata*	Hawaii	3,433 (0.52)	3,433 (0.52)	Year-round resident	N/A
Short-finned pilot whale[2]	*Globicephala macrorhynchus*	Hawaii	12,422 (0.43)	12,422 (0.43)	Commonly observed around Main Hawaiian Islands and Northwestern Hawaiian Islands	N/A
Melon-headed whale Hawaiian Islands Stock Complex[2]	*Peponocephala electra*	Hawaii Islands stock	5,794 (0.20)	5,794 (0.20)	Regular	N/A
		Kohala Resident Stock	447 (0.12)	Not applicable to study area	Regular	N/A
Bottlenose dolphin Hawaiian Islands Stock Complex[2]	*Tursiops truncatus*	Hawaii Pelagic	5,950 (0.59)	5,950 (0.59)	Common in deep offshore waters	N/A
		Kauai and Niihau	184 (0.11)	Not applicable to study area	Common in shallow nearshore waters ≤ 1,000 m depth)	N/A
		Oahu	743 (0.54)	Not applicable to study area	Common in shallow nearshore waters ≤ 1,000 m depth)	N/A
		4-Island Region	191 (0.24)	Not applicable to study area	Common in shallow nearshore waters ≤ 1,000 m depth)	N/A

Common Name	Scientific Name	Stock	Stock Abundance (CV)[4]	Study Area Abundance (CV)[4]	Occurrence	ESA/MMPA Status
		Hawaii Island	128 (0.13)	Not applicable to study area	Common in shallow nearshore waters ≤ 1,000 m depth)	N/A
Pantropical spotted dolphin Hawaiian Islands Stock Complex[2]	*Stenella attenuata*	Hawaii Pelagic	15,917 (0.40)	15,917 (0.40)	Common; primary occurrence between 100 and 4,000 m depth	N/A
		Oahu	No data	Not applicable to study area	Common; primary occurrence between 100 and 4,000 m depth	N/A
		4-Island Region	No data	Not applicable to study area	Common; primary occurrence between 100 and 4,000 m depth	N/A
		Hawaii Island	No data	Not applicable to study area	Common; primary occurrence between 100 and 4,000 m depth	N/A
Striped dolphin[2]	*Stenella coeruleoalba*	Hawaii Pelagic	20,650 (0.36)	20,650 (0.36)	Occurs regularly year-round but infrequent sighting during survey (Barlow, 2006)	N/A
Spinner dolphin Hawaiian Islands Stock Complex[2]	*Stenella longirostris*	Hawaii Pelagic	No data	No data	Common year-round in offshore waters	N/A
		Hawaii Island	631 (0.04)	Not applicable to study area	Common year-round; rest in nearshore waters during the day and move offshore to feed at night	N/A
		Oahu and 4-Island	355 (0.09)	Not applicable to study area	Common year-round; rest in nearshore waters during the day and move offshore to feed at night	N/A
		Kauai and Niihau	601 (0)	Not applicable to study area	Common year-round; rest in nearshore waters during the day and move offshore to feed at night	N/A

Common Name	Scientific Name	Stock	Stock Abundance (CV)[4]	Study Area Abundance (CV)[4]	Occurrence	ESA/MMPA Status
		Midway Atoll/Kure	No data	Not applicable to study area	Common year-round; rest in nearshore waters during the day and move offshore to feed at night	N/A
		Pearl and Hermes Reef	No data	Not applicable to study area	Common year-round; rest in nearshore waters during the day and move offshore to feed at night	N/A
Rough-toothed dolphin[2]	*Steno bredanensis*	Hawaii Stock (Hawaiian Islands EEZ)	6,288 (0.39)	6,288 (0.39)	Common throughout the Main Hawaiian Islands and Hawaii EEZ	N/A
		Kauai/Niihau area (not a designated stock)	1,665 (0.33)	1,665 (0.33)	Common throughout the Main Hawaiian Islands and Hawaii EEZ	N/A
		Hawaii Island (not a designated stock)	198 (0.12)	Not applicable to study area	Common throughout the Main Hawaiian Islands and Hawaii EEZ	N/A
Fraser's dolphin[2]	*Lagenodelphis hosei*	Hawaii	16,992 (0.66)	16,992 (0.66)	Tropical species only recently documented within Hawaii EEZ (2002 survey)	N/A
Risso's dolphin[2]	*Grampus griseus*	Hawaii	7,256 (0.41)	7,256 (0.41)	Previously considered rare but multiple sightings in Hawaii EEZ during various surveys conducted from 2002-2012	N/A
Cuvier's beaked whale[2]	*Ziphius cavirostris*	Hawaii Pelagic	1,941 (n/a)	1,941 (0.70)	Year-round occurrence but difficult to detect due to diving behavior	N/A
Blainville's beaked whale[2]	*Mesoplodon densirostris*	Hawaii Pelagic	2,338 (1.13)	2,338 (1.13)	Year-round occurrence but difficult to detect due to diving behavior	N/A

Common Name	Scientific Name	Stock	Stock Abundance (CV)[4]	Study Area Abundance (CV)[4]	Occurrence	ESA/MMPA Status
Longman's beaked whale[2]	*Indopacetus pacificus*	Hawaii	4,571 (0.65)	4,571 (0.65)	Considered rare; however, multiple sightings during 2010 survey	N/A
Pinnipeds						
Hawaiian monk seal[5]	*Neomonachus schauinslandi*	Hawaii	1,324 (n/a) (Northwestern Hawaiian Islands)	145 (n/a) (Main Hawaiian Islands)	Predominantly occur at Northwestern Hawaiian Islands; approximately 145 in Main Hawaiian Islands	Endangered/Depleted

≤ = less than or equal to; CV = coefficient of variation; EEZ = Exclusive Economic Zone; ESA = Endangered Species Act; m = meters; MMPA = Marine Mammal Protection Act; N/A = not applicable

[1]Stock designations and abundance were obtained from Muto et al., 2016.

[2]Stock designations and abundance were obtained from Carretta et al., 2016.

[3]Stock designations were obtained from Carretta et al., 2016 and Bradford et al., 2015; abundance was obtained from Bradford et al., 2015.

[4]The stated coefficient of variation (CV) is an indicator of uncertainty in the abundance estimate and describes the amount of variation with respect to the statistical population mean. It is expressed as a fraction or percentage and can range upward from zero (no uncertainty) to high values (greater uncertainty). For example, a CV of 0.8 would indicate much higher uncertainty than a CV of 0.2. When the CV reaches or exceeds 1.0, the estimate is highly uncertain, as the variation could be 100 percent or more of the estimated abundance. The uncertainty associated with movements of animals into or out of an area (due to factors such as prey availability or oceanographic conditions) is much larger than is indicated by the statistical CVs that are given.

[5]Hawaiian monk seal stock abundance and study area abundance obtained from Baker et al., 2016.

4.1 Humpback Whale (*Megaptera novaeangliae*)

Status and Management

Humpback whales are currently listed as depleted under the MMPA and endangered under the ESA. In the U.S. North Pacific Ocean, the stock structure of humpback whales is defined based on feeding areas because of the species' fidelity to feeding grounds (Carretta et al., 2016). Three stocks are currently designated by NMFS in the north Pacific: (1) the Central North Pacific stock, consisting of winter and spring populations of the Hawaiian Islands that migrate to northern British Columbia and Alaska, the Gulf of Alaska, the Bering Sea, and Aleutian Islands; (2) the Western North Pacific stock, consisting of winter and spring populations off Asia that migrate to Russia and the Bering Sea and Aleutian Islands; and (3) the California/Oregon/Washington stock, consisting of animals along the U.S. west coast (Muto et al., 2016; Carretta et al., 2016).

However, in April 2015, NMFS announced a proposal to divide the species into 14 DPSs worldwide, including a Hawaii DPS, and to revise the listing status for the various populations (50 Code of Federal Regulations (CFR) Parts 223 and 224, 21 April 2015). A final rule on this proposal was issued on September 8, 2016 (81 FR 62260, September 8, 2016) with NMFS's determination to revise the listing status of the humpback whale under the ESA, which divides the globally listed endangered species into 14 DPSs, four of which are listed as endangered and one is listed as threatened. The Hawaii DPS (formerly known as the Central North Pacific stock) is not considered to be in danger of extinction or likely to become so in the foreseeable future. Therefore, under the final rule effective on October 11, 2016, the Hawaii DPS of humpback whales will not be listed as endangered or threatened under the ESA.

The Hawaiian Islands Humpback Whale National Marine Sanctuary, which was designated in 1992 to protect humpback whales and their habitat, is located within the HRC. The sanctuary is delineated from the shoreline to the 100-fathom (183-m) isobath in discrete areas of the Hawaiian Islands region, including an area off the north shore of Kauai. However, the sanctuary does not coincide with the Long Range Strike WSEP mission location, which is located in water depth of over 4,600 meters.

Geographic Range and Distribution

General. Humpback whales are distributed worldwide in all major oceans and most seas. They typically are found during the summer in high-latitude feeding grounds and during the winter in the tropics and subtropics around islands, over shallow banks, and along continental coasts, where calving occurs.

Insular Pacific-Hawaiian Large Marine Ecosystem. The Central North Pacific stock of humpback whales occurs throughout known breeding grounds in the Hawaiian Islands during winter and spring (November through April) (Muto et al. 2016). Peak occurrence is from late February through early April (Carretta et al., 2010; Mobley et al., 2000), with a peak in acoustic detections in March (Norris et al., 1999). A recent study that also used acoustic recordings near the Northwestern Hawaiian Islands indicates that humpback whales were present from early December through early June (Lammers et al., 2011). During the fall-winter period, primary occurrence is expected from the coast to 50 NM offshore (Mobley et al., 2000; Mobley, 2004). The greatest densities of humpback whales (including calves) are in the four-island region consisting of Maui, Molokai, Kahoolawe, and Lanai, as well as Penguin Bank (Mobley et al., 2000; Maldini et al., 2005) and around Kauai (Mobley, 2005). During the spring-summer period, secondary occurrence is expected offshore out to 50 NM. Occurrence farther offshore or inshore (e.g., Pearl Harbor) has rarely been documented.

Survey results suggest that humpbacks may also be wintering in the northwestern Hawaiian Island region and not just using it as a migratory corridor. A recent study that also used acoustic recordings near the Northwestern Hawaiian Islands indicates that humpback whales were present from early December through early June (Lammers et al., 2011). It is not yet known if this represents a previously undocumented breeding stock or if the whales occurring at the Northwestern Hawaiian Islands are part of the same population that winters near the Main Hawaiian Islands.

In breeding grounds, females with calves occur in significantly shallower waters than other groups of whales, and breeding adults use deeper more offshore waters (Smultea, 1994; Ersts and Rosenbaum, 2003). The habitat requirements of wintering humpbacks appear to be controlled by the conditions necessary for calving, such as warm water (75 to 80 ° Fahrenheit [24° to 28° Celsius]) and relatively shallow, low-relief ocean bottom in protected areas created by islands or reefs (Smultea, 1994; Clapham, 2000; Craig and Herman, 2000).

Open Ocean. Most humpback whale sightings are in nearshore and continental shelf waters; however, humpback whales frequently travel through deep oceanic waters during migration (Calambokidis et al., 2001; Clapham and Mattila, 1990; Clapham, 2000). Humpback migrations are complex and cover long distances (Calambokidis, 2009; Barlow et al., 2011). Each year, most humpback whales migrate from high-latitude summer feeding grounds to low-latitude winter breeding grounds, one of the longest migrations known for any mammal; individuals can travel nearly 4,970 miles (7,998.4 km) from feeding to breeding areas (Clapham and Mead, 1999). Humpback whales that breed in Hawaii generally migrate to northern British Columbia and southeast Alaska to feed. Animals breeding in Hawaii have also been "matched" (identified as the same individual) to humpbacks feeding in southern British Columbia and northern Washington (where matches were also found to animals breeding in Central America). Hawaii humpbacks are also known to feed in the Gulf of Alaska, the Aleutian Islands, and Bering Sea, where surprisingly, matches were also found to animals that breed near islands off Mexico (Forestell and Urban-Ramirez, 2007; Barlow et al., 2011; Lagerquist et al., 2008) and between Japan and Hawaii (Salden et al., 1999). This study indicates that humpback whales migrating between Hawaii and British Columbia/southeast Alaska must cross paths with humpback whales migrating between the Gulf of Alaska/Aleutian Islands/Bering Sea and islands off Mexico. In addition, based on the identification of individual whales, there is evidence that some humpback whales (most likely males) move between winter breeding areas in Hawaii and Mexico (Forestall and Urban-Ramirez, 2007) and Hawaii and Japan (Salden et al., 1999).

Satellite tagging of humpback whales in the Hawaiian Islands found that one adult traveled 155 miles (249.4 km) to Oahu, Hawaii, in 4 days, while a different individual traveled to Penguin Bank and five islands, totaling 530 miles (852.9 km) in 10 days. Both of these trips imply faster travel between the islands than had been previously recorded (Mate et al., 1998). Three whales traveled independent courses, following north and northeast headings toward the Gulf of Alaska, with the fastest averaging 93 miles (150 km) per day. At this rate, the animal would take an estimated 39 days to travel the entire 2,600-mile (4,200-km) migration route to the upper Gulf of Alaska (Mate et al., 1998).

Population and Abundance

The overall abundance of humpback whales in the north Pacific was recently estimated at 21,808 individuals (coefficient of variation [CV] = 0.04; this is an indicator of statistical uncertainty and is described in the footnote in Table 4-2), confirming that this population of humpback whales has continued to increase and is now greater than some pre-whaling abundance estimates (Barlow et al., 2011). Data indicate the north Pacific population has been increasing at a rate of between 5.5 percent and 6.0 percent per year, approximately doubling every 10 years (Calambokidis et al., 2008). The Central North Pacific stock has been estimated at 10,103 individuals on wintering grounds throughout the Main Hawaiian Islands (Muto et al., 2016). The Hawaiian Islands Humpback Whale National Marine Sanctuary reported in 2010 that over 50 percent of the entire North Pacific humpback whale population migrates to Hawaiian waters each year (NOAA, 2010). Based on aerial surveys conducted around the Main Hawaiian Islands, the number of humpback whales was estimated at 4,491 (Mobley, Spitz, et al., 2001).

Predator/Prey Interactions

The most common invertebrate prey are krill (tiny crustaceans); the most common fish prey are herring, mackerel, sand lance, sardines, anchovies, and capelin (Clapham and Mead, 1999). Feeding occurs both at the surface and in deeper waters, wherever prey is abundant. Humpback whales are the only species of baleen whale that show strong evidence of cooperation when they feed in large groups (D'Vincent et al., 1985). It is believed that minimal feeding occurs in wintering grounds, such as the Hawaiian Islands (Balcomb, 1987; Salden, 1989). This species is known to be attacked by both killer whales and false killer whales as evidenced by tooth rake scars on their bodies and fins (Jefferson et al., 2015).

Species-Specific Threats

Entanglement in fishing gear poses a threat to individual humpback whales throughout the Pacific. Humpback whales from the Central North Pacific stock have been reported seriously injured and killed from entanglement in fishing gear while in their Alaskan feeding grounds (Muto et al., 2016). From 2009 to 2013, an average of 2.6 humpback whales per year were seriously injured or killed due to entanglements with commercial fishing gear in Alaskan waters. This number is considered a minimum since observers have not been assigned to several fisheries known to interact with this stock and quantitative data on Canadian fishery entanglements are uncertain (Muto et al., 2016). In the Hawaiian Islands, there are also reports of humpback whale entanglements with fishing gear. Between 2002 and 2014, the Hawaiian Islands Disentanglement Network responded to 139 confirmed large whale entanglement reports (Hawaiian Islands Humpback Whale National Marine Sanctuary, 2014). All but three of the reports (a sei whale and two sperm whales) involved humpback whales. In the 2013–2014 season, at least 13 whales were reported as entangled, with fishing gear (crab trap and longline gear) confirmed in three of the events.

Humpback whales, especially calves and juveniles, are highly vulnerable to ship strikes. Younger whales spend more time at the surface, are less visible, and are found closer to shore (Herman et al., 1980; Mobley et al., 1999), thereby making them more susceptible to collisions. In their Alaskan feeding grounds, eight ship strikes were implicated in mortality or serious injuries of humpback whales between 2003 and 2007 and seven between 2006 and 2010 (Allen and Angliss, 2011; Allen and Angliss, 2013); when they migrate to and from Alaska, some of these whales spend time in Hawaii. The mean annual mortality and serious injury rate due to ship strikes reported in Hawaii between 2008 and 2012 is 2.4 humpback whales (Muto et al. 2016).

In the Hawaiian Islands, there were nine reported ship collisions with humpback whales in 2006 (none involved Navy vessels), as recorded by the NMFS Pacific Islands Region Marine Mammal Response Network Activity Updates (NMFS, 2007a). The number of confirmed ship strike reports was greater in 2007/2008; there were 12 reported ship-strikes with humpback whales: 9 reported as hit by vessels and 3 observed with wounds indicating a recent ship strike (NMFS, 2008). A humpback carcass was discovered on the shore of west Molokai in 2010 with indications that the death resulted from trauma consistent with a ship strike (NMFS, 2010a).

Humpback whales are potentially affected by loss of habitat, loss of prey, underwater noise, and pollutants. The Central North Pacific stock of humpback whales is the focus of whale-watching activities in both its feeding grounds (Alaska) and breeding grounds (Hawaii). Regulations addressing minimum approach distances and vessel operating procedures are in place to help protect the whales; however, there is still concern that whales may abandon preferred habitats if the disturbance is too high (Muto et al. 2016).

4.2 Blue Whale (*Balaenoptera musculus*)

The world's population of blue whales can be separated into three subspecies, based on geographic location and some morphological differences. The true blue whales have been divided into two subspecies found in the northern hemisphere (*Balaenoptera musculus musculus*) and the southern hemisphere (*Balaenoptera musculus intermedia*). The third subspecies, the pygmy blue whale

(*Balaenoptera musculus brevicauda*), is known to have overlapping ranges with both subspecies of true blue whales (Best et al., 2003; Reeves et al., 2002).

Status and Management

The blue whale is listed as endangered under the ESA and as depleted under the MMPA. For the MMPA stock assessment reports, the Central North Pacific Stock of blue whales includes animals found around the Hawaiian Islands during winter (Carretta et al., 2016).

Geographic Range and Distribution

General. The blue whale inhabits all oceans and typically occurs near the coast, over the continental shelf, though it is also found in oceanic waters. Their range includes the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems and the open ocean. Blue whales have been sighted, acoustically recorded, and satellite tagged in the eastern tropical Pacific (Ferguson, 2005; Stafford et al., 2004).

Insular Pacific-Hawaiian Large Marine Ecosystem. Blue whales are found seasonally in the Hawaii region, but sighting frequency is low. Whales feeding along the Aleutian Islands of Alaska likely migrate to offshore waters north of Hawaii in winter.

Open Ocean. Most blue whale sightings are in nearshore and continental shelf waters; however, blue whales frequently travel through deep oceanic waters during migration (Širović et al., 2004). Most baleen whales spend their summers feeding in productive waters near the higher latitudes and winters in the warmer waters at lower latitudes (Širović et al., 2004). Blue whales belonging to the western Pacific stock may feed in summer, south of the Aleutians and in the Gulf of Alaska, and migrate to wintering grounds in lower latitudes in the western Pacific and central Pacific, including Hawaii (Stafford et al., 2004; Watkins et al., 2000).

Population and Abundance

In the north Pacific, up to five distinct populations of blue whales are believed to occur, although only one stock is currently identified. The overall abundance of blue whales in the eastern tropical Pacific is estimated at 1,400 individuals. The most recent survey data indicate a summer/fall abundance estimate of 81 individuals (CV = 1.14) in the Hawaiian Islands EEZ (Carretta et al., 2016). This estimate could potentially be low, as the majority of blue whales would be expected to be at higher latitude feeding grounds at that time.

Predator/Prey Interactions

This species preys almost exclusively on various types of zooplankton, especially krill. Blue whales lunge feed and consume approximately 6 tons (5,500 kilograms) of krill per day (Jefferson et al., 2015; Pitman et al., 2007). They sometimes feed at depths greater than 330 feet (100 m), where their prey maintains dense groupings (Acevedo-Gutiérrez et al., 2002). Blue whales have been documented to be preyed on by killer whales (Jefferson et al., 2015; Pitman et al., 2007). There is little evidence that killer whales attack this species in the north Atlantic or southern hemisphere, but 25 percent of photo-identified whales in the Gulf of California carry rake scars from killer whale attacks (Sears and Perrin, 2008).

Species-Specific Threats

Blue whales are considered to be susceptible to entanglement in fishing gear and ship strikes.

4.3 Fin Whale (*Balaenoptera physalus*)

Status and Management

The fin whale is listed as endangered under the ESA and as depleted under the MMPA. Pacific fin whale population structure is not well known. In the North Pacific, recognized stocks include the California/Oregon/Washington, Hawaii, and Northeast Pacific stocks (Carretta et al., 2016).

Geographic Range and Distribution

General. The fin whale is found in all the world's oceans and is the second largest species of whale (Jefferson et al., 2015). Fin whales prefer temperate and polar waters and are scarcely seen in warm, tropical waters (Reeves et al., 2002). Fin whales typically congregate in areas of high productivity. They spend most of their time in coastal and shelf waters but can often be found in waters of approximately 6,562 feet (2,000 m) (Aissi et al., 2008; Reeves et al., 2002). Attracted for feeding, fin whales are often seen closer to shore after periodic patterns of upwelling and the resultant increased krill density (Azzellino et al., 2008). This species of whale is not known to have a specific habitat and is highly adaptable, following prey, typically off the continental shelf (Azzellino et al., 2008; Panigada et al., 2008). The range of the fin whale is known to include the Insular Pacific-Hawaiian Large Marine Ecosystems and the open ocean.

Insular Pacific-Hawaiian Large Marine Ecosystem. Fin whales are found in Hawaiian waters, but this species is considered rare in this area (Carretta et al., 2010; Shallenberger, 1981). There are known sightings from Kauai and Oahu and a single stranding record from Maui (Mobley et al., 1996; Shallenberger, 1981; U.S. Department of the Navy, 2011). Summer/fall shipboard surveys of the Hawaiian Islands EEZ resulted in five sightings in 2002 and two sightings in 2010 (Barlow, 2003; Bradford et al., 2013). A single sighting was made during aerial surveys from 1993 to 1998 (Mobley et al., 1996; Mobley et al., 2000). The most recent sighting was a single juvenile fin whale reported off Kauai in 2011 (U.S. Department of the Navy, 2011). Based on sighting data and acoustic recordings, fin whales are likely to occur in Hawaiian waters mainly in fall and winter (Barlow et al., 2006; Barlow et al., 2008; Barlow et al., 2004).

Open Ocean. Fin whales have been recorded in the eastern tropical Pacific (Ferguson, 2005) and are frequently sighted there during offshore ship surveys. Fin whales are relatively abundant in north Pacific offshore waters, including areas off Hawaii (Berzin and Vladimirov, 1981; Mizroch et al., 2009). Locations of breeding and calving grounds for the fin whale are unknown, but it is known that the whales typically migrate seasonally to higher latitudes every year to feed and migrate to lower latitudes to breed (Kjeld et al., 2006; MacLeod, Simmonds, et al., 2006). The fin whale's ability to adapt to areas of high productivity controls migratory patterns (Canese et al., 2006; Reeves et al., 2002). Fin whales are one of the fastest cetaceans, capable of attaining speeds of 25 miles (40.2 km) per hour (Jefferson et al., 2015; Marini et al., 1996).

Population and Abundance

Based on summer/fall surveys in the Hawaiian Islands EEZ, the current best available abundance estimate for the Hawaii stock of fin whales is 58 (CV = 1.12). This may be an underestimate because the majority of blue would be expected to be at higher latitude feeding grounds at the time the surveys were conducted (Carretta et al., 2016).

Predator/Prey Interactions

This species preys on small invertebrates such as copepods, squid, and schooling fishes such as capelin, herring, and mackerel (Goldbogen et al., 2006; Jefferson et al., 2015). The fin whale is not known to have a significant number of predators. However, in regions where killer whales are abundant, some fin whales exhibit attack scars on their flippers, flukes, and flanks, suggesting possible predation by killer whales (Aguilar, 2008).

Species-Specific Threats

Fin whales are susceptible to ship strikes and entanglement in fishing gear.

4.4 Sei Whale (*Balaenoptera borealis*)

The sei whale is a medium-sized rorqual falling in size between fin whale and Bryde's whale and, given the difficulty of some field identifications and similarities in the general appearance of the three species, may sometimes be recorded in surveys as unidentified rorqual.

Status and Management

The sei whale is listed as endangered under the ESA and as depleted under the MMPA. A recovery plan for the sei whale was completed in 2011 and provides a research strategy for obtaining data required to estimate population abundance and trends, and to identify factors that may be limiting the recovery of this species (NMFS, 2011a). Although the International Whaling Commission recognizes one stock of sei whales in the North Pacific, some evidence indicates that more than one population exists. For the MMPA stock assessment reports, sei whales in the Pacific EEZ are divided into three areas: Hawaii, California/Oregon/Washington, and Alaska (Carretta et al., 2016).

Geographic Range and Distribution

General. Sei whales have a worldwide distribution and are found primarily in cold temperate to subpolar latitudes. During the winter, sei whales are found from 20° north (N) to 23° N and during the summer from 35° N to 50° N (Horwood, 2009; Masaki, 1976; Masaki, 1977; Smultea et al., 2010). However, a recent survey of the Northern Mariana Islands recorded sei whales south of 20° N in the winter (Fulling et al., 2011). They are considered absent or at very low densities in most equatorial areas.

Insular Pacific-Hawaiian Large Marine Ecosystem. The first verified sei whale sighting made nearshore of the Main Hawaiian Islands occurred in 2007 (Smultea et al., 2007; Smultea et al., 2010) and included the first subadults seen in the Main Hawaiian Islands. A line-transect survey conducted in February 2009 by the Cetacean Research Program surrounding the Hawaiian Islands resulted in the sighting of three Bryde's/sei whales. An additional sighting occurred in 2010 of Perret Seamount (U.S. Department of Navy, 2011). In March 2011 off Maui, the Hawaiian Islands Entanglement Response Network found a subadult sei whale entangled in rope and fishing gear (NMFS, 2011b). An attempt to disentangle the whale was unsuccessful, although a telemetry buoy attached to the entangled gear was reported to be tracking the whale over 21 days as it moved north and over 250 NM from the Hawaiian Islands.

The sei whale has been considered rare in the Hawaii region based on reported sighting data and the species' preference for cool temperate waters. Sei whales were not sighted during aerial surveys conducted within 25 NM of the Main Hawaiian Islands from 1993 to 1998 (Mobley et al., 2000). Based on sightings made during the NMFS-Southwest Fisheries Science Center shipboard survey assessment of Hawaiian cetaceans (Barlow et al., 2004), sei whales were expected to occur in deep waters on the north side of the islands only. However, in 2007 two sei whale sightings occurred north of Oahu, Hawaii, during a short survey in November, and these included three subadult whales. These latter sightings suggest that the area north of the Main Hawaiian Islands may be part of a reproductive area for north Pacific sei whales (Smultea et al., 2010). Summer/fall shipboard surveys of the Hawaiian Islands EEZ resulted in four sightings in 2002 and three in 2010 (Barlow, 2003; Bradford et al., 2013).

Open Ocean. Sei whales are most often found in deep oceanic waters of the cool temperate zone. They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins between banks and ledges (Best and Lockyer, 2002; Gregr and Trites, 2001; Kenney and Winn, 1987; Schilling et al., 1992). On feeding grounds, the distribution is largely associated with oceanic frontal systems (Horwood, 1987). Characteristics of preferred breeding grounds are unknown, since they have generally not been identified.

Sei whales spend the summer feeding in high latitude subpolar latitudes and return to lower latitudes to calve in winter. Whaling data provide some evidence of differential migration patterns by reproductive class, with females arriving at and departing from feeding areas earlier than males (Horwood, 1987; Perry et al., 1999). Sei whales are known to swim at speeds greater than 15 miles (25 km) per hour and may be the second fastest cetacean, after the fin whale (Horwood, 2009; Jefferson et al., 2015).

Population and Abundance

Based on summer/fall surveys, the best current estimate of abundance for the Hawaii stock of sei whales is 178 animals (CV = 0.90). This abundance estimate is considered the best available estimate for the Hawaiian Islands EEZ but may be an underestimate, as sei whales are expected to be mostly at higher latitudes on their feeding grounds during this time of year. No data are available on current population trends.

Predator/Prey Interactions

In the north Pacific, sei whales feed on a diversity of prey, including copepods, krill, fish (specifically sardines and anchovies), and cephalopods (squids, cuttlefish, octopuses) (Horwood, 2009; Nemoto and Kawamura, 1977). Feeding occurs primarily around dawn, which appears to be correlated with vertical migrations of prey species (Horwood, 2009). Unlike other rorquals, the sei whale skims to obtain its food, although, like other rorqual species, it does some lunging and gulping (Horwood, 2009).

Sei whales, like other large baleen whales, are likely subject to occasional attacks by killer whales.

Species-Specific Threats

Based on the statistics for other large whales, it is likely that ship strikes also pose a threat to sei whales.

4.5 Bryde's Whale (*Balaenoptera brydei/edeni*)

Bryde's whales are among the least known of the large baleen whales. Their classification and true number remain uncertain (Alves et al., 2010). Until recently, all medium-sized baleen whales were considered members of one of two species, Bryde's whale or sei whale. However, at least three genetically distinct types of these whales are now known, including the so-called pygmy or dwarf Bryde's whales (*Balaenoptera brydei*) (Kato and Perrin, 2008; Rice, 1998). The International Whaling Commission continues to use the name *Balaenoptera edeni* for all Bryde's-like whales, although at least two species are recognized. In 2003, a new species (Omura's whale, *Balaenoptera omurai*) was described, and it became evident that the term pygmy Bryde's whale had been mistakenly used for specimens of *Balaenoptera omurai* (Reeves et al., 2004). Omura's whale is not currently known to occur in the Study Area and appears to be restricted to the western Pacific and Indian Oceans (Jefferson et al., 2015); therefore, it is not described or evaluated in this document.

Status and Management

This species is protected under the MMPA and is not listed under the ESA. The International Whaling Commission recognizes three management stocks of Bryde's whales in the north Pacific: Western North Pacific, Eastern North Pacific, and East China Sea (Donovan, 1991), though the biological basis for defining separate stocks of Bryde's whales in the central north Pacific is not clear (Carretta et al., 2010). For MMPA stock assessment reports, Bryde's whales within the Pacific U.S. EEZ are divided into two areas: Hawaii and Eastern Pacific (Carretta et al., 2016).

Geographic Range and Distribution

Insular Pacific-Hawaiian Large Marine Ecosystem. Bryde's whales are only occasionally sighted in the Insular Pacific-Hawaiian Large Marine Ecosystems (Carretta et al., 2010; Jefferson et al., 2015; Smultea et al., 2008). The first verified Bryde's whale sighting made nearshore of the Main Hawaiian Islands occurred in 2007 (Smultea et al., 2008; Smultea et al., 2010). A line-transect survey conducted in February 2009 by the Cetacean Research Program surrounding the Hawaiian Islands resulted in the sighting of three Bryde's/sei whales (Oleson and Hill, 2009). Summer/fall shipboard surveys of waters within the Hawaiian Islands EEZ in 2002 and 2010 resulted in 13 and 30 Bryde's whale sightings, respectively (Barlow, 2003; Bradford et al., 2013). Sightings are more frequent in the Northwestern Hawaiian Islands than in the Main Hawaiian Islands (Barlow et al., 2004; Carretta et al., 2010; Smultea et al., 2008; Smultea et al., 2010).

Open Ocean. Bryde's whales occur primarily in offshore oceanic waters of the north Pacific. Data suggest that winter and summer grounds partially overlap in the central north Pacific (Kishiro, 1996; Ohizumi et al., 2002). Bryde's whales are distributed in the central north Pacific in summer; the southernmost summer distribution of Bryde's whales inhabiting the central north Pacific is about 20° N (Kishiro, 1996). Some whales remain in higher latitudes (around 25° N) in both winter and summer but are not likely to move poleward of 40° N (Jefferson et al., 2015; Kishiro, 1996). Bryde's whales in some areas of the world are sometimes seen very close to shore and even inside enclosed bays (Baker and Madon, 2007; Best et al., 1984).

Long migrations are not typical of Bryde's whales, although limited shifts in distribution toward and away from the equator, in winter and summer, have been observed (Best, 1996; Cummings, 1985). They have been recorded swimming at speeds of 15 miles (24.1 km) per hour (Jefferson et al., 2015; Kato and Perrin, 2008).

Population and Abundance

Little is known of population status and trends for most Bryde's whale populations. Current genetic research confirms that gene flow among Bryde's whale populations is low and suggests that management actions treat each as a distinct entity to ensure proper conservation of biological diversity (Kanda et al., 2007). A 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ yielded an abundance estimate of 798 (CV = 0.28) Bryde's whales (Bradford et al., 2013), which is the best available abundance estimate for the Hawaiian stock.

Predator/Prey Interactions

Bryde's whales primarily feed on schooling fish and are lunge feeders. Prey includes anchovy, sardine, mackerel, herring, krill, and other invertebrates such as pelagic red crab (Baker and Madon, 2007; Jefferson et al., 2015; Nemoto and Kawamura, 1977). Bryde's whales have been observed using "bubble nets" to herd prey (Jefferson et al., 2015; Kato and Perrin, 2008). Bubble nets are used in a feeding strategy where the whales dive and release bubbles of air that float up in a column and trap prey inside where they lunge through the column to feed. Bryde's whale is known to be prey for killer whales, as evidenced by an aerial observation of 15 killer whales attacking a Bryde's whale in the Gulf of California (Weller, 2008).

Species-Specific Threats

Serious injury or mortality from interactions with fishing gear poses a threat to Bryde's whales.

4.6 Minke Whale (*Balaenoptera acutorostrata*)

Until recently, all minke whales were classified as the same species. However, the taxonomy is currently complex, as NMFS recognizes two species: northern or common minke whale (*Balaenoptera* *acutorostrata*) and Antarctic minke whale (*Balaenoptera bonaerensis*) (NOAA, 2014). The dwarf minke whale form (*Balaenoptera acutorostrata* subspecies, no official scientific name) is a possible third species, and there are several other subspecies as well. The northern minke whale is divided into two subspecies, *Balaenoptera acutorostrata scammoni* in the north Pacific and *Balaenoptera acutorostrata acutorostrata* in the north Atlantic. Accordingly, only *Balaenoptera acutorostrata scammoni* occurs in the Study Area. For stock assessment reports, NMFS currently recognizes three stocks in the Pacific U.S. EEZ: Hawaii, California/Oregon/Washington, and Alaska (Carretta et al., 2016).

Status and Management

The minke whale is protected under the MMPA and is not listed under the ESA.

Geographic Range and Distribution

General. The minke whale range is known to include the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems, North Pacific Gyre, and the North Pacific Transition Zone (Okamura et al., 2001; Yamada, 1997). The northern boundary of their range is within subarctic and arctic waters (Kuker et al., 2005).

Insular Pacific-Hawaiian Large Marine Ecosystem. Minke whales previously were considered a rare species in Hawaiian waters due to limited sightings during surveys. The first documented sighting of a minke whale close to the main Hawaiian islands was made off the southwest coast of Kauai in 2005 (Norris et al., 2005; Rankin et al., 2007). However, recent research suggests minke whales are somewhat common in Hawaii (Rankin et al., 2007; U.S. Department of the Navy, 2011). Whales found in the Hawaii region are known to belong to seasonally migrating populations that feed in higher latitudes (Barlow, 2006). During a survey around the Hawaiian Islands, minke whales were identified as the source of the mysterious “boing” sound of the north Pacific Ocean, specifically offshore of Kauai and closer in, near the PMRF, Barking Sands region (Barlow et al., 2004; Rankin and Barlow, 2005). This new information has allowed acoustical detection of minke whales, although they are rarely observed during visual surveys (Barlow, 2006; Barlow et al., 2004; Rankin et al., 2007). Recent research using a survey vessel’s towed acoustic array and the Navy’s hydrophones off Kauai in 2009–2010 (35 days total) provided bearings to 1,975 minke whale “boing” vocalizations located within the instrumented range offshore of the PMRF (U.S. Department of the Navy, 2011).

Open Ocean. These whales generally participate in annual migrations between low-latitude breeding grounds in the winter and high-latitude feeding grounds in the summer (Kuker et al., 2005). Minke whales generally occupy waters over the continental shelf, including inshore bays, and even occasionally enter estuaries. However, records from whaling catches and research surveys worldwide indicate an open ocean component to the minke whale’s habitat. The migration paths of the minke whale include travel between breeding to feeding grounds and have been shown to follow patterns of prey availability (Jefferson et al., 2015).

Population and Abundance

There currently is no population estimate for the Hawaii stock of minke whale, which appears to occur seasonally (about October to April) around the Hawaiian Islands. During summer/fall shipboard surveys of the Hawaiian Islands EEZ in 2002 and 2010 (Barlow, 2003; Bradford et al., 2013), one individual was sighted in each year. However, the majority of individuals would typically be expected to be located farther north at this time of year.

Predator/Prey Interactions

This species preys on small invertebrates and schooling fish, such as sand eel, pollock, herring, and cod. Similar to other rorquals, minke whales are lunge feeders, often plunging through patches of shoaling fish or krill (Hoelzel et al., 1989; Jefferson et al., 2015). In the north Pacific, major foods include small invertebrates, krill, capelin, herring, pollock, haddock, and other small shoaling fish (Jefferson et al., 2015; Kuker et al., 2005; Lindstrom and Haug, 2001). Minke whales are prey for killer whales (Ford et al., 2005); a minke was observed being attacked by killer whales near British Columbia (Weller, 2008).

Species-Specific Threats

Serious injury or mortality from interactions with fishing gear poses a threat to minke whales.

4.7 Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the only large whale that is an odontocete (toothed whale).

Status and Management

The sperm whale has been listed as endangered since 1970 under the precursor to the ESA and is depleted under the MMPA. Sperm whales are divided into three stocks in the Pacific. Of these, the Hawaii stock occurs within the Study Area.

Geographic Range and Distribution

General. The sperm whale occurs in all oceans, ranging from the pack ice in both hemispheres to the equator. Primarily, this species is typically found in the temperate and tropical waters of the Pacific (Rice, 1989). This species appears to have a preference for deep waters (Jefferson et al., 2015). Typically, sperm whale concentrations correlate with areas of high productivity, including areas near drop-offs and with strong currents and steep topography (Gannier and Praca, 2007; Jefferson et al., 2015).

Insular Pacific-Hawaiian Large Marine Ecosystem. Sperm whales occur in Hawaii waters and are one of the more abundant large whales found in that region (Baird, McSweeney, et al., 2003; Mobley et al., 2000).

Open Ocean. Sperm whales show a strong preference for deep waters (Rice, 1989; Whitehead, 2003). Their distribution is typically associated with waters over the continental shelf break, over the continental slope, and into deeper waters.

Sperm whales are somewhat migratory. General shifts occur during summer months for feeding and breeding, while in some tropical areas, sperm whales appear to be largely resident (Rice, 1989; Whitehead, 2003; Whitehead et al., 2008). Pods of females with calves remain on breeding grounds throughout the year, between 40° N and 45° N (Rice, 1989; Whitehead, 2003), while males migrate between low-latitude breeding areas and higher-latitude feeding grounds (Pierce et al., 2007). In the northern hemisphere, “bachelor” groups (males typically 15 to 21 years old and bulls [males] not taking part in reproduction) generally leave warm waters at the beginning of summer and migrate to feeding grounds that may extend as far north as the perimeter of the arctic zone. In fall and winter, most return south, although some may remain in the colder northern waters during most of the year (Pierce et al., 2007).

Population and Abundance

The abundance of sperm whales in the eastern tropical Pacific has been estimated as 22,700 individuals. The current best available abundance estimate for the Hawaii stock of sperm whales is 3,354 (CV = 0.34). Sperm whales are frequently identified via visual observation and hydrophones on the PMRF range (U.S. Department of the Navy, 2015).

Predator/Prey Interactions

Sperm whales are known to occur in groups for both predator defense and foraging purposes. Sperm whales feed on squid, other cephalopods, and bottom-dwelling fish and invertebrates (Davis et al., 2007; Marcoux et al., 2007; Rice, 1989). Exactly how sperm whales search for, detect, and capture their prey remains uncertain. False killer whales, pilot whales, and killer whales have been documented harassing and, on occasion, attacking sperm whales (Baird, 2009a).

Species-Specific Threats

Sperm whales are susceptible to entanglement in fishing gear, ingestion of marine debris, and ship strikes.

4.8 Pygmy Sperm Whale (*Kogia breviceps*)

There are two species of *Kogia*: the pygmy sperm whale (*Kogia breviceps*) and the dwarf sperm whale (*Kogia sima*). Before 1966 they were considered to be the same species until morphological distinction was shown (Handley, 1966). Dwarf and pygmy sperm whales are difficult to distinguish from one another at sea, and many misidentifications have been made. Sightings of either species are often categorized as the genus *Kogia* (Jefferson et al., 2015).

Status and Management

The pygmy sperm whale is protected under the MMPA but is not listed under the ESA. Two stocks are identified in the Pacific Ocean. Of these, only the Hawaii stock occurs in the Study Area.

Geographic Range and Distribution

General. Pygmy sperm whales apparently occur close to shore, sometimes over the outer continental shelf. However, several studies have suggested that this species generally occurs beyond the continental shelf edge (Bloodworth and Odell, 2008; MacLeod et al., 2004). The pygmy sperm whale frequents more temperate habitats than the other *Kogia* species, which is more of a tropical species.

Insular Pacific-Hawaiian Large Marine Ecosystem. Sightings of pygmy sperm whales are rarely reported in Hawaii. During boat surveys between 2000 and 2003 in the Main Hawaiian Islands, this species was observed but less commonly than the dwarf sperm whale (Baird, 2005; Baird, McSweeney, et al., 2003; Barlow et al., 2004). A freshly dead specimen was observed about 100 NM north of French Frigate Shoals during a 2010 survey. Pygmy sperm whales are one of the more commonly stranded species in the Hawaiian Islands, and this frequency of strandings indicates that the species is likely more common than sightings suggest (Maldini et al., 2005).

Open Ocean. Although deep oceanic waters may be the primary habitat for pygmy sperm whales, very few oceanic sightings offshore have been recorded within the Study Area. However, this may be because of the difficulty of detecting and identifying these animals at sea (Caldwell and Caldwell, 1989; Maldini et al., 2005). Records of this species from both the western (Japan) and eastern Pacific (California) suggest that the range of this species includes the North Pacific Central Gyre, and North Pacific Transition Zone (Carretta et al., 2010; Jefferson et al., 2015; Katsumata et al., 2004; Marten, 2000; Norman et al., 2004). Their range generally includes tropical and temperate warm water zones and is not likely to extend north into subarctic waters (Bloodworth and Odell, 2008; Jefferson et al., 2015).

Little is known about possible migrations of this species. No specific information regarding routes, seasons, or resighting rates in specific areas is available.

Population and Abundance

Few abundance estimates have been made for this species. Previously, based on results of a 2002 shipboard line-transect survey of the entire Hawaiian Islands EEZ, abundance was estimated as 7,138 individuals. However, NMFS no longer considers this information valid because it is out of date. There is no abundance estimate currently available. The frequency of strandings suggests pygmy sperm whales may not be as uncommon as sightings would suggest (Jefferson et al., 2015; Maldini et al., 2005).

Predator/Prey Interactions

Pygmy sperm whales feed on cephalopods and, less often, on deep-sea fishes and shrimps (Beatson, 2007; Caldwell and Caldwell, 1989). A recent study in Hawaiian waters showed cephalopods were the primary prey of pygmy sperm whales, making up 78.7 percent of prey abundance and 93.4 percent contribution by mass (West et al., 2009). Stomach samples revealed an extreme diversity of cephalopod prey, with 38 species from 17 different families (West et al., 2009). Pygmy sperm whales have not been documented to be prey to any other species although, similar to other whale species, they are likely subject to occasional killer whale predation.

Species-Specific Threats

Pygmy sperm whales are susceptible to fisheries interactions.

4.9 Dwarf Sperm Whale (*Kogia sima*)

There are two species of *Kogia*, the pygmy sperm whale and the dwarf sperm whale, which had been considered to be the same species until recently. Genetic evidence suggests that there might also be two separate species of dwarf sperm whales globally, one in the Atlantic and one in the Indo-Pacific (Jefferson et al., 2015). Dwarf and pygmy sperm whales are difficult to distinguish from one another at sea, and many misidentifications have been made. Sightings of either species are often categorized as the genus *Kogia* (Jefferson et al., 2015).

Status and Management

The dwarf sperm whale is protected under the MMPA and is not listed under the ESA. NMFS has designated two stocks of dwarf sperm whales in the Pacific Ocean. Of these, the Hawaii stock occurs in the Study Area.

Geographic Range and Distribution

General. Dwarf sperm whales tend to occur over the outer continental shelf, and they may be relatively coastal in some areas with deep waters nearshore (MacLeod et al., 2004). Although the dwarf sperm whale appears to prefer more tropical waters than the pygmy sperm whale, the exact habitat preferences of the species are not well understood. Dwarf sperm whales have been observed in both outer continental shelf and more oceanic waters. Records of this species from both the western Pacific (Taiwan) and eastern Pacific (California) suggest that its range includes the southern portions of the California Current Large Marine Ecosystem, all waters of the North Pacific Central Gyre, the Insular Pacific-Hawaiian Large Marine Ecosystem, and the southern portion of the North Pacific Transition Zone (Carretta et al., 2010; Jefferson et al., 2015; Wang and Yang, 2006; Wang et al., 2001).

Insular Pacific-Hawaiian Large Marine Ecosystem. During vessel surveys between 2000 and 2003 in the Main Hawaiian Islands, this species was the sixth most commonly observed species, typically in deep water (down to 10,400 feet [3,169.9 m]) (Baird, 2005; Baird, McSweeney, et al., 2003; Barlow et al., 2004). Small boat surveys within the Main Hawaiian Islands since 2002 have documented dwarf sperm whales on 73 occasions, most commonly in water depths between 500 m and 1,000 m (Baird et al., 2013). Dwarf sperm whales are one of the more commonly stranded species in the Hawaiian Islands (Maldini et al., 2005), and the frequency of strandings indicates that the species is likely more common than sightings suggest.

Open Ocean. Although deep oceanic waters may be the primary habitat for this species, very few oceanic sightings offshore have occurred within the Study Area. The lack of sightings may be due to the difficulty of detecting and identifying these animals at sea (Jefferson et al., 2015; Maldini et al., 2005).

Population and Abundance

Results of a 2002 shipboard line-transect survey of the entire Hawaiian Islands EEZ indicated an abundance of 17,519 individuals. However, NMFS considers this information to be out of date and no longer valid. Accordingly, there is no abundance estimate currently available. The frequency of strandings suggests that dwarf sperm whales may not be as uncommon as sightings would suggest (Jefferson et al., 2015).

Predator/Prey Interactions

Dwarf sperm whales feed on cephalopods and, less often, on deep sea fishes and shrimps (Caldwell and Caldwell, 1989; Sekiguchi et al., 1992). Dwarf sperm whales generally forage near the seafloor (McAlpine, 2009). Killer whales are predators of dwarf sperm whales (Dunphy-Daly et al., 2008).

Species-Specific Threats

There are no significant species-specific threats to dwarf sperm whales in the Study Area.

4.10 Killer Whale (*Orcinus orca*)

A single species of killer whale is currently recognized, but genetic and morphological evidence has led some cetacean biologists to consider the possibility of multiple species or subspecies worldwide. In the north Pacific, these forms are variously known as ‘‘residents,’’ ‘‘transients,” and “offshore” ecotypes (Hoelzel et al., 2007).

Status and Management

The killer whale is protected under the MMPA, and overall the species is not listed under the ESA (the southern resident population in Puget Sound, not found in the Study Area, is listed as endangered under the ESA and depleted under the MMPA). The AT1 transient stock is also depleted under the MMPA. In the Pacific Ocean, NMFS recognizes the AT1 Transient stock, four Eastern North Pacific stocks, the West Coast Transient stock, the Eastern North Pacific Offshore stock, and a Hawaii stock (Carretta et al., 2016). Only the Hawaii stock occurs in the Study Area.

Geographic Range and Distribution

General. Killer whales are found in all marine habitats from the coastal zone (including most bays and inshore channels) to deep oceanic basins and from equatorial regions to the polar pack ice zones of both hemispheres. Although killer whales are also found in tropical waters and the open ocean, they are most numerous in coastal waters and at higher latitudes (Dahlheim and Heyning, 1999). The range of this species is known to include the Insular Pacific-Hawaiian Large Marine Ecosystem, the North Pacific Gyre, and North Pacific Transition Zone.

Insular Pacific-Hawaiian Large Marine Ecosystem. Although killer whales apparently prefer cooler waters, they have been observed in Hawaiian waters (Barlow, 2006; Shallenberger, 1981). Sightings are extremely infrequent in Hawaiian waters and typically occur during winter, suggesting those sighted are seasonal migrants (Baird, Hanson, et al., 2003; Mobley, Mazzuca, et al., 2001). Baird (2006) documented 21 sightings of killer whales within the Hawaiian Islands EEZ, primarily around the Main Hawaiian Islands. Summer/fall surveys of the Hawaiian Islands EEZ resulted in one sighting (Bradford et al., 2013). Killer whales are occasionally sighted off Kauai (e.g., Cascadia Research, 2012a). There are also documented strandings for this species from the Hawaiian Islands (Maldini et al., 2005).

Open Ocean. This species is known to occur in deep oceanic waters off Hawaii and elsewhere in the Pacific (Carretta et al., 2010; Miyashita et al., 1996; Wang et al., 2001). In the eastern tropical Pacific, killer whales are known to occur from offshore waters of San Diego to Hawaii and south to Peru (Barlow, 2006; Ferguson, 2005). Offshore killer whales are known to inhabit both the western and eastern temperate Pacific and likely have a continuous distribution across the north Pacific (Steiger et al., 2008).

In most areas of their range, killer whales do not show movement patterns that would be classified as traditional migrations. However, there are often seasonal shifts in density, both onshore/offshore and north/south.

Population and Abundance

The current best available abundance estimate for the Hawaii stock, based on a 2010 shipboard survey of the entire Hawaiian Islands EEZ, is 101 (CV = 1.00) killer whales.

Predator/Prey Interactions

Killer whales feed on a variety of prey, including bony fishes, elasmobranchs (a class of fish composed of sharks, skates, and rays), cephalopods, seabirds, sea turtles, and other marine mammals (Fertl et al., 1996; Jefferson et al., 2015). Some populations are known to specialize in specific types of prey (Jefferson et al., 2015; Krahn et al., 2004; Wade et al., 2009). The killer whale has no known natural predators; it is considered to be the top predator of the oceans (Ford, 2008).

Species-Specific Threats

Boat traffic has been shown to affect the behavior of the endangered southern resident killer whale population around San Juan Island, Washington (Lusseau et al., 2009). In the presence of boats, whales were significantly less likely to be foraging and significantly more likely to be traveling (Lusseau et al., 2009). These changes in behavior were particularly evident when boats were within 330 feet (100 m) of the whales. While this population of killer whales is not present in the Study Area, their behavior may be indicative of other killer whale populations that are present.

Another issue that has been recognized as a potential threat to the endangered southern resident killer whale population is the potential reduction in prey, particularly Chinook salmon (Ford et al., 2009). As noted above, while this population of killer whales is not present in the Study Area, prey reduction may be a threat to other killer whale populations as well. Additionally, killer whales may be particularly susceptible to interactions with fisheries including entanglement.

4.11 False Killer Whale (*Pseudorca crassidens*)

Status and Management

Not much is known about most false killer whale populations globally, but the species is known to be present in Hawaiian waters. NMFS currently recognizes a Hawaiian Islands Stock Complex, which includes the Hawaii Pelagic stock, the Northwestern Hawaiian Islands stock, and the Main Hawaiian Islands insular stock. All stocks of false killer whales are protected under the MMPA. The Main Hawaiian Islands insular stock (considered resident to the Main Hawaiian Islands consisting of Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii) is listed as endangered under the ESA and as depleted under the MMPA. The historical decline of this stock has been the result of various factors, including small population size, evidence of decline of the local Hawaii stock, and incidental take by commercial fisheries (Oleson et al., 2010). It is estimated that approximately eight false killer whales from the Main Hawaiian Islands insular and Hawaii Pelagic stocks are killed or seriously injured by commercial longline fisheries each year (McCracken and Forney, 2010). This number is most likely an underestimate since it does not include any animals that were unidentified and might have been false killer whales. Due to evidence of a serious decline in the population (Reeves et al., 2009), a Take Reduction Team (a team of experts to study the specific topic, also referred to as a Biological Reduction Team) was formed by NOAA in 2010 as required by the MMPA. As a result of the Take Reduction Team's activities, a Take Reduction Plan was published in 2012. The plan identifies regulatory and non-regulatory measures designed to reduce mortalities and serious injuries of false killer whales that are associated with Hawaii long-line fisheries.

The NMFS considers all false killer whales found within 72 km (39 NM) of each of the Main Hawaiian Islands as part of the Main Hawaiian Islands Insular stock. In the vicinity of the Main Hawaiian Islands, the Hawaii Pelagic stock is considered to inhabit waters greater than 11 km (6 NM) from shore. There is no inner boundary for the Hawaii Pelagic stock within the Northwestern Hawaiian Islands. Animals belonging to the Northwestern Hawaiian Islands stock are considered to inhabit waters within a 93 km (50 NM) radius of the Northwestern Hawaiian Islands, or the boundary of the Papahānaumokuākea Marine National Monument, with the radial boundary extended to the southeast to encompass Kauai and Niihau. NMFS recognizes that there is geographic overlap between the stocks in some areas. In particular, individuals from the Northwestern Hawaiian Islands and Hawaii Pelagic stocks have potential for occurrence at the Long Range Strike WSEP impact location. This overlap precludes analysis of differential impact between the two stocks based on spatial criteria.

The density data used in the Navy's modeling and analyses were derived from habitat-based density models for the combined stocks, since limited sighting data did not allow for stock-specific models (Becker et al., 2012). Habitat-based density models allow predictions of cetacean densities on a finer spatial scale than traditional analyses (Barlow et al., 2009) and are thus better suited for spatially explicit effects analyses. In the most recent draft stock assessment report (Carretta et al., 2016), separate abundance numbers are provided for each stock of the false killer whale Hawaiian Islands Stock Complex.

Geographic Range and Distribution

General. The range of this species is known to include waters of the Insular Pacific-Hawaiian Large Marine Ecosystems and the North Pacific Gyre.

Insular Pacific-Hawaiian Large Marine Ecosystem. The false killer whale is regularly found within Hawaiian waters and has been reported in groups of up to 100 (Shallenberger, 1981; Baird, Hanson, et al., 2003). A handful of stranding records exists in the Hawaiian Islands (Maldini et al., 2005). Distribution of Main Hawaiian Islands insular false killer whales has been assessed using data from visual surveys and satellite tag data. Tagging data from seven groups of individuals tagged off the islands of Hawaii and Oahu indicate that the whales move rapidly and semi-regularly throughout the Main Hawaiian Islands and have been documented as far as 112 km offshore over a total range of 31,969 square miles (mi^2) (82,800 square kilometers [km^2]) (Baird et al., 2012). Baird et al. (2012) note, however, that limitations in the sampling "suggest the range of the population is likely underestimated, and there are probably other high-use areas that have not been identified." Photo-identification studies also document that the animals regularly use both leeward and windward sides of the islands (Baird et al., 2005a; Baird, 2009a; Baird et al., 2010a; Forney et al., 2010; Baird et al., 2012). Some individual false killer whales tagged off the island of Hawaii have remained around that island for extended periods (days to weeks), but individuals from all tagged groups eventually were found broadly distributed throughout the Main Hawaiian Islands (Baird, 2009a; Forney et al., 2010). Individuals utilize habitat over varying water depths from less than 164 feet (50 m) to greater than 13,123 feet (4,000 m) (Baird et al., 2010a). It has been hypothesized that interisland movements may depend on the density and movement patterns of their prey species (Baird, 2009a).

Open Ocean. In the north Pacific, this species is known to occur in deep oceanic waters off Hawaii and elsewhere in the Pacific (Carretta et al., 2010; Miyashita et al., 1996; Wang et al., 2001). False killer whales are not considered a migratory species, although seasonal shifts in density likely occur. Seasonal movements in the western north Pacific may be related to prey distribution (Odell and McClune, 1999). Satellite-tracked individuals around the Hawaiian Islands indicate that false killer whales can move extensively among different islands and also sometimes move from an island coast to as far as 60 miles. (96.6 km) offshore (Baird, 2009a; Baird et al., 2010a).

Population and Abundance

False killer whales found in waters surrounding the Main Hawaiian Islands are known to be genetically separate from the population in the outer part of the Hawaiian Islands EEZ and the central tropical Pacific (Chivers et al., 2007; Reeves et al., 2009). Recent genetic research by Chivers et al. (2010) indicates that the Main Hawaiian Islands insular and Hawaii Pelagic populations of false killer whales are independent and do not interbreed. The current abundance estimate of the Main Hawaiian Islands insular stock is 151 individuals (CV = 0.20), the Hawaii Pelagic stock is 1,540 individuals (CV = 0.67), and the Northwestern Hawaiian Islands stock is 617 individuals (CV = 1.11).

Reeves et al. (2009) summarized information on false killer whale sightings near Hawaii between 1989 and 2007, based on various survey methods, and suggested that the Main Hawaiian Islands stock may have declined during the last two decades. Baird (2009a) reviewed trends in sighting rates of false killer whales from aerial surveys conducted using consistent methodology around the Main Hawaiian Islands between 1994 and 2003. Sighting rates during these surveys exhibited a significant decline that could not be attributed to any weather or methodological changes. Data are currently insufficient to determine population trends for the Northwestern Hawaiian Islands or Hawaii Pelagic stocks (Carretta et al., 2016).

Predator/Prey Interactions

False killer whales feed primarily on deep-sea cephalopods and fish (Odell and McClune, 1999). They may prefer large fish species, such as mahi mahi and tunas. Twenty-five false killer whales that stranded off the coast of the Strait of Magellan were examined and found to feed primarily on cephalopods and fish. Squid beaks were found in nearly half of the stranded animals. The most important prey species were found to be the squid species *Martialiabyadesi* and *Illex argentinus* followed by the coastal fish, *Macruronus magellanicus* (Alonso et al., 1999). False killer whales have been observed to attack other cetaceans, including dolphins and large whales such as humpback and sperm whales (Baird, 2009b). They are known to behave aggressively toward small cetaceans in tuna purse seine nets. Unlike other whales or dolphins, false killer whales frequently pass prey back and forth among individuals before they start to eat the fish, in what appears to be a way of affirming social bonds (Baird et al., 2010a). This species is believed to be preyed on by large sharks and killer whales (Baird, 2009b). Like many marine mammals, false killer whales accumulate high levels of toxins in their blubber over the course of their long lives. Because they feed on large prey at the top of the food chain (e.g., squid, tunas) they may be impacted by competition with fisheries (Cascadia Research, 2010).

Species-Specific Threats

In Hawaiian waters, false killer whales are particularly susceptible to fishery interactions and entanglements (Forney et al., 2010).

4.12 Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale is often confused with the false killer whale and melon-headed whale, which are similar in overall appearance.

Status and Management

The pygmy killer whale is protected under the MMPA and is not listed under the ESA. For the MMPA stock assessment reports, there is a single Pacific management stock including animals found within the Hawaiian Islands EEZ and in adjacent high seas waters. However, due to lack of data regarding abundance, distribution, and impacts for high seas waters, the status of the stock is evaluated based only on occurrence in waters of the Hawaiian Islands EEZ.

Geographic Range and Distribution

General. The pygmy killer whale is generally an open ocean deepwater species (Davis et al., 2000; Wursig et al., 2000).

Insular Pacific-Hawaiian Large Marine Ecosystem. Although rarely seen in nearshore waters, sightings have been relatively frequent in the Insular Pacific-Hawaiian Large Marine Ecosystem (Barlow et al., 2004; Donahue and Perryman, 2008; Pryor et al., 1965; Shallenberger, 1981; Smultea et al., 2007). A line-transect survey conducted in February 2009 by the Cetacean Research Program surrounding the

Hawaiian Islands resulted in the sighting of one pygmy killer whale (Oleson and Hill, 2009). Shipboard surveys in the Hawaiian Islands EEZ in 2002 and 2010 resulted in a total of eight additional sightings (Barlow, 2006; Bradford et al., 2013). Six strandings have been documented from Maui and the Island of Hawaii (Carretta et al., 2010; Maldini et al., 2005).

Open Ocean. This species' range in the open ocean generally extends to the southern regions of the North Pacific Gyre and the southern portions of the North Pacific Transition Zone. Many sightings have occurred from cetacean surveys of the eastern tropical Pacific (Au and Perryman, 1985; Barlow and Gisiner, 2006; Wade and Gerrodette, 1993). This species is also known to be present in the western Pacific (Wang and Yang, 2006). Its range is generally considered to be south of 40° N and continuous across the Pacific (Donahue and Perryman, 2008; Jefferson et al., 2015). Migrations or seasonal movements are not known.

Population and Abundance

Although the pygmy killer whale has an extensive global distribution, it is not known to occur in high densities in any region and thus is probably one of the least abundant of the pantropical delphinids. The current best available abundance estimate for the pygmy killer whale derives from a 2010 shipboard survey of the Hawaiian Islands EEZ; the estimate was 3,433 individuals (CV = 0.52) (Bradford et al., 2013).

Predator/Prey Interactions

Pygmy killer whales feed predominantly on fish and squid. They have been known to attack other dolphin species, apparently as prey, although this is not common (Jefferson et al., 2015; Perryman and Foster, 1980; Ross and Leatherwood, 1994). The pygmy killer whale has no documented predators (Weller, 2008). However, like other cetaceans, it may be subject to predation by killer whales.

Species-Specific Threats

Fisheries interactions are likely as evidenced by a pygmy killer whale that stranded on Oahu with signs of hooking injury (NMFS, 2007a) and the report of mouthline injuries noted in some individuals (Baird unpublished data cited in Carretta et al., 2011). It has been suggested that pygmy killer whales may be particularly susceptible to loud underwater sounds, such as active sonar and seismic operations, based on the stranding of pygmy killer whales in Taiwan (Wang and Yang, 2006). However, this suggestion is probably not supported by the data available.

4.13 Short-Finned Pilot Whale (*Globicephala macrorhynchus*)

Status and Management

Short-finned pilot whales are protected under the MMPA and are not listed under the ESA. For MMPA stock assessment reports, short-finned pilot whales within the Pacific U.S. EEZ are divided into two discrete areas: (1) waters off California, Oregon, and Washington and (2) Hawaiian waters. The short-finned pilot whale is widely distributed throughout most tropical and warm temperate waters of the world.

Geographic Range and Distribution

General. A number of studies in different regions suggest that the distribution and seasonal inshore/offshore movements of pilot whales coincide closely with the abundance of squid, their preferred prey (Bernard and Reilly, 1999; Hui, 1985; Payne and Heinemann, 1993). This species' range generally extends to the southern regions of the North Pacific Gyre and the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Many sightings have occurred from cetacean surveys of the eastern tropical Pacific, where the species is reasonably common (Au and Perryman, 1985; Barlow, 2006; Wade and Gerrodette, 1993).

Insular Pacific-Hawaiian Large Marine Ecosystem. Short-finned pilot whales are known to occur in waters surrounding the Hawaiian Islands (Barlow, 2006; Shallenberger, 1981; Smultea et al., 2007). They are most commonly observed around the Main Hawaiian Islands, are relatively abundant around Oahu and the Island of Hawaii, and are also present around the Northwestern Hawaiian Islands (Barlow, 2006; Maldini Feinholz, 2003; Shallenberger, 1981). Fourteen strandings of this species have been recorded at the Main Hawaiian Islands, including five mass strandings (Carretta et al., 2010; Maldini et al., 2005). Short-finned pilot whales were detected in nearshore waters off the western shore of Kauai during passive acoustic and visual surveys in 2014.

Open Ocean. The short-finned pilot whale occurs mainly in deep offshore areas; thus, the species occupies waters over the continental shelf break, in slope waters, and in areas of high topographic relief (Olson, 2009). While pilot whales are typically distributed along the continental shelf break, movements over the continental shelf are commonly observed in the northeastern United States (Payne and Heinemann, 1993) and close to shore at oceanic islands, where the shelf is narrow and deeper waters are found nearby (Gannier, 2000; Mignucci-Giannoni, 1998). Short-finned pilot whales are not considered a migratory species, although seasonal shifts in abundance have been noted in some portions of the species' range.

Population and Abundance

A 2010 shipboard survey of the entire Hawaiian Islands EEZ resulted in an abundance estimate of 12,422 (CV = 0.43) short-finned pilot whales and is considered to be the best available estimate (Bradford et al., 2013).

Predator/Prey Interactions

Pilot whales feed primarily on squid but also take fish (Bernard and Reilly, 1999). They are generally well adapted to feeding on squid (Jefferson et al., 2015; Werth, 2006a; Werth, 2006b). Pilot whales are not generally known to prey on other marine mammals, but records from the eastern tropical Pacific suggest that the short-finned pilot whale does occasionally chase and attack, and may eat, dolphins during fishery operations (Olson, 2009; Perryman and Foster, 1980). They have also been observed harassing sperm whales in the Gulf of Mexico (Weller et al., 1996).

This species is not known to have any predators (Weller, 2008). It may be subject to predation by killer whales.

Species-Specific Threats

Short-finned pilot whales are particularly susceptible to fisheries interactions and entanglement.

4.14 Melon-Headed Whale (*Peponocephala electra*)

This small tropical dolphin species is similar in appearance to the pygmy killer whale.

Status and Management

The melon-headed whale is protected under the MMPA and is not listed under the ESA. NMFS has identified a Hawaiian Islands Stock Complex, which consists of Hawaiian Islands and Kohala Resident stocks. The Kohala resident stock includes melon-headed whales off the Kohala Peninsula and west coast of Hawaii Island, in waters less than 2,500 m depth. These whales would not be expected in the Study Area. The Hawaiian Islands stock includes whales occurring throughout the Hawaiian Islands EEZ (including the area of the Kohala resident stock) and adjacent high seas waters. Due to a lack of data, stock evaluation is based on whales in the Hawaiian Islands EEZ only. In addition, in the area of overlap between the two stocks, individual animals can currently only be distinguished by photographic identification.

Geographic Range and Distribution

General. Melon-headed whales are found worldwide in tropical and subtropical waters. They have occasionally been reported at higher latitudes, but these movements are considered to be beyond their normal range because the records indicate these movements occurred during incursions of warm water currents (Perryman et al., 1994). The range of this species is known to include waters of the Insular Pacific-Hawaiian Large Marine Ecosystems and the North Pacific Gyre (Jefferson et al., 2015; Perryman, 2008). In the north Pacific, occurrence of this species is well known in deep waters off many areas, including Hawaii (Au and Perryman, 1985; Carretta et al., 2010; Ferguson, 2005; Perrin, 1976; Wang et al., 2001).

Insular Pacific-Hawaiian Large Marine Ecosystem. The melon-headed whale is regularly found within Hawaiian waters (Baird, Hanson, et al., 2003; Baird, McSweeney, et al., 2003; Mobley et al., 2000; Shallenberger, 1981). Large groups are seen regularly, especially off the Waianae coast of Oahu, the north Kohala coast of Hawaii, and the leeward coast of Lanai (Baird, 2006; Shallenberger, 1981). A line-transect survey conducted in February 2009 by the Cetacean Research Program surrounding the Hawaiian Islands resulted in the sighting of one melon-headed whale (Oleson and Hill, 2009). Similarly, a shipboard survey of the entire Hawaiian Islands EEZ in 2010 resulted in one sighting (Bradford et al., 2013). A total of 14 stranding records exist for this species in the Hawaiian Islands (Carretta et al., 2010; Maldini et al., 2005).

Open Ocean. Melon-headed whales are most often found in offshore deep waters but sometimes move close to shore over the continental shelf. Brownell et al. (2009) found that melon-headed whales near oceanic islands rest near shore during the day and feed in deeper waters at night. The melon-headed whale is not known to migrate.

Population and Abundance

As described in the most recent stock assessment report (Carretta et al., 2016), the current best available abundance estimate for the Hawaiian Islands stock of melon-headed whale is 5,794 (CV = 0.20). The abundance estimate for the Kohala resident stock is 447 individuals (CV = 0.12).

Predator/Prey Interactions

Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mid-water forms found in waters to 4,920 feet (1,500 m) deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros, 1997). Melon-headed whales are believed to be preyed on by killer whales and have been observed fleeing from killer whales in Hawaiian waters (Baird et al., 2006a).

Species-Specific Threats

There are no significant species-specific threats to melon-headed whales in Hawaii, although it is likely that they are susceptible to fisheries interactions.

4.15 Bottlenose Dolphin (*Tursiops truncatus*)

The classification of the genus *Tursiops* continues to be in question; two species are recognized, the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (Rice, 1998), though additional species are likely to be recognized with future analyses (Natoli et al., 2004).

Status and Management

The bottlenose dolphin is protected under the MMPA and is not listed under the ESA. For the MMPA stock assessment reports, multiple bottlenose dolphin stocks are designated within the Pacific U.S. EEZ. However, within the region of the Study Area, NMFS has identified five stocks that compose the bottlenose dolphin Hawaiian Islands Stock Complex: (1) Hawaii Pelagic, (2) Kauai/ Niihau, (3) Oahu, (4) the 4-Island region, and (5) Hawaii Island. The most recent stock assessment report (Carretta et al., 2016) indicates that demographically independent populations likely exist in the Northwestern Hawaiian Islands. However, data are currently insufficient to delineate such stocks, and bottlenose dolphins in this portion of Hawaii are included in the Hawaii Pelagic stock (Carretta et al., 2016).

Geographic Range and Distribution

General. Common bottlenose dolphins are found most commonly in coastal and continental shelf waters of tropical and temperate regions of the world. They occur in most enclosed or semi-enclosed seas. The species inhabits shallow, murky, estuarine waters and also deep, clear offshore waters in oceanic regions (Jefferson et al., 2015; Wells et al., 2009). Common bottlenose dolphins are often found in bays, lagoons, channels, and river mouths and are known to occur in very deep waters of some ocean regions. The range of this species is known to include waters of the Insular Pacific-Hawaiian Large Marine Ecosystems, the North Pacific Gyre, and the North Pacific Transition Zone (Au and Perryman, 1985; Carretta et al., 2010; Miyashita, 1993; Wang and Yang, 2006).

Insular Pacific-Hawaiian Large Marine Ecosystem. Common bottlenose dolphins are common throughout the Hawaiian Islands, and they are typically observed throughout the main islands and from the Island of Hawaii to Kure Atoll within 5 miles (8.05 km) of the coast (Baird et al., 2009a; Shallenberger, 1981). In the Hawaiian Islands, this species is found in both shallow coastal waters and deep offshore waters (Baird, McSweeney, et al., 2003). The offshore variety is typically larger than the inshore. Twelve stranding records from the Main Hawaiian Islands exist (Maldini et al., 2005; Maldini Feinholz, 2003). Common bottlenose dolphin vocalizations have been documented during acoustic surveys, and the species has been commonly sighted during aerial surveys in the Hawaiian Islands (Barlow et al., 2008; Barlow et al., 2004; Mobley et al., 2000). Bottlenose dolphins were detected in nearshore waters off the western shore of Kauai during passive acoustic and visual surveys in 2014.

Open Ocean. In the eastern tropical Pacific and elsewhere, open ocean populations occur far from land. However, population density appears to be higher in nearshore areas (Scott and Chivers, 1990). In the north Pacific, common bottlenose dolphins have been documented in offshore waters as far north as about 41° N (Carretta et al., 2010). Although in most areas bottlenose dolphins do not migrate (especially where they occur in bays, sounds, and estuaries), seasonal shifts in abundance do occur in many areas (Griffin and Griffin, 2004).

Population and Abundance

The current best available abundance estimate of the Hawaiian Islands Stock Complex of common bottlenose dolphins comes from a ship survey of the entire Hawaiian Islands EEZ in 2010 (Bradford et al., 2013). The resulting abundance estimates for the various stocks are as follows: (1) Hawaii Pelagic - 5,794 individuals (CV = 0.59); (2) Kauai and Niihau – 184 individuals (CV = 0.11); (3) Oahu – 743 individuals (CV = 0.54); (4) 4-Island Region – 191 individuals (CV = 0.24); and (5) Hawaii Island – 128 individuals (CV = 0.13).

The criteria and thresholds developed by the Navy and NMFS result in consideration of potential impacts at distances ranging from immediately adjacent to the activity (meters) to tens of kilometers from some acoustic stressors. Therefore, the abundance estimates and generalized boundaries and locations for bottlenose dolphins stocks in Hawaii are insufficient to allow for an analysis of impacts on individual stocks, and they are treated as a group and discussed in terms of the Hawaiian Islands Stock Complex.

Predator/Prey Interactions

These animals are opportunistic feeders, taking a wide variety of fishes, cephalopods, and shrimps (Wells and Scott, 1999), and using a variety of feeding strategies (Shane, 1990). In addition to using echolocation, a process for locating prey by emitting sound waves that reflect back, bottlenose dolphins likely detect and orient to fish prey by listening for the sounds their prey produce (so-called passive listening) (Barros and Myrberg, 1987; Barros and Wells, 1998). Nearshore bottlenose dolphins prey predominantly on coastal fish and cephalopods, while offshore individuals prey on open ocean cephalopods and a large variety of near-surface and mid-water fish species (Mead and Potter, 1995). Throughout its range, this species is known to be preyed on by killer whales and sharks (Wells and Scott, 2008).

Species-Specific Threats

Common bottlenose dolphins are particularly susceptible to entanglement and other interactions with fishery operations.

4.16 Pantropical Spotted Dolphin (*Stenella attenuata*)

Status and Management

The species is protected under the MMPA and is not listed under the ESA. For the MMPA stock assessment reports, NMFS has identified four stocks that compose the pantropical spotted dolphin Hawaiian Islands Stock Complex: (1) Hawaii Pelagic, (2) Oahu, (3) the 4-Island region, and (4) Hawaii Island.

Geographic Range and Distribution

General. The pantropical spotted dolphin is distributed in offshore tropical and subtropical waters of the Pacific, Atlantic, and Indian Oceans between about 40° N and 40° S (Baldwin et al., 1999; Perrin, 2008b). The species is much more abundant in the lower latitudes of its range. It is found mostly in deeper offshore waters but does approach the coast in some areas (Jefferson et al., 2015; Perrin, 2001).

Insular Pacific-Hawaiian Large Marine Ecosystem. Based on known habitat preferences and sighting data, the primary occurrence for the pantropical spotted dolphin in the Insular Pacific-Hawaiian Large Marine Ecosystem is between 330 and 13,122 feet (100.6 to 3,999.6 m) deep. This area of primary occurrence also includes a continuous band connecting all the Main Hawaiian Islands, Nihoa, and Kaula, taking into account possible interisland movements. Secondary occurrence is expected from the shore to 330 feet (100.6 m), as well as seaward of 13,120 feet (3,998.9 m). Pantropical spotted dolphins make up a relatively large portion of odontocete sightings around Oahu, the 4-Islands, and the Island of Hawaii (about one-fourth of total sightings); however, they are largely absent from nearshore waters around Kauai and Niihau (about 4 percent of sightings) (Baird et al., 2013).

Open Ocean. In the open ocean, this species ranges from 25° N (Baja California, Mexico) to 17° south (S) (southern Peru) (Perrin and Hohn, 1994). Pantropical spotted dolphins are associated with warm tropical surface water in the eastern tropical Pacific (Au and Perryman, 1985; Reilly, 1990). Au and Perryman (1985) noted that the species occurs primarily north of the equator, off southern Mexico, and westward along 10° N.

Although pantropical spotted dolphins do not migrate, extensive movements are known in the eastern tropical Pacific (although these have not been strongly linked to seasonal changes) (Scott and Chivers, 2009).

Population and Abundance

Morphological and coloration differences and distribution patterns have been used to establish that the spotted dolphins around Hawaii belong to a stock that is distinct from those in the eastern tropical Pacific (Carretta et al., 2010). Based on shipboard surveys of the Hawaiian Islands EEZ, the current best available abundance estimate of the Hawaii Pelagic stock of the Hawaiian Islands Stock Complex is 15,917 individuals (CV = 0.40). There is currently insufficient information to provide abundance estimates for the remaining three stocks (Oahu, 4-Island Region, and Hawaii Island).

Predator/Prey Interactions

Pantropical spotted dolphins prey on near-surface fish, squid, and crustaceans and on some mid-water species (Perrin and Hohn, 1994). Results from various tracking and food habit studies suggest that pantropical spotted dolphins off Hawaii feed primarily at night on surface and mid-water species that rise with the deep scattering layer toward the water's surface after dark (Baird et al., 2001; Robertson and Chivers, 1997). Pantropical spotted dolphins may be preyed on by killer whales and sharks and have been observed fleeing killer whales in Hawaiian waters (Baird et al., 2006a). Other predators may include the pygmy killer whale, false killer whale, and occasionally the short-finned pilot whale (Perrin, 2008b).

Species-Specific Threats

Although information on fishery-related impacts to cetaceans in Hawaiian waters is limited, the gear types used result in marine mammal mortality and injury in other fisheries throughout U.S. waters, and pantropical spotted dolphins in the Hawaii region are likely impacted to some degree as well. The most recent stock assessment report (Carretta et al., 2016) describes both anecdotal and documented negative interactions with fishing activities. Pantropical spotted dolphins located in the eastern tropical Pacific have had high mortality rates associated with the tuna purse seine fishery (Wade, 1994).

4.17 Striped Dolphin (*Stenella coeruleoalba*)

Status and Management

This species is protected under the MMPA and is not listed under the ESA. In the western north Pacific, three migratory stocks are recognized. In the eastern Pacific, NMFS divides striped dolphin management stocks within the U.S. EEZ into two separate areas: waters off California, Oregon, and Washington and waters around Hawaii.

Geographic Range and Distribution

General. Although primarily a warm-water species, the range of the striped dolphin extends higher into temperate regions than those of any other species in the genus *Stenella*. Striped dolphins also are generally restricted to oceanic regions and are seen close to shore only where deep water approaches the coast. In some areas (e.g., the eastern tropical Pacific), they are mostly associated with convergence zones and regions of upwelling (Au and Perryman, 1985; Reilly, 1990). The northern limits are the Sea of Japan, Hokkaido, Washington State, and along roughly 40° N across the western and central Pacific (Reeves et al., 2002). In the eastern tropical Pacific, striped dolphins inhabit areas with large seasonal changes in surface temperature and thermocline depth, as well as seasonal upwelling (Au and Perryman, 1985; Reilly, 1990). In some areas, this species appears to avoid waters with sea temperatures less than 68° Fahrenheit (20° Celsius) (Van Waerebeek et al., 1998).

Insular Pacific-Hawaiian Large Marine Ecosystem. The striped dolphin regularly occurs around the Insular Pacific-Hawaiian Large Marine Ecosystem, although sightings are relatively infrequent there (Carretta et al., 2010). Summer/fall shipboard surveys of the Hawaiian Islands EEZ in 2002 and 2010 resulted in 15 and 29 sighting, respectively (Barlow, 2006; Bradford et al., 2013). The species occurs primarily seaward at a depth of about 547 feet (1,000 m), based on sighting records and the species' known preference for deep waters. Striped dolphins are occasionally sighted closer to shore in Hawaii, so an area of secondary occurrence is expected from a depth range of 55 to 547 feet (100 to 1,000 m). Occurrence patterns are assumed to be the same throughout the year (Mobley et al., 2000).

Open Ocean. The primary range of the striped dolphin includes the eastern and western waters of the North Pacific Transition Zone (Perrin et al., 1994a). The species is non-migratory in the Study Area.

Population and Abundance

The best available estimate of abundance for the Hawaii Pelagic stock of the striped dolphin, based on the 2010 shipboard surveys described above, is 20,650 individuals (CV = 0.36).

Predator/Prey Interactions

Striped dolphins often feed in open sea or sea bottom zones along the continental slope or just beyond it in oceanic waters. Most of their prey possess light-emitting organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to 655 to 2,295 feet (200 to 700 m) (Archer and Perrin, 1999). Striped dolphins may feed at night in order to take advantage of the deep scattering layer's diurnal vertical movements. Small mid-water fishes (in particular lanternfishes) and squids are the predominant prey (Perrin et al., 1994a). This species has been documented to be preyed upon by sharks (Ross, 1971). It may also be subject to predation by killer whales.

Species-Specific Threats

There are no significant species-specific threats to striped dolphins in the Study Area.

4.18 Spinner Dolphin (*Stenella longirostris*)

Six morphotypes within four subspecies of spinner dolphins have been described worldwide in tropical and warm-temperate waters, including *Stenella longirostris longirostris* (Gray's, or pantropical, spinner dolphin), *Stenella longirostris orientalis* (eastern spinner dolphin), *Stenella longirostris centroamericana* (Central American spinner dolphin), and *Stenella longirostris roseiventris* (dwarf spinner dolphin) (Perrin et al., 2009). The Gray's spinner dolphin is the most widely distributed and is the subspecies that occurs in the Study Area. Hawaiian spinner dolphins belong to a stock that is separate from animals in the eastern tropical Pacific.

Status and Management

The spinner dolphin is protected under the MMPA and the species is not listed under the ESA. Although the eastern spinner dolphin (*Stenella longirostris orientalis*) is listed as depleted under the MMPA, the Gray's spinner dolphin, which occurs in the Study Area, is not designated as depleted. NMFS has identified six stocks that compose the spinner dolphin Hawaiian Islands Stock Complex: (1) Hawaii Pelagic, (2) Hawaii Island, (3) Oahu and 4-Island, (4) Kauai and Niihau, (5) Midway Atoll/Kure, and (6) Pearl and Hermes Reef. The Hawaii Pelagic stock includes animals found both within the Hawaiian Islands EEZ (but outside of island-associated boundaries) and in adjacent international waters. Based on an analysis of individual spinner dolphin movements, no dolphins have been found farther than 10 NM from shore and few individuals move long distances (from one main Hawaiian Island to another) (Hill et al., 2011).

Geographic Range and Distribution

General. Spinner dolphins occur in both oceanic and coastal environments. Most sightings have been associated with inshore waters, islands, or banks (Perrin and Gilpatrick, 1994). Open ocean populations, such as those in the eastern tropical Pacific, often are found in waters with a shallow thermocline (rapid temperature difference with depth) (Au and Perryman, 1985; Perrin, 2008c; Reilly, 1990). The thermocline concentrates open sea organisms in and above it, which spinner dolphins feed on. In the eastern tropical Pacific, spinner dolphins are associated with tropical surface waters typified by extensive stable thermocline ridging and relatively little annual variation in surface temperature (Au and Perryman, 1985; Perrin, 2008c). Coastal populations are usually found in island archipelagos, where they are associated with coastal trophic and habitat resources (Norris and Dohl, 1980; Poole, 1995).

Insular Pacific-Hawaiian Large Marine Ecosystem. In the Hawaiian Islands, spinner dolphins occur along the leeward coasts of all the major islands and around several of the atolls northwest of the Main

Hawaiian Islands. Long-term site fidelity has been noted for spinner dolphins along the Kona coast of Hawaii, and along Oahu (Marten and Psarakos, 1999; Norris et al., 1994). Navy monitoring for the Rim of the Pacific Exercise in 2006 resulted in daily sightings of spinner dolphins within the offshore area of Kekaha Beach, Kauai, near the PMRF (U.S. Department of the Navy, 2006).

Spinner dolphins occur year round throughout the Insular Pacific-Hawaiian Large Marine Ecosystem, with primary occurrence from the shore to the 13,122 feet (3,999.6 m) depth. This takes into account offshore resting habitat and offshore feeding areas. Spinner dolphins are expected to occur in shallow water resting areas (about 162 feet [49.4 m] deep or less) throughout the middle of the day, moving into deep waters offshore during the night to feed. Primary resting areas are along the west side of Hawaii, including Makako Bay, Honokohau Bay, Kailua Bay, Kealakekua Bay, Honaunau Bay, and Kauhako Bay, and off Kahena on the southeast side of the island (Östman-Lind et al., 2004). Along the Waianae coast of Oahu, Hawaii, spinner dolphins rest along Makua Beach, Kahe Point, and Pokai Bay during the day (Lammers, 2004). Kilauea Bay on Kauai is also a popular resting bay for Hawaiian spinner dolphins (U.S. Department of the Navy, 2006). Another area of occurrence is seaward of 2,187 fathoms (4,000 m). Although sightings have been recorded around the mouth of Pearl Harbor, Hawaii, spinner dolphin occurrence is rare there (Lammers, 2004). Occurrence patterns are assumed to be the same throughout the year. Spinner dolphins were detected in nearshore waters off the western shore of Kauai during passive acoustic and visual surveys in 2014.

Open Ocean. Throughout much of their range, spinner dolphins are found in the open ocean. Spinner dolphins are pantropical, ranging through oceanic tropical and subtropical zones in both hemispheres (the range is nearly identical to that of the pantropical spotted dolphin). The primary range of Gray's spinner dolphin is known to include waters of the North Pacific Gyre and the southern waters of the North Pacific Transition Zone. Its range generally includes tropical and subtropical oceanic waters south of 40° N, continuous across the Pacific (Jefferson et al., 2015; Perrin and Gilpatrick, 1994).

Spinner dolphins are not considered a migratory species.

Population and Abundance

Hawaiian spinner dolphins belong to a separate stock than animals found in the eastern tropical Pacific. Abundance estimates are currently available for only three of the stocks composing the Hawaiian Islands Stock Complex: Hawaii Island – 790 individuals (CV = 0.04); Oahu and 4-Island – 355 individuals (CV = 0.09); and Kauai/Niihau – 601 individuals (CV = 0). Data are currently insufficient to calculate an abundance estimate for the remaining three stocks (Hawaii Pelagic, Midaway Atoll/Kure, and Pearl and Hermes Reef).

Predator/Prey Interactions

Spinner dolphins feed primarily on small mid-water fishes, squids, and shrimp, and they dive to at least 655 to 985 feet (200 to 300 m) (Perrin and Gilpatrick, 1994). They forage primarily at night, when the midwater community migrates toward the surface and the shore (Benoit-Bird, 2004; Benoit-Bird et al., 2001). Spinner dolphins track the horizontal migrations of their prey (Benoit-Bird and Au, 2003), allowing for foraging efficiencies (Benoit-Bird, 2004; Benoit-Bird and Au, 2003). Foraging behavior has also been linked to lunar phases in scattering layers off of Hawaii (Benoit-Bird and Au, 2004). Spinner dolphins may be preyed on by sharks, killer whales, pygmy killer whales, and short-finned pilot whales (Perrin, 2008c).

Species-Specific Threats

There are no significant species-specific threats to spinner dolphins in the Study Area.

4.19 Rough-Toothed Dolphin (*Steno bredanensis*)

Status and Management

This species is protected under the MMPA and is not listed under the ESA. Rough-toothed dolphins are among the most widely distributed species of tropical dolphins, but little information is available regarding population status (Jefferson, 2009; Jefferson et al., 2015). Genetic studies and sighting data indicate there may be at least two island-associated stocks in the Main Hawaiian Islands (Hawaii Island and Kauai/Niihau stocks). However, at this time, NMFS has designated only a single Pacific management stock including animals found within the Hawaiian Islands EEZ (Carretta et al., 2010).

Geographic Range and Distribution

General. The range of this species is known to include waters of the Insular Pacific-Hawaiian Large Marine Ecosystems and the North Pacific Gyre. This species is known to prefer deep water but has been observed in waters of various depths. At the Society Islands, rough-toothed dolphins were sighted in waters with bottom depths ranging from less than 330 feet (100 m) to more than 9,845 feet (more than 3,000 m), although they apparently favored the 1,640- to 4,920-foot (500- to 1,500-m) range (Gannier, 2000).

Insular Pacific-Hawaiian Large Marine Ecosystem. The occurrence of this species is well known in deep ocean waters off Hawaii (Baird et al., 2008; Barlow et al., 2008; Carretta et al., 2010; Pitman and Stinchcomb, 2002; Shallenberger, 1981). Rough-toothed dolphin vocalizations have been detected during acoustic surveys in the eastern tropical Pacific (Oswald et al., 2003). A ship survey in the Hawaiian Islands found that sighting rates were highest in depths greater than 4,920 feet (1,500 m) and resightings were frequent, indicating the possibility of a small population with high site fidelity (Baird et al., 2008). This species has been observed as far northwest as French Frigate Shoals (Carretta et al., 2010). Eight strandings have been reported from the Hawaiian Islands of Maui, Oahu, and Hawaii (Maldini et al., 2005). Rough-toothed dolphins were detected in nearshore waters off the western shore of Kauai during passive acoustic and visual surveys in 2014.

Open Ocean. The rough-toothed dolphin is regarded as an offshore species that prefers deep water, but it can occur in waters of variable bottom depth (Gannier and West, 2005). It rarely occurs close to land, except around islands with steep drop-offs nearshore (Gannier and West, 2005). However, in some areas, this species may frequent coastal waters and areas with shallow bottom depths (Davis et al., 1998; Fulling et al., 2003; Lodi and Hetzel, 1999; Mignucci-Giannoni, 1998; Ritter, 2002).

There is no evidence that rough-toothed dolphins migrate. No information regarding routes, seasons, or resighting rates in specific areas is available.

Population and Abundance

Based on shipboard surveys of the Hawaiian Islands EEZ conducted in 2010 (Bradford et al., 2013), the best available abundance estimate for the Hawaii stock of rough-toothed dolphins is 6,288 individuals (CV = 0.39). Although island-specific stocks are not currently recognized by NMFS for management purposes, abundance estimates are provided in the most recent stock assessment report (Carretta et al., 2016) for Kauai/Niihau (1,665 individuals; CV = 0.33) and Hawaii Island (198 individuals; CV = 0.12). The island-specific estimates are based on photographic identification surveys conducted primarily within 40 km of shore and are not considered representative of abundance within the Hawaiian Islands EEZ.

Predator/Prey Interactions

Prey of rough-toothed dolphins includes fish and cephalopods. They are known to feed on large fish species, such as mahi mahi (Miyazaki and Perrin, 1994; Pitman and Stinchcomb, 2002). They also prey on reef fish, as Perkins and Miller (1983) noted that parts of reef fish had been found in the stomachs of stranded rough-toothed dolphins in Hawaii. Gannier and West (2005) observed rough-toothed dolphins feeding during the day on near-surface fishes, including flying fishes.

Although this species has not been documented as prey by other species, it may be subject to predation from killer whales.

Species-Specific Threats

Rough-toothed dolphins are particularly susceptible to commercial and recreational fishery interactions.

4.20 Fraser's Dolphin (*Lagenodelphis hosei*)

Although information on Fraser's dolphin has increased in recent years, the species is still one of the least-known cetaceans. Fraser's dolphin was discovered in 1956, and after that time was known only from skeletal remains until it was once again identified in the early 1970s (Perrin et al., 1973).

Status and Management

Fraser's dolphin is protected under the MMPA and is not listed under the ESA. For the MMPA stock assessment reports, there is a single Pacific management stock that includes only animals found within the Hawaiian Islands EEZ.

Geographic Range and Distribution

General. Fraser's dolphin is a tropical oceanic species, except where deep water approaches the coast (Dolar, 2008).

Insular Pacific-Hawaiian Large Marine Ecosystem. Fraser's dolphins have only recently been documented within the Insular Pacific-Hawaiian Large Marine Ecosystem. The first published sightings were during a 2002 cetacean survey (Barlow, 2006; Carretta et al., 2010), at which time the mean group size recorded was 286 (Barlow, 2006). An additional sighting was recorded off the Island of Hawaii in 2008. There are no records of strandings of this species in the Hawaiian Islands (Maldini et al., 2005). Fraser's dolphin vocalizations have been documented in the Hawaiian Islands (Barlow et al., 2008; Barlow et al., 2004). It is not known whether Fraser's dolphins found in Hawaiian waters are part of the same population that occurs in the eastern tropical Pacific (Carretta et al., 2010).

Open Ocean. In the offshore eastern tropical Pacific, this species is distributed mainly in upwelling-modified waters (Au and Perryman, 1985; Reilly, 1990). The range of this species includes deep open ocean waters of the North Pacific Gyre and the Insular Pacific-Hawaiian Large Marine Ecosystem and other locations in the Pacific (Aguayo and Sanchez, 1987; Ferguson, 2005; Miyazaki and Wada, 1978).

This does not appear to be a migratory species, and little is known about its potential migrations. No specific information regarding routes, seasons, or resighting rates in specific areas is available.

Population and Abundance

The current best available abundance estimate for the Hawaii stock of Fraser's dolphin derives from a 2002 shipboard survey of the entire Hawaiian Islands EEZ, resulting in an estimate of 16,992 (CV = 0.66) (Bradford et al., 2013).

Predator/Prey Interactions

Fraser's dolphin feeds on mid-water fishes, squids, and shrimps and has not been documented to be prey to any other species (Jefferson and Leatherwood, 1994; Perrin et al., 1994b). It may, however, be subject to predation by killer whales.

Species-Specific Threats

There are no significant species-specific threats to Fraser's dolphins in the Study Area.

4.21 Risso's Dolphin (*Grampus griseus*)

Status and Management

Risso's dolphin is protected under the MMPA and is not listed under the ESA. For the MMPA stock assessment reports, Risso's dolphins within the Pacific U.S. EEZ are divided into two separate areas: waters off California, Oregon, and Washington and Hawaiian waters (Carretta et al., 2010).

Geographic Range and Distribution

General. In the Pacific, the range of this species is known to include the North Pacific Gyre and the California Current and Insular Pacific-Hawaiian Large Marine Ecosystems. Occurrence of this species is well known in deep open ocean waters off Hawaii and in other locations in the Pacific (Au and Perryman, 1985; Carretta et al., 2010; Leatherwood et al., 1980; Miyashita, 1993; Miyashita et al., 1996; Wang et al., 2001).

Insular Pacific-Hawaiian Large Marine Ecosystem. Risso's dolphins have been considered rare in Hawaiian waters (Shallenberger, 1981). However, during a 2002 survey of the Hawaiian Islands EEZ, seven sightings were reported; in addition, two sightings were reported from recent aerial surveys in the Hawaiian Islands (Barlow, 2006; Mobley et al., 2000). During a more recent 2010 systematic survey of the Hawaiian Islands EEZ, there were 12 sightings of Risso's dolphins. In 2009, Risso's dolphins were acoustically detected near Hawaii using boat-based hydrophones (U.S. Department of the Navy, 2009). In addition, Risso's dolphins were sighted eight times during Navy monitoring activities within HRC between 2005 and 2012 (HDR, 2012). Five stranding records exist from the Main Hawaiian Islands (Maldini et al., 2005).

Open Ocean. Several studies have documented that Risso's dolphins are found offshore, along the continental slope, and over the outer continental shelf (Baumgartner, 1997; Canadas et al., 2002; Cetacean and Turtle Assessment Program, 1982; Davis et al., 1998; Green et al., 1992; Kruse et al., 1999; Mignucci-Giannoni, 1998). Risso's dolphins are also found over submarine canyons (Mussi et al., 2004).

Risso's dolphin does not migrate, although schools may range over very large distances. Seasonal shifts in centers of abundance are known for some regions.

Population and Abundance

This is a widely distributed species that occurs in all major oceans, and although no global population estimates exist, it is generally considered to be one of the most abundant of the large dolphins. The current best available abundance estimate for the Hawaiian stock of Risso's dolphin derives from a 2010 shipboard survey of the entire Hawaiian Islands EEZ (Bradford et al., 2013). The resulting abundance estimate is 7,526 individuals (CV = 0.41).

Predator/Prey Interactions

Cephalopods and crustaceans are the primary prey for Risso's dolphins (Clarke, 1996), which feed mainly at night (Baird et al., 2008; Jefferson et al., 2015). This dolphin may be preyed on by both killer whales and sharks, although there are no documented reports of predation by either species (Weller, 2008).

Species-Specific Threats

Risso's dolphins are particularly susceptible to entanglement and fisheries interactions.

4.22 Cuvier's Beaked Whale (*Ziphius cavirostris*)

Status and Management

Cuvier's beaked whale is protected under the MMPA and is not listed under the ESA. Cuvier's beaked whale stocks are defined for three separate areas within Pacific U.S. waters: (1) Alaska; (2) California, Oregon, and Washington; and (3) Hawaii Pelagic.

Geographic Range and Distribution

General. Cuvier's beaked whales have an extensive range that includes all oceans, from the tropics to the polar waters of both hemispheres. Worldwide, beaked whales normally inhabit continental slope and deep oceanic waters. Cuvier's beaked whales are generally sighted in waters with a bottom depth greater than 655 feet (199.6 m) and are frequently recorded in waters with bottom depths greater than 3,280 feet (999.7 m) (Falcone et al., 2009; Jefferson et al., 2015). Cuvier's beaked whale range is known to include all waters of the Insular Pacific-Hawaiian Large Marine Ecosystems, the North Pacific Gyre, and the North Pacific Transition Zone (Jefferson et al., 2015; MacLeod and D'Amico, 2006).

Insular Pacific-Hawaiian Large Marine Ecosystem. Cuvier's beaked whales are regularly found in waters surrounding the Hawaiian Islands, having been sighted from vessels and aerial surveys. A line-transect survey conducted in February 2009 by the Cetacean Research Program surrounding the Hawaiian Islands (Oleson and Hill, 2009) resulted in the sighting of 2 Cuvier's beaked whales, while shipboard surveys of the Hawaiian Islands EEZ in 2020 (Bradford et al., 2013) resulted in 22 sightings. They typically are found at depths exceeding 6,560 feet (2,000 m) (Baird et al., 2009b; Baird et al., 2006b; Barlow et al., 2004). In the Hawaiian Islands, five strandings have been reported from Midway Island, Pearl and Hermes Reef, Oahu, and the Island of Hawaii (Maldini et al., 2005; Shallenberger, 1981). Sightings have been reported off the Hawaiian Islands of Lanai, Maui, Hawaii, Niihau, and Kauai, supporting the hypothesis that there is a resident population found in the Hawaiian Islands (Baird et al., 2010b; Carretta et al., 2010; Mobley et al., 2000; Shallenberger, 1981).

Open Ocean. Cuvier's beaked whales are widely distributed in offshore waters of all oceans and thus occur in temperate and tropical waters of the Pacific, including waters of the eastern tropical Pacific (Barlow et al., 2006; Ferguson, 2005; Jefferson et al., 2015; Pitman et al., 1988). In the Study Area, they are found mostly offshore in deeper waters off Hawaii (MacLeod and Mitchell, 2006; Mead, 1989; Ohizumi and Kishiro, 2003; Wang et al., 2001). A single population likely exists in offshore waters of the eastern north Pacific, ranging from Alaska south to Mexico (Carretta et al., 2010). Little is known about potential migration.

Population and Abundance

The current best available abundance estimate for the Hawaii Pelagic stock is 1,941 individuals (CV = n/a), based on a 2010 shipboard line-transect survey of the Hawaiian Islands EEZ (Bradford et al., 2013).

Predator/Prey Interactions

Cuvier's beaked whales, similar to other beaked whale species, are apparently deepwater feeders. Stomach content analyses show that they feed mostly on deep-sea squid, fish, and crustaceans (Hickmott, 2005; Santos et al., 2007). They apparently use suction to swallow prey (Jefferson et al., 2015; Werth, 2006a; Werth, 2006b). Cuvier's beaked whales may be preyed upon by killer whales (Heyning and Mead, 2008; Jefferson et al., 2015).

Species-Specific Threats

Cuvier's beaked whales commonly strand, and they are considered vulnerable to acoustic impacts (Frantzis et al., 2002; Cox et al., 2006; Southall et al., 2012). Additionally, Cuvier's beaked whales have been documented being entangled in fishing gear.

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

Status and Management

Due to difficulty in distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is usually defined to include all *Mesoplodon* species that occur in an area. Blainville's beaked whale is protected under the MMPA and is not listed under the ESA. Although little is known of stock structure for this species, based on resightings and genetic analysis of individuals around the Hawaiian Islands, NMFS recognizes a Hawaii Pelagic stock of Blainville's beaked whale.

Geographic Range and Distribution

General. Blainville's beaked whales are one of the most widely distributed of the distinctive toothed whales within the *Mesoplodon* genus (Jefferson et al., 2015; MacLeod and Mitchell, 2006). Blainville's beaked whale range is known to include the Insular Pacific-Hawaiian Large Marine Ecosystems, North Pacific Gyre, and the North Pacific Transition Zone (Jefferson et al., 2015; Pitman, 2008).

Insular Pacific-Hawaiian Large Marine Ecosystem. Blainville's beaked whales are regularly found in Hawaiian waters (Baird, Hanson, et al., 2003; Baird et al., 2006b; Barlow et al., 2004). In Hawaiian waters, this species is typically found in areas where water depths exceed 3,280 feet (1,000 m) along the continental slope (Barlow et al., 2006; Baird et al., 2010b). Blainville's beaked whale has been detected off the coast of Oahu, Hawaii, for prolonged periods annually, and this species is consistently observed in the same site off the west coast of the island of Hawaii (McSweeney et al., 2007). Blainville's beaked whales' vocalizations have been detected on acoustic surveys in the Hawaiian Islands, and stranding records are available for the region (Maldini et al., 2005; Rankin and Barlow, 2007). A recent tagging study off the island of Hawaii found the movements of a Blainville's beaked whale to be restricted to the waters of the west and north side of the island (Baird et al., 2010b). Blainville's beaked whales were detected in nearshore waters off the western shore of Kauai during passive acoustic and visual surveys in 2014.

Open Ocean. Blainville's beaked whales are found mostly offshore in deeper waters along the California coast, Hawaii, Fiji, Japan, and Taiwan, as well as throughout the eastern tropical Pacific (Leslie et al., 2005; MacLeod and Mitchell, 2006; Mead, 1989). It is unknown whether this species makes specific migrations, and none have so far been documented. Populations studied in Hawaii have evidenced some level of residency (McSweeney et al., 2007).

Population and Abundance

The best available abundance estimate for Blainville's beaked whale Hawaii Pelagic stock is based on a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ (Bradford et al., 2013). The resulting estimate is 2,338 individuals (CV = 1.13).

Predator/Prey Interactions

This species preys on squid and possibly deepwater fish. Like other *Mesoplodon* species, Blainville's beaked whales apparently use suction for feeding (Jefferson et al., 2015; Werth, 2006a; Werth, 2006b). This species has not been documented to be prey to any other species although, like other cetaceans, it is likely subject to occasional killer whale predation.

Species-Specific Threats

Blainville's beaked whales have been shown to react to anthropogenic noise by avoidance (Tyack et al., 2011). In response to a simulated sonar signal and pseudorandom noise (a signal of pulsed sounds that are generated in a random pattern), a tagged whale ceased foraging at depth and slowly moved away from the source while gradually ascending toward the surface (Tyack et al., 2011).

4.24 Longman's Beaked Whale (*Indopacetus pacificus*)

Status and Management

Longman's beaked whale is protected under the MMPA and is not listed under the ESA. Longman's beaked whale is a rare beaked whale species and is considered one of the world's least-known cetaceans (Dalebout et al., 2003; Pitman, 2008). Only one Pacific stock, the Hawaii stock, is identified (Carretta et al., 2010).

Geographic Range and Distribution

General. Longman's beaked whales generally are found in warm tropical waters, with most sightings occurring in waters with sea surface temperatures warmer than 78° Fahrenheit (26° Celsius) (Anderson et al., 2006; MacLeod and D'Amico, 2006; MacLeod, Hauser, et al., 2006). Sighting records of this species in the Indian Ocean showed Longman's beaked whale typically found over deep slopes 655 to 6,560 (or more) feet (200 to 2,000 [or more] m) (Anderson et al., 2006).

Although the full extent of this species distribution is not fully understood, there have been many recorded sightings at various locations in tropical waters of the Pacific and Indian Oceans (Afsal et al., 2009; Dalebout et al., 2002; Dalebout et al., 2003; Moore, 1972). Ferguson et al. (2001) reported that all Longman's beaked whale sightings were south of 25° N.

Records of this species indicate presence in the eastern, central, and western Pacific. The range of Longman's beaked whale generally includes the Insular Pacific-Hawaiian Large Marine Ecosystems and the North Pacific Gyre (Gallo-Reynoso and Figueroa-Carranza, 1995; Jefferson et al., 2015; MacLeod and D'Amico, 2006).

Insular Pacific-Hawaiian Large Marine Ecosystem. Sighting records for this species indicate presence in waters to the west of the Hawaiian Islands (four Longman's beaked whales were observed during the 2002 Hawaiian Islands Cetacean and Ecosystem Assessment, also known as the HICEAS survey [Barlow et al., 2004]) and to the northwest of the Hawaiian archipelago (23°42'38" N and 176°33'78" W). During a more recent 2010 HICEAS survey, there were multiple sightings of Longman's beaked whale. Longman's beaked whales have also been sighted off Kona (Cascadia Research, 2012b). Shipboard surveys of the Hawaiian Islands EEZ in 2010 resulted in three sightings (Bradford et al., 2013). Two known records exist of this species stranding in the Hawaiian Islands (Maldini et al., 2005; West et al., 2012).

Open Ocean. Worldwide, Longman's beaked whales normally inhabit continental slope and deep oceanic waters (greater than 655 feet [200 m]) and are only occasionally reported in waters over the continental shelf (Canadas et al., 2002; Ferguson et al., 2006; MacLeod, Hauser, et al., 2006; Pitman, 2008; Waring et al., 2001).

Little information regarding the migration of this species is available, but it is considered to be widely distributed across the tropical Pacific and Indian Oceans (Jefferson et al., 2015). It is unknown whether the Longman's beaked whale participates in a seasonal migration (Jefferson et al., 2015; Pitman, 2008).

Population and Abundance

Based on 2010 surveys of the Hawaiian Islands EEZ (Bradford et al., 2013), the best available abundance estimate of the Hawaii stock is 4,571 individuals (CV = 0.65).

Predator/Prey Interactions

Based on recent tagging data from Cuvier's and Blainville's beaked whales, Baird et al. (2005b) suggested that feeding for Longman's beaked whale might occur at mid-water rather than only at or near the bottom (Heyning, 1989; MacLeod et al., 2003). This species has not been documented to be prey to any other species, though it is likely subject to occasional killer whale predation.

Species-Specific Threats

Little information exists regarding species-specific threats to Longman's beaked whales in the Study Area. However, recently the first case of morbillivirus in the central Pacific was documented for a stranded juvenile male Longman's beaked whale at Hamoa Beach, Hana, Maui (West et al., 2012).

4.25 Hawaiian Monk Seal (*Neomonachus schauinslandi*)

Status and Management

The Hawaiian monk seal was listed as endangered under the ESA in 1976 and is listed as depleted under the MMPA. The species is considered a high priority for recovery, based on the high magnitude of threats, the high recovery potential, and the potential for economic conflicts while implementing recovery actions (NMFS, 2007b). Hawaiian monk seals are managed as a single stock. NMFS has identified reproductive subpopulations at French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, Kure Atoll, and Necker and Nihoa Islands in the Northwestern Hawaiian Islands (NMFS, 2014). The species also occurs throughout the Main Hawaiian Islands (e.g., there is a population of approximately 200 individuals in the Main Hawaiian Islands [NMFS, 2016a] and the total population is estimated to be fewer than 1,200 individuals). The approximate area encompassed by the Northwestern Hawaiian Islands was designated as the Papahānaumokuākea Marine National Monument in 2006.

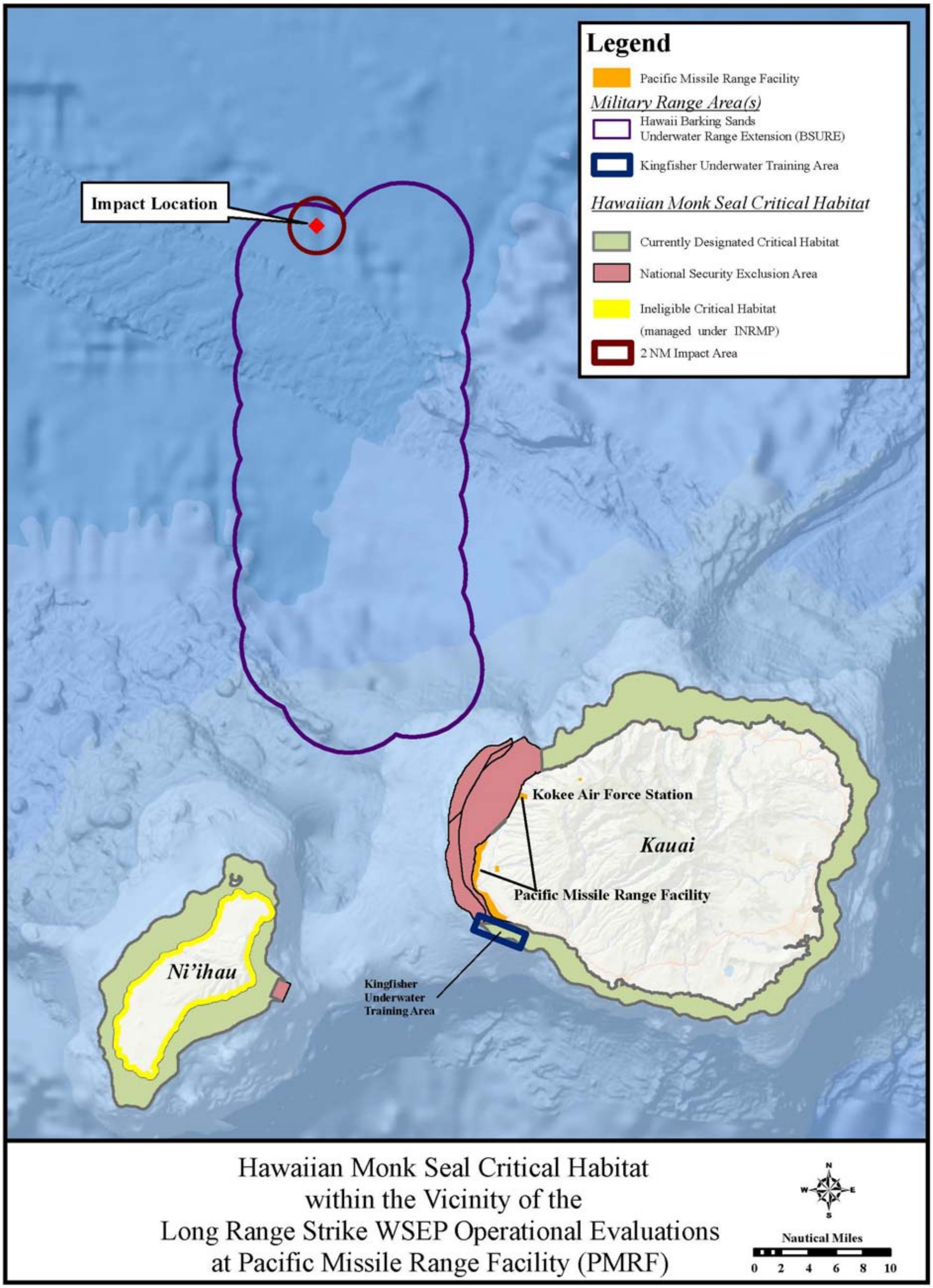
A recovery plan for the Hawaiian monk seal was completed in 1983 and was revised in 2007 (NMFS, 2007b). In 1986, critical habitat was designated for all beach areas, sand spits and islets, lagoon waters, inner reef waters, and ocean waters to a depth of 10 fathoms (18.3 m) around Kure Atoll, Midway Islands (except Sand Island), Pearl and Hermes Reef, Lisianski Island, Laysan Island, Gardner Pinnacles, French Frigate Shoals, Necker Island, and Nihoa Island in the Northwestern Hawaiian Islands (NMFS, 1986). In 1988, the critical habitat was extended to include Maro Reef and waters around previously recommended areas out to the 20 fathom (36.6 m) isobath (NMFS, 1988). In order to reduce the probability of direct interaction between Hawaiian-based long-line fisheries and monk seals, a Protected Species Zone was established in the Northwestern Hawaiian Islands, prohibiting long-line fishing in this zone. In 2000, the waters from 3 to 50 NM around the Northwestern Hawaiian Islands were designated as the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, and specific restrictions were placed on human activities there (Antonelis et al., 2006).

In 2008, NMFS received a petition requesting that the critical habitat in the Northwestern Hawaiian Islands be expanded to include Sand Island at Midway and ocean waters out to a depth of 500 m and that the following critical habitat be added in the Main Hawaiian Islands: key beach areas, sand spits and islets, lagoon waters, inner reef waters, and ocean waters to a depth of 200 m. In 2009, NMFS announced a 12-month finding indicating the intention to revise critical habitat, and in 2011 NMFS proposed that critical habitat in the Northwestern Hawaiian Islands be expanded to include Sand Island at Midway and ocean waters out to a depth of 500 m and that six new extensive areas in the Main Hawaiian Islands be added. In August 2015, NMFS published a final rule revising critical habitat designation to include 10 areas in the Northwestern Hawaiian Islands and 6 areas in the Main Hawaiian Islands (50 CFR Part 226, 21 August 2015). NMFS excluded several areas from designation because either (1) the national security benefits of exclusion outweigh the benefits of inclusion (and exclusion will not result in extinction of the species), or (2) they are managed under Integrated Natural Resource Management Plans that provide a benefit to the species (these areas are termed "ineligible" for critical habitat designation). Critical Habitat Specific Area 13 includes portions of the Kauai coastline and associated marine waters. However, portions of the PMRF were excluded, including the PMRF Main Base at Barking Sands and the PMRF Offshore Areas in marine areas off the western coast of Kauai. Hawaiian monk seal critical habitat is shown in Figure 4-1.

The Pacific Island Regional Office of NMFS has the lead responsibility for the recovery of Hawaiian monk seals under the ESA and the MMPA. Since the early 1980s, NMFS has routinely applied flipper tags to weaned pups in the Northwestern Hawaiian Islands (Antonelis et al., 2006). NMFS performed capture and release programs through the Head Start Program between 1981 and 1991, "to enhance the survival of young females and thereby increase their subsequent recruitment into the adult female population." From 1984 to 1995, under NMFS's Rehabilitation Project, undersized, weaned female pups from French Frigate Shoals and, in some cases, undersized juvenile females, were brought into captivity for 8 to 10 months on Oahu to increase their weight. They were then released into the wild at either Kure Atoll or Midway Islands, where they had a higher probability of survival (Antonelis et al., 2006). Because some males were injuring female seals, in July and August of 1994, 21 adult male Hawaiian monk seals were relocated from Laysan Island to the Main Hawaiian Islands (NMFS, 2009). NMFS has relocated three female monk seals (a juvenile in 1981, a pup in 1991, and an adult in 2009) from the Main Hawaiian Islands to the Northwestern Hawaiian Islands (NMFS, 2009).

Other agencies that also play an important role in the Northwestern Hawaiian Islands are the Marine Mammal Commission; the USFWS, which manages wildlife habitat and human activities within the lands and waters of the Hawaiian Islands National Wildlife Refuge and the Midway Atoll National Wildlife Refuge; the U.S. Coast Guard, which assists with enforcement and efforts to clean up marine pollution; the National Ocean Service, which conserves natural resources in the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve; and the Western Pacific Regional Fishery Management Council, which develops fishery management plans and proposes regulations to NMFS for commercial fisheries around the Northwestern Hawaiian Islands (Marine Mammal Commission, 2002).

Figure 4-1. Critical Habitat of the Hawaiian Monk Seal near the Study Area



The State of Hawaii also has important responsibilities for monk seal conservation and recovery. It owns Kure Atoll and has jurisdiction over waters between the reserve boundary and 3 NM around all emergent lands in the Northwestern Hawaiian Islands (except Midway) (Marine Mammal Commission, 2002). In March 2007, the State of Hawaii put new regulations into place to restrict the use of lay nets on Oahu, Molokai, Lanai, Kauai, and Niihau and prohibited lay net use in state waters around the entire island of Maui and certain areas on Oahu (NMFS, 2010b). In 2008, in hopes of raising awareness of the species, Hawaii's Lieutenant Governor signed into law legislation that established the Hawaiian monk seal as the official state mammal.

When seals are reported on beaches in the main islands, NMFS works with state and local agencies to cordon off sections of beach around the seals. NMFS also relies on volunteer groups to observe seals and educate the public about their endangered status and protection measures. On Oahu, the Hawaiian Monk Seal Response Team Oahu is a team of over 50 volunteers who routinely assist NOAA Fisheries Pacific Island Regional Office and the Pacific Island Fisheries Science Center in monk seal response issues. Monk seal response programs also exist on Kauai, Maui, and the Island of Hawaii, with some reporting from Molokai and Lanai (NMFS, 2010b).

There is also a multiagency marine debris working group that was established in 1998 to remove derelict fishing gear, which has been identified as a top threat to this species, from the Northwestern Hawaiian Islands (Donohue and Foley, 2007). Agencies involved in these efforts include The Ocean Conservancy, the City and County of Honolulu, the Coast Guard, the USFWS, the Hawaii Wildlife Fund, the Hawaii Sea Grant Program, the National Fish and Wildlife Foundation, the Navy, the University of Alaska Marine Advisory Program, and numerous other state and private agencies and groups (Marine Mammal Commission, 2002).

The Navy has previously funded some monk seal tagging projects conducted by Pacific Islands Fisheries Science Center personnel. In addition, since 2013, some collaborative projects have been undertaken under the PMRF Integrated Natural Resources Management Plan.

Geographic Range and Distribution

General. Monk seals can rapidly cover large areas in search of food and may travel hundreds of miles in a few days (Littnan et al., 2007).

Insular Pacific-Hawaiian Large Marine Ecosystem. The Hawaiian monk seal is the only endangered marine mammal whose range is entirely within the United States (NMFS, 2007b). Hawaiian monk seals can be found throughout the Hawaiian Island chain in the Insular Pacific-Hawaiian Large Marine Ecosystem. Sightings have also occasionally been reported on nearby island groups south of the Hawaiian Island chain, such as Johnston Atoll, Wake Island, and Palmyra Atoll (Carretta et al., 2010; Gilmartin and Forcada, 2009; Jefferson et al., 2015; NMFS, 2009). The main breeding sites are in the Northwestern Hawaiian Islands: French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, Kure Atoll, and Necker and Nihoa Islands. Monk seals have also been observed at Gardner Pinnacles and Maro Reef. A small breeding population of monk seals is found throughout the Main Hawaiian Islands, where births have been documented on most of the major islands, especially Kauai (Gilmartin and Forcada, 2009; NMFS, 2007b; NMFS, 2010c). It is possible that, before Western contact, Polynesians drove many Hawaiian monk seals from the Main Hawaiian Islands to less desirable habitat in the Northwestern Hawaiian Islands (Baker and Johanos, 2004).

Although the Hawaiian monk seal is found primarily on the Northwestern Hawaiian Islands (NMFS, 2014), sightings on the Main Hawaiian Islands have become more common (Johanos et al., 2015). During Navy-funded marine mammal surveys from 2007 to 2012, there were 41 sightings of Hawaiian monk seals, with a total of 58 individuals on or near Kauai, Kaula, Niihau, Oahu, and Molokai (HDR, 2012). Forty-seven (81 percent) individuals were seen during aerial surveys, and 11 (19 percent) during vessel surveys. Monk seals were most frequently observed at Niihau.

Monk seals are generally thought to spend most of their time at sea in nearshore, shallow marine habitats (Littnan et al., 2007). However, recent research suggests that the seals may use the open ocean more extensively than previously thought (see the *Predator/Prey Interactions* subsection below). When hauled out, Hawaiian monk seals seem to prefer beaches of sand, coral rubble, and rocky terraces (Baker et al., 2006; Jefferson et al., 2015).

Climate models predict that global average sea levels may rise this century, potentially affecting species that rely on the coastal habitat. Topographic models of the low-lying Northwestern Hawaiian Islands were created to evaluate potential effects of sea level rise by 2100. Monk seals, which require the islands for resting, molting, and nursing, may experience more crowding and competition if islands shrink (Baker et al., 2006).

Based on one study, on average, 10 to 15 percent of the monk seals migrate among the Northwestern Hawaiian Islands and the Main Hawaiian Islands (Carretta et al., 2010). Another source suggests that about 36 percent of the main Hawaiian Island seals travel between islands throughout the year (Littnan, 2011).

Population and Abundance

Currently, the best available abundance estimate of monk seals is 1,324 (CV = n/a) (Baker et al., 2016). Population dynamics at the different locations in the Northwestern Hawaiian Islands and the Main Hawaiian Islands has varied considerably (Antonelis et al., 2006). A population model for 2003 through 2012 suggests a decline in overall population of about 3.3 percent. However, the Main Hawaiian Islands population appears to be increasing, possibly at a rate of about 7 percent per year (NMFS, 2014). In the Main Hawaiian Islands, a minimum abundance of 45 seals was found in 2000, and this increased to 52 in 2001 (Baker, 2004). In 2009, 113 individual seals were identified in the Main Hawaiian Islands based on flipper tag ID numbers or unique natural markings. The total number in the Main Hawaiian Islands is currently estimated to be about 200 animals (NMFS, 2016a). Beach counts in the Northwestern Hawaiian Islands since the late 1950s have shown varied population trends at specific times, but in general, abundance is low at most islands (NMFS, 2014). In 2015, site specific estimates of abundance for Main Hawaiian Islands (other than Ni'ihau and Lehua) were 145 animals (Baker et al. 2016).

Possible links between the spatial distribution of primary productivity in the Northwestern Hawaiian Islands and trends of Hawaiian monk seal abundance have been assessed for the past 40 years. Results demonstrate that monk seal abundance trends appear to be affected by the quality of local environmental conditions (including sea surface temperature, vertical water column structure, and integrated chlorophyll) (Schmelzer, 2000). Limited prey availability may be restricting the recovery of the Northwestern Hawaiian Islands monk seals (Baker, 2008; Brillinger et al., 2006; Carretta et al., 2010). Studies performed on pup survival rate in the Northwestern Hawaiian Islands between 1995 and 2004 showed severe fluctuations between 40 percent and 80 percent survival in the first year of life. Survival rates between 2004 and 2008 showed an increase at Lisianski Island and Pearl, Hermes, Midway, and Kure Atoll and a decrease at French Frigate Shoals and Laysan Island. Larger females have a higher survival rate than males and smaller females (Baker, 2008).

Estimated chances of survival from weaning to age one are higher in the Main Hawaiian Islands (77 percent) than in the Northwestern Hawaiian Islands (42 to 57 percent) (Littnan, 2011). The estimated Main Hawaiian Islands intrinsic rate of population growth is greater as well. If current trends continue, abundances in the Main Hawaiian Islands could eventually exceed that of the Northwestern Hawaiian Islands (NMFS, 2014). There are a number of possible reasons why pups in the Main Hawaiian Islands are faring better. One is that the per capita availability of prey may be higher in the Main Hawaiian

Islands, due to the low monk seal population (Baker and Johanos, 2004). Another may have to do with the structure of the marine communities. In the Main Hawaiian Islands, the seals have less competition with other top predators, like large sharks, jacks, and other fish, which may enhance their foraging success (Baker and Johanos, 2004; Parrish et al., 2008).

A third factor may be the limited amount of suitable foraging habitat in the Northwestern Hawaiian Islands (Stewart et al., 2006). While foraging conditions are better in the Main Hawaiian Islands than in the Northwestern Hawaiian Islands, health hazards from exposure to pollutants and infectious disease agents associated with terrestrial animals pose risks not found in the Northwestern Hawaiian Islands (Littnan et al., 2007). Despite these risks, a self-sustaining subpopulation in the Main Hawaiian Islands could improve the monk seal's long-term prospects for recovery (Baker and Johanos, 2004; Carretta et al., 2005; Marine Mammal Commission, 2003).

Predator/Prey Interactions

The Hawaiian monk seal is a foraging generalist, often moving rocks to capture prey underneath (NMFS, 2014). Monk seals feed on many species of fish, cephalopods, and crustaceans. Prey species include representatives of at least 31 bony fish families, 13 cephalopod (octopus, squid, and related species) families, and numerous crustaceans (e.g., crab and lobster). Foraging typically occurs on the seafloor from the shallows to water depths of over 500 m. Data from tagged individuals indicate foraging occurs primarily in areas of high bathymetric relief within 40 km (25 miles) of atolls or islands, although submerged banks and reefs located over 300 km from breeding sites may also be used (NMFS, 2014). In general, seals associated with the Main Hawaiian Islands appear to have smaller home ranges, travel shorter distances to feed, and spend less time foraging than seals associated with the Northwestern Hawaiian Islands. The inner reef waters next to the islands are critical to weaned pups learning to feed; pups move laterally along the shoreline, but do not appear to travel far from shore during the first few months after weaning (Gilmartin and Forcada, 2009). Feeding has been observed in reef caves, as well as on fish hiding among coral formations (Parrish et al., 2000). A recent study showed that this species is often accompanied by large predatory fish, such as jacks, sharks, and snappers, which possibly steal or compete for prey that the monk seals flush with their probing, digging and rock-flipping behavior. The juvenile monk seals may not be of sufficient size or weight to get prey back once it has been stolen. This was noted only in the French Frigate Shoals (Parrish et al., 2008).

Monk seals and are known to be preyed on by both killer whales and sharks. Shark predation is one of the major sources of mortality for this species especially in the Northwestern Hawaiian Islands. Galapagos sharks are a large source of juvenile mortality in the Northwestern Hawaiian Islands, with most predation occurring in the French Frigate Shoals (Antonelis et al., 2006; Gilmartin and Forcada, 2009; Jefferson et al., 2015).

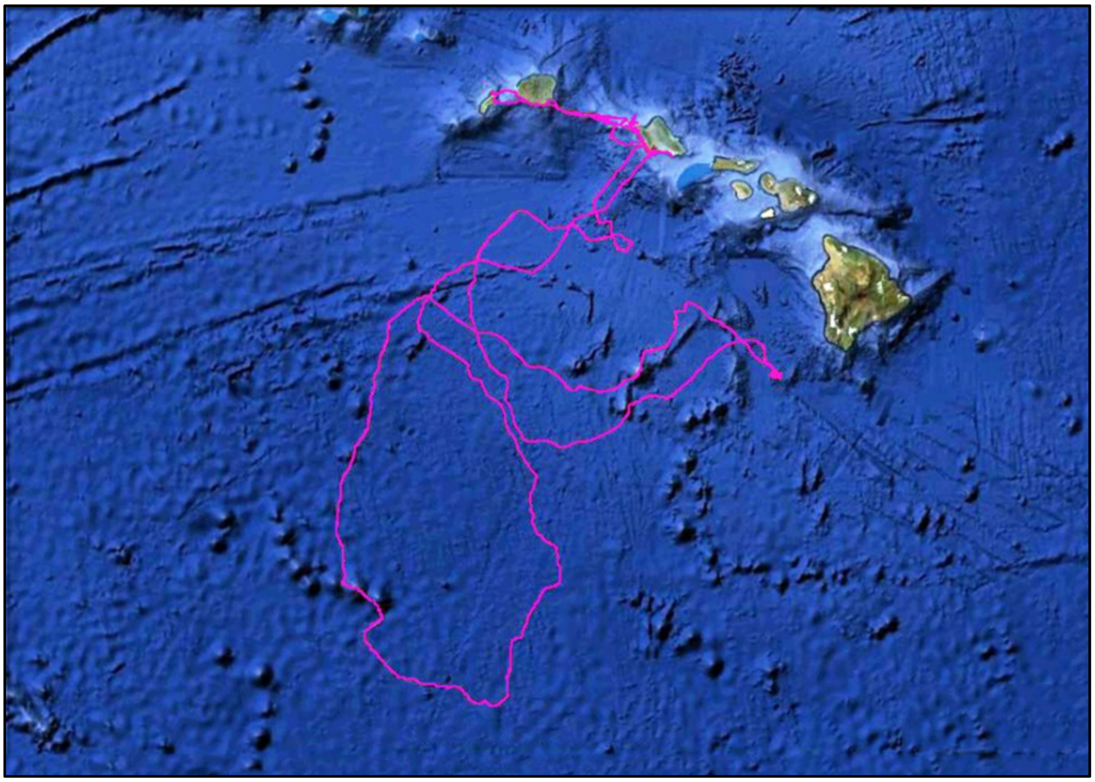
In an effort to better understand the habitat needs of foraging monk seals, Stewart et al. (2006) used satellite-linked radio transmitters to document the geographic and vertical foraging patterns of 147 Hawaiian monk seals from all six Northwestern Hawaiian Islands breeding colonies, from 1996 through 2002. Geographic patterns of foraging were complex and varied among colonies by season, age, and sex, but some general patterns were evident. Seals were found to forage extensively within barrier reefs of the atolls and on the leeward slopes of reefs and islands at all colony sites. They also ranged away from these sites along the Hawaiian Islands submarine ridge to most nearby seamounts and submerged reefs and banks (Stewart et al., 2006).

In 2005, 11 juvenile and adult monk seals were tracked in the Main Hawaiian Islands using satellite-linked radio transmitters showing location, but not depth (Littnan et al., 2007). Similar to the Northwestern Hawaiian Islands, monk seals showed a high degree of individual variability. Overall results showed most foraging trips to last from a few days to two weeks, with seals remaining within the 200 m isobaths surrounding the Main Hawaiian Islands and nearby banks (Littnan et al., 2007).

NMFS and the Navy have also monitored monk seals with cell phone tags (Littnan, 2011; Reuland, 2010). Results from one individual monk seal (R012) indicated travel of much greater distances and water depths than previously documented (Littnan, 2011). The track of this monk seal extended as much as 470 miles (756.4 km) from shore and a total distance of approximately 2,000 miles (3,218.7 km) where the ocean depth is over 5,000 m (Figure 4-2). However, the distance traveled by this individual was substantially greater than that of foraging trips undertaken by other seals in the study and may not represent typical behavior (Littnan, 2012).

Figure 4-2. Track of Hawaiian Monk Seal R012 in June 2010

Source: NOAA Fisheries, 2015



Species-Specific Threats

Monk seals are particularly susceptible to fishery interactions and entanglements. In the Northwestern Hawaiian Islands, derelict fishing gear has been identified as a top threat to the monk seal (Donohue and Foley, 2007), while in the Main Hawaiian Islands, high risks are associated with health hazards from exposure to pollutants and infectious disease agents associated with terrestrial animals. Limited prey availability may be restricting the recovery of the Northwestern Hawaiian Islands monk seals (Baker, 2008; Brillinger et al., 2006; Carretta et al., 2010). Since they rely on coastal habitats for survival, monk seals may be affected by future sea level rise and loss of habitat as predicted by global climate models. Another species-specific threat includes aggressive male monk seals that have been documented to injure and sometimes kill females and pups (NMFS, 2010b). Other threats include reduced prey availability, shark predation, disease and parasites, and contaminants (NMFS, 2014).

5.0 TAKE AUTHORIZATION REQUESTED

The MMPA established, with limited exceptions, a moratorium on the "taking" of marine mammals in waters under U.S. jurisdiction. The act further regulates "takes" of marine mammals in the high seas by vessels or persons under U.S. jurisdiction. The term *take*, as defined in Section 3 (16 United States Code [USC] 1362) of the MMPA, means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." *Harassment* was further defined in the 1994 amendments to the MMPA, which provided for two levels: Level A (potential injury) and Level B (potential disturbance).

The National Defense Authorization Act of fiscal year 2004 (Public Law 108-136) amended the definition of harassment for military readiness activities. Military readiness activities, as defined in Public Law 107-314, Section 315(f), includes all training and operations related to combat and the adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability for combat. This definition, therefore, includes air-to-surface test activities occurring in the BSURE. The amended definition of harassment for military readiness activities is any act that:

- Injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild ("Level A harassment") or
- Disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns including but not limited to migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered ("Level B harassment") (16 USC 1362 [18][B][i],[ii]).

Section 101(a)(5) of the MMPA directs the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of marine mammals by U.S. citizens who engage in a specified activity (exclusive of commercial fishing) within a specified geographic region. These incidental takes may be allowed if NMFS determines the taking will have a negligible impact on the species or stock and the taking will not have an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses.

Pursuant to Section 101(a)(5), a LOA for the incidental taking (but not intentional taking) of marine mammals is requested for air-to-surface evaluation activities within the BSURE area, as described in Section 1, *Description of Activities*. The results of acoustic modeling for surface detonations associated with the evaluation missions indicate the potential for Level A and Level B (physiological and behavioral) harassment, and take is requested for these levels of impact. It is expected that the mitigation measures identified in Section 11 will decrease the potential for impacts. The subsequent analyses in this request will identify the applicable types of take.

In addition to protections provided to all marine mammals by the MMPA, some species are also listed under the ESA (see Table 4-2). Potential impacts to species listed under the ESA are further analyzed in a separate Biological Assessment, prepared by the Air Force pursuant to Section 7 of the ESA.

6.0 NUMBERS AND SPECIES TAKEN

Potential impacts to marine mammals resulting from Long Range Strike WSEP mission activities, including munition strikes, ingestion of military expended materials, and detonation effects (overpressure and acoustic components), are discussed in the following subsections.

6.1 Physical Strike

Marine mammals could be physically struck by weapons during Long Range Strike WSEP missions. During the five-year period of 2017 to 2021, up to 550 bombs and missiles would be deployed, for an average of 110 per year. All weapons will be deployed in summer. The velocity of bombs, missiles, and other munitions decreases quickly after striking the water and, therefore, injury and mortality are considered unlikely for animals swimming in the water column at a depth of more than a few meters. Strike potential would generally be limited to animals located at the water surface or in the water column near the surface and would be affected by factors such as size and relative speed of the munition. Strike potential would be reduced by pre-mission surveys, avoidance of observed marine mammals in the mission area, and the generally dispersed distribution of marine mammals. Although the probability of a direct strike by test weapons is not quantified, the Air Force considers it to be low.

6.2 Ingestion Stressors

Military expended materials that would be produced during Long Range Strike WSEP missions include inert munitions and fragments of exploded bombs and missiles. Intact, inert munitions would be too large to ingest. However, some munition fragments could be ingested by some species, possibly resulting in injury or death.

A small quantity of exploded weapons components, such as small plastic pieces, could float on the surface. Species feeding at the surface could incidentally ingest these floating items. Sei whales are known to skim feed, and there is potential for other species to feed at the surface. Laist (1997) provides a review of numerous marine mammal species that have been documented to ingest debris, including 21 odontocetes. Most of these species had apparently ingested debris floating at the surface. A marine mammal would suffer a negative impact from military expended materials if the item becomes imbedded in tissue or is too large to pass through the digestive system. Some of the items would be small enough to pass through an animal's digestive system without harm. In addition, an animal would not likely ingest every expended item it encountered. The number of items at the surface encountered by a given animal would be decreased by the low initial density of items and dispersal by currents and wind. Due to the small amount of floating military expended materials produced and the dispersed nature of marine mammals and marine mammal groups potentially encountering an item at the surface, floating military expended materials are unlikely to negatively affect marine mammals.

Most military expended materials would not remain on the water surface but would sink at various rates of speed, depending on the density and shape of the item. Individual marine mammals feeding in the water column (for example, dolphins preying on fish or squid at middle depths) could potentially ingest a sinking item. Most items would sink relatively quickly and would not remain suspended in the water column indefinitely. In addition, not all items encountered would be ingested, as a marine mammal would probably be able to distinguish military expended materials from prey in many instances. Overall, sinking items are not expected to present a substantial ingestion threat to marine mammals.

Most of the military expended materials resulting from Long Range Strike WSEP missions would sink to the bottom and would probably eventually become encrusted and/or covered by sediments, although cycles of covering/exposure could occur due to water currents. Several marine mammal species feed at or near the seafloor. For example, although sperm whales feed primarily on squid (presumably deep in the water column), demersal fish species are also sometimes consumed. Humpback whales may also feed near the bottom, and beaked whales use suction feeding to ingest benthic prey. Hawaiian monk seals feed on numerous species that may occur on or near the seafloor, including fish, cephalopods, and lobsters. Therefore, there is some potential for such species to incidentally ingest military expended materials while feeding. However, the potential for such encounters is low based on the relatively low number and patchy distribution of the items produced, the patchy distribution of marine mammal feeding habitat, and water depth at the impact location (over 4,000 meters). Further, an animal would not likely ingest every military expended material it encounters. Animals may attempt to ingest an item and then reject it after realizing it is not a food item. Additionally, ingestion of an item would not necessarily result in injury or mortality to the individual if the item does not become embedded in tissue (Wells et al., 2008). Therefore, impacts resulting from ingestion of military expended materials would be limited to the unlikely event that a marine mammal suffers a negative response from ingesting an item that becomes embedded in tissue or is too large to pass through the digestive system. Military expended materials that become encrusted or covered by sediments would have a lower potential for ingestion. In general, it is not expected that large numbers of items on the seafloor would be consumed and result in harm to marine mammals, particularly given the water depth at the impact location. Based on the discussion above, the Air Force considers potential impacts unlikely and population-level effects on any species are considered remote.

6.3 Detonation Effects

Cetaceans spend their entire lives in the water and are submerged below the surface much of the time. When at the surface, unless engaging in behaviors such as jumping, spyhopping, etc., the body is almost entirely below the water's surface, with only the blowhole exposed to allow breathing. This can make cetaceans difficult to locate visually and also exposes them to underwater noise, both natural and anthropogenic, most of the time because their ears are nearly always below the water's surface. Hawaiian monk seals spend some portion of their time out of the water. However, when swimming under the surface (e.g., during foraging dives), seals are also exposed to natural and anthropogenic noise. As a result, marine mammals located near a surface detonation could be exposed to the resulting shock wave and acoustic energy. Potential effects include mortality, injury, impacts to hearing, and behavioral disturbance.

The potential numbers and species of marine mammal exposures are assessed in this section. Appendix A provides a description of the acoustic modeling methodology used to estimate exposures, as well as the model outputs. Three sources of information are necessary for estimating potential acoustic effects on marine mammals: (1) the zone of influence, which is the distance from an explosion to which particular levels of impact would extend; (2) the density of animals within the zone of influence; and (3) the number of detonations (events). Each of these components is described in the following subsections.

Zone of Influence

The zone of influence is defined as the area or volume of ocean in which marine mammals could be exposed to various pressure or acoustic energy levels caused by exploding ordnance. Refer to Appendix A for a description of the method used to calculate impact volumes for explosives. The pressure and energy levels considered to be of concern are defined in terms of metrics, criteria, and thresholds. A *metric* is a technical standard of measurement that describes the acoustic environment (e.g., frequency duration, temporal pattern, and amplitude) and pressure at a given location. *Criteria* are the resulting types of possible impact and include mortality, injury, and harassment. A *threshold* is the level of pressure or noise above which the impact criteria are reached. The analysis of potential impacts to marine mammals utilizes criteria and thresholds presented in Finneran and Jenkins (2012) and technical guidance provided by NMFS (2016b). The paragraphs below provide a general discussion of the various metrics, criteria, and thresholds used for impulsive noise impact assessment. More detailed information is provided in Appendix A.

Metrics

Standard impulsive and acoustic metrics were used for the analysis of underwater energy and pressure waves in this document. Several different metrics are important for understanding risk assessment analysis of impacts to marine mammals.

SPL (sound pressure level): A ratio of the absolute sound pressure to a reference level. Units are in decibels referenced to 1 micropascal (dB re 1 μPa).

SEL (sound exposure level): SEL is a measure of sound intensity and duration. When analyzing effects on marine animals from multiple moderate-level sounds, it is necessary to have a metric that quantifies cumulative exposures. SEL can be thought of as a composite metric that represents both the intensity of a sound and its duration. SEL is determined by calculating the decibel level of the cumulative sum-of-squared pressures over the duration of a sound, with units of decibels referenced to 1 micropascal-squared seconds (dB re 1 $\mu Pa^2 \cdot s$) for sounds in water.

Positive impulse: This is the time integral of the pressure over the initial positive phase of an arrival. This metric represents a time-averaged pressure disturbance from an explosive source. Units are typically pascal-seconds (Pa·s) or pounds per square inch per millisecond (psi·msec). There is no decibel analog for impulse.

Criteria and Thresholds

The criteria and thresholds used to estimate potential pressure and acoustic impacts to marine mammals resulting from detonations were obtained from Finneran and Jenkins (2012) and include mortality, injurious harassment (Level A), and non-injurious harassment (Level B). In some cases, separate thresholds have been developed for different species groups or functional hearing groups. Functional hearing groups included in the analysis are low-frequency cetaceans, mid-frequency cetaceans, high-frequency cetaceans, and phocids. A more detailed description of each of the criteria and thresholds is provided in Appendix A.

<u>Mortality</u>

Mortality risk assessment may be considered in terms of direct injury, which includes primary blast injury and barotrauma. The potential for direct injury of marine mammals has been inferred from terrestrial mammal experiments and from post-mortem examination of marine mammals believed to have been exposed to underwater explosions (Finneran and Jenkins, 2012; Ketten et al., 1993; Richmond et al., 1973). Actual effects on marine mammals may differ from terrestrial animals due to anatomical and physiological differences, such as a reinforced trachea and flexible thoracic cavity, which may decrease the risk of injury (Ridgway and Dailey, 1972).

Primary blast injuries result from the initial compression of a body exposed to a blast wave and is usually limited to gas-containing structures (e.g., lung and gut) and the auditory system (U.S. Department of the Navy, 2001). Barotrauma refers to injuries caused when large pressure changes occur across tissue interfaces, normally at the boundaries of air-filled tissues such as the lungs. Primary blast injury to the respiratory system may be fatal depending upon the severity of the trauma. Rupture of the lung may introduce air into the vascular system, producing air emboli that can restrict oxygen delivery to the brain or heart.

Whereas a single mortality threshold was previously used in acoustic impacts analysis, species-specific thresholds are currently required. Thresholds are based on the level of impact that would cause extensive lung injury resulting in mortality to 1 percent of exposed animals (that is, an impact level from which 1 percent of exposed animals would not recover) (Finneran and Jenkins, 2012). The threshold represents the expected onset of mortality, where 99 percent of exposed animals would be expected to survive. Most survivors would have moderate blast injuries. The lethal acoustic exposure level of a blast, associated with the positive impulse pressure of the blast, is expressed as Pa·s and is determined using the Goertner (1982) modified positive impulse equation. This equation incorporates source/animal depths and the mass of a newborn calf for the affected species. The threshold is conservative because animals of greater mass can withstand greater pressure waves, and newborn calves typically make up a very small percentage of any marine mammal group. While the mass of newborn calves for some species are provided in literature, in many cases this information is unknown and a surrogate species (considered to be generally comparable in mass) is used instead. Finneran and Jenkins (2012) provide known or surrogate masses for newborn calves of several cetacean species. The Goertner equation, as presented in Finneran and Jenkins (2012), is used in the acoustic model to develop impacts analysis in this LOA request. The equation is provided in Appendix A.

<u>Injury (Level A Harassment)</u>

Finneran and Jenkins (2012) recognizes two types of blast-related injury: gastrointestinal (GI) tract injury and slight lung injury. NMFS's technical guidance (2016b) addresses irrecoverable auditory damage (permanent threshold shift). These injury categories are all types of Level A harassment.

Gastrointestinal Tract Injuries. Though often secondary in life-threatening severity to pulmonary blast trauma, the GI tract can also suffer contusions and lacerations from blast exposure, particularly in air-containing regions of the tract. Although hemorrhage of solid organs (e.g., liver, spleen, and kidney) from blast exposure is possible, rupture of these organs is rarely encountered. GI tract injuries are correlated with the peak pressure of an underwater detonation. GI tract injury thresholds are based on the results of experiments in the 1970s in which terrestrial mammals were exposed to small charges. The peak pressure of the shock wave was found to cause recoverable contusions (bruises) in the GI tract (Richmond et al., 1973; Finneran and Jenkins, 2012). The experiments found that a peak SPL of 237 dB re 1 μPa predicts the onset of GI tract injuries, regardless of an animal's mass or size. Therefore, the unweighted peak SPL of 237 dB re 1 μPa is used in explosive impacts assessments as the threshold for slight GI tract injury for all marine mammals.

Slight Lung Injury. This threshold is based on a level of exposure where most animals may experience slight blast injury to the lungs, but all would survive (0 percent mortality) (Finneran and Jenkins, 2012). Similar to the mortality determination, the metric is positive impulse and the equation for determination is that of the Goertner injury model (1982), corrected for atmospheric and hydrostatic pressures and based on the cube root scaling of body mass (Richmond et al., 1973; U.S. Department of the Navy, 2001). The equation is provided in Appendix A.

Auditory Damage (Permanent Threshold Shift). Another type of injury correlated to Level A harassment is permanent threshold shift (PTS), which is auditory damage that does not fully recover and results in a permanent decrease in hearing sensitivity. There have been no studies to determine the onset of PTS in marine mammals and, therefore, this threshold must be estimated from other available information associated with temporary threshold shift. The NMFS technical guidance (NMFS, 2016b) defines separate PTS thresholds for three groups of cetaceans based on hearing sensitivity (low-frequency, mid-frequency, and high-frequency), and for phocids. Dual criteria are provided for PTS thresholds, one based on the SEL and one based on the SPL of an underwater blast. For a given analysis, the more conservative of the two is typically applied. The PTS thresholds are provided in Appendix A.

<u>Non-Injurious Impacts (Level B Harassment)</u>

Two categories of non-injurious Level B harassment are currently recognized: temporary threshold shift (TTS) and behavioral impacts. Although TTS is a physiological impact, it is not considered injury because auditory structures are temporarily fatigued instead of being permanently damaged.

Temporary Threshold Shift. Non-injurious effects on marine mammals, such as TTS, are generally extrapolated from data on terrestrial mammals (Southall et al., 2007). Similar to PTS, dual criteria are provided for TTS thresholds, and the more conservative is typically applied in impacts analysis. TTS criteria are provided from the most recent guidance (NMFS, 2016b) and are based on data from impulse sound exposures when available. If impulse TTS data are not available, data from non-impulse exposures may be used (adjusted for the relationship between impulse and non-impulse TTS observed in dolphins and belugas). For species where no data exist, TTS thresholds are based on the most closely related species for which data are available. The TTS thresholds are provided in Appendix A.

Behavioral Impacts. Behavioral impacts refer to disturbances that may occur at acoustic levels below those considered to cause TTS in marine mammals, particularly in cases of multiple detonations. During an activity with a series of explosions (not concurrent multiple explosions), an animal is expected to exhibit a startle reaction to the first detonation followed by a behavioral response after multiple detonations. At close ranges and high sound levels, avoidance of the area around the explosions is the assumed behavioral response in most cases. Behavioral impacts may include decreased ability to feed, communicate, migrate, or reproduce, among others. Such effects, known as sub-TTS Level B harassment, are based on observations of behavioral reactions in captive dolphins and beluga whales exposed to pure tones, a different type of sound than that produced from a detonation (Finneran and Schlundt, 2004; Schlundt et al., 2000). Behavioral effects are generally considered to occur when animals are exposed to multiple, successive detonations at the same location within a 24-hour period. For single detonations, behavioral disturbance is likely limited to short-term startle reactions. The behavioral impact thresholds for marine mammals exposed to multiple, successive detonations are provided in Appendix A and are set 5 dB below the SEL-based TTS threshold, unless there are species or group specific data indicating that a lower threshold should be used.

Marine Mammal Density

Density estimates for marine mammals occurring in the Study Area are provided in Table 3-4. As discussed in Section 3, marine mammal density estimates were obtained from the U.S. Navy's Marine Species Density Database (U.S. Department of the Navy, 2016), which provides the most relevant and comprehensive density information for waters associated with the HRC. Density is typically reported for an area (e.g., animals per square kilometer). Density estimates usually assume that animals are uniformly distributed within the affected area, even though this is rarely true. Marine mammals may be clumped in areas of greater importance; for example, animals may be more concentrated in areas offering high productivity, lower predation, safe calving, etc. However, because there are usually insufficient data to calculate density for small areas, an even distribution is typically assumed for impact analyses.

Although the Study Area is depicted as only the surface of the water, in reality, density implicitly includes animals anywhere within the water column under that surface area. Assuming that marine mammals are distributed evenly within the water column does not accurately reflect animal behaviors. Databases of behavioral and physiological parameters obtained through tagging and other technologies have demonstrated that marine animals use the water column in various ways. Some species conduct regular deep dives while others engage in much shallower dives, regardless of bottom depth. The depth distribution for each species included in the Study Area is provided in Appendix B. Combining marine mammal density with depth information would allow impact estimates to be based on three-dimensional density distributions, resulting in more accurate modeling of potential exposures.

Number of Events

An "event" refers to a single, unique action that has the potential to expose marine mammals to pressure and/or noise levels associated with take under the MMPA. For Long Range Strike WSEP activities, the number of events generally corresponds to the number of live ordnance items released within a 24-hour period. With the exception of SDB-I/II bombs, each live munition would detonate separately in time. Up to four SDBs may be released simultaneously and would detonate within a few seconds of each other in the same vicinity and is referred to as a "burst." The exact number and type of munitions that would be released each day is not known and would vary. To account for total annual impacts, the total number of each munition proposed to be released per year was divided by five (annual number of mission days) and treated as a representative mission day. The total energy for all weapon releases as part of a representative mission day is summed for impact calculations. There will be a total of five mission days per year during the time frame of 2017–2021. Refer to Appendix A for a detailed explanation of modeling methods.

Exposure Estimates

The maximum estimated range, or radius, from the detonation point to which the various thresholds extend for all munitions proposed to be released in a 24-hour time period was calculated based on explosive acoustic characteristics, sound propagation, and sound transmission loss in the Study Area, which incorporates water depth, sediment type, wind speed, bathymetry, and temperature/salinity profiles (Table 6-1). Transmission loss was calculated from the explosive source depth down to an array of water depth bins extending to the maximum depths where marine mammals may occur (see depth distributions in Appendix B). From there, impact volumes were computed for each explosive source (i.e., total number of munitions released on a representative mission day). Impact areas were calculated from scaling the impact volumes by each depth bin, dividing by their depth intervals, summing each value over the entire water column and converting to square kilometers. The radii shown in Table 6-1 are based on these impact areas and are used for mitigation considerations.

The estimated number of marine mammals potentially exposed to the various impact thresholds was calculated as the product of the impact volumes (described above), extrapolated animal volumes, and number of events. Density estimates provided in Table 3-4 are extrapolated over the depth distributions by multiplying the density values by the percentage of time spent at each depth interval. These scaled densities are multiplied by the corresponding depth bin in the impact volume for each threshold and summed to create a three-dimensional exposure estimate. These estimates are then multiplied by the number of events, or total number of mission days proposed annually.

The resulting total number of marine mammals potentially exposed to the various levels of thresholds is listed in Table 6-2. An animal is considered "exposed" to a sound if the received sound level at the animal's location is above the background ambient acoustic level within a similar frequency band. The exposure calculations from the model output resulted in decimal values, suggesting in most cases that a fraction of an animal was exposed. To eliminate this, the acoustic model results were rounded to the nearest whole animal to obtain the exposure estimates. Furthermore, to eliminate "double-counting" of animals, exposure results from higher impact categories (e.g., mortality) were subtracted from lower impact categories (e.g., Level A harassment). For impact categories with dual criteria (e.g., SEL and SPL metrics for PTS associated with Level A harassment), numbers in the table are based on the criterion resulting in the greatest number of exposures. Exposure levels include the possibility of injury and non-injurious harassment (including behavioral harassment) to marine mammals in the absence of mitigation measures. The numbers represent total impacts for all detonations combined and do not take into account the required mitigation and monitoring measures (Section 11), which are expected to decrease the number of exposures shown in the table.

Table 6-1. Threshold Radii (in meters) for a Long Range Strike WSEP Typical Mission Day

Species	Mortality	Level A Harassment				Level B Harassment		
		Slight Lung Injury	GI Tract Injury	PTS		TTS		Behavioral
	Based on Goertner (1982)	Based on Richmond et al. (1973)	237 dB SPL	Applicable SEL*	Applicable SPL*	Applicable SEL*	Applicable SPL*	Applicable SEL*
Humpback whale	99	200	204	5,415	1,241	55,464	2,266	59,039
Blue whale	74	149	204	5,415	1,241	55,464	2,266	59,039
Fin whale	76	157	204	5,415	1,241	55,464	2,266	59,039
Sei whale	101	204	204	5,415	1,241	55,464	2,266	59,039
Bryde's whale	99	200	204	5,415	1,241	55,464	2,266	59,039
Minke whale	138	268	204	5,415	1,241	55,464	2,266	59,039
Sperm whale	91	177	204	1,575	413	8,019	763	11,948
Pygmy sperm whale	248	457	204	20,058	4,879	71,452	7,204	74,804
Dwarf sperm whale	273	509	204	20,058	4,879	71,452	7,204	74,804
Killer whale	149	287	204	1,575	413	8,019	763	11,948
False killer whale (MHI Insular stock)	177	340	204	1,575	413	8,019	763	11,948
False killer whale (all other stocks)	177	340	204	1,575	413	8,019	763	11,948
Pygmy killer whale	324	604	204	1,575	413	8,019	763	11,948
Short-finned pilot whale	217	413	204	1,575	413	8,019	763	11,948
Melon-headed whale	273	502	204	1,575	413	8,019	763	11,948
Bottlenose dolphin	273	509	204	1,575	413	8,019	763	11,948
Pantropical spotted dolphin	324	604	204	1,575	413	8,019	763	11,948
Striped dolphin	324	604	204	1,575	413	8,019	763	11,948
Spinner dolphin	324	604	204	1,575	413	8,019	763	11,948
Rough-toothed dolphin	273	509	204	1,575	413	8,019	763	11,948
Fraser's dolphin	257	480	204	1,575	413	8,019	763	11,948
Risso's dolphin	207	384	204	1,575	413	8,019	763	11,948
Cuvier's beaked whale	131	257	204	1,575	413	8,019	763	11,948
Blainville's beaked whale	195	368	204	1,575	413	8,019	763	11,948
Longman's beaked whale	133	261	204	1,575	413	8,019	763	11,948
Hawaiian monk seal	306	564	204	4,621	1,394	55,687	2,549	58,736

GI = gastrointestinal; MHI = Main Hawaiian Islands; PTS = permanent threshold shift; SEL = sound exposure level; SPL = sound pressure level; TTS = temporary threshold shift
*Based on the applicable Functional Hearing Group

Table 6-2. Number of Marine Mammals Potentially Affected by Long Range Strike WSEP Missions

Species	Mortality	Level A Harassment (PTS only*)	Level B Harassment (TTS)	Level B Harassment (Behavioral)
Mysticetes (baleen whales)				
Humpback whale	0	4	54	38
Blue whale	0	0	0	0
Fin whale	0	0	0	0
Sei whale	0	0	0	1
Bryde’s whale	0	0	0	0
Minke whale	0	1	11	19
Odontocetes (toothed whales and dolphins)				
Sperm whale	0	0	0	0
Pygmy sperm whale	0	9	83	36
Dwarf sperm whale	0	22	203	87
Killer whale	0	0	0	0
False killer whale (MHI Insular stock)	0	0	0	0
False killer whale (all other stocks)	0	0	0	0
Pygmy killer whale	0	0	1	2
Short-finned pilot whale	0	0	5	6
Melon-headed whale	0	0	1	1
Bottlenose dolphin	0	0	2	2
Pantropical spotted dolphin	0	0	3	4
Striped dolphin	0	0	2	2
Spinner dolphin	0	0	1	1
Rough-toothed dolphin	0	0	3	3
Fraser’s dolphin	0	0	10	14
Risso’s dolphin	0	0	2	2
Cuvier’s beaked whale	0	0	0	0
Blainville’s beaked whale	0	0	0	0
Longman’s beaked whale	0	0	1	1
Pinnipeds				
Hawaiian monk seal	0	0	0	0
Total	**0**	**36**	**382**	**219**

PTS = permanent threshold shift; TTS = temporary threshold shift; WSEP = Weapon Systems Evaluation Program
* Zero exposures were calculated for slight lung injury and gastrointestinal tract injury thresholds for Level A Harassment

7.0 IMPACTS TO MARINE MAMMAL SPECIES OR STOCKS

A variety of effects may result from exposure to sound-producing activities. The severity of the effects can range from minor effects with no real cost to the animal to more severe effects that may have lasting consequences. The types of effects potentially experienced by marine mammals, as well as the estimated number of animals potentially affected, is provided in the following paragraphs. None of the estimates take into account the mitigation measures outlined in Section 11, which are expected to reduce the number and severity of effects. The majority of impacts (TTS and Behavioral) are expected to be recoverable; some permanent impacts may result (PTS) however, no adverse population level effects are anticipated.

Marine mammals potentially affected by Long Range Strike WSEP activities conducted in the BSURE area include primarily odontocetes and one mysticete species (Bryde's whale). The sperm whale (Hawaii stock) and Main Hawaiian Island Insular stock of false killer whale are listed as endangered under the ESA and are considered depleted under the MMPA. No other potentially affected odontocete stocks are listed under the ESA or considered depleted under the MMPA. Most of the other odontocetes are associated with Hawaii stocks (pygmy sperm whale, dwarf sperm whale, pygmy killer whale, short-finned pilot whale, striped dolphin, Fraser's dolphin, Risso's dolphin, rough-toothed dolphin, Blainville's beaked whale, and Longman's beaked whale). The remaining odontocetes (false killer whale, melon-headed whale, bottlenose dolphin, pantropical spotted dolphin, and spinner dolphin) are part of stock complexes, which generally consist of stocks associated with particular islands, multi-island regions, or pelagic waters around Hawaii. The one mysticete species potentially affected is the Bryde's whale, associated with the Hawaii stock.

The numbers of marine mammals potentially experiencing overpressure or acoustic exposure due to surface detonations are provided in Section 6, *Numbers and Species Taken*. A variety of effects may result from exposure to sound-producing activities. The severity of the effects can range from minor effects with no real cost to the animal to more severe effects that may have lasting consequences. The types of effects potentially experienced by marine mammals, as well as the estimated number of animals potentially affected, is provided in the following paragraphs. None of the estimates take into account the mitigation measures outlined in Section 11, which are expected to reduce the number and severity of effects.

Based on acoustic modeling described in Section 6 and Appendix A, no marine mammals would be affected by impulse pressure levels associated with mortality, slight lung injury, or GI tract injury. A total of 36 marine mammals (22 pygmy sperm whales, 9 dwarf sperm whales, 4 humpback whales, and 1 minke whale) could potentially be exposed to injurious Level A harassment resulting from PTS auditory injury. Auditory injury is a reduction in hearing ability resulting from overstimulation to sounds. The mechanisms differ from those of auditory trauma and include damage or distortion of the tympanic membrane and hair cells, hair cell death, changes in cochlear blood flow, and cochlear nerve swelling. Auditory injury is manifested as hearing loss, also called noise-induced threshold shift. Level A harassment is associated with permanent effects (PTS), where some portion of the threshold shift remains indefinitely. Animals are most susceptible to auditory injury within their most sensitive hearing range. The greater the degree of threshold shift, the smaller the ocean space within which an animal can detect biologically relevant sounds. For example, deafness would affect social communications, navigation, foraging, and predator detection. The threshold resulting in the highest exposure estimates was used to determine takes, which in this document is the applicable SEL threshold. If an animal suffers trauma or auditory injury, a physiological stress response will typically occur. A stress response generally involves the release of hormones and other biochemicals into the bloodstream to help the animal in responding to the stressor.

A total of approximately 382 marine mammals could potentially be exposed to sound corresponding to non-injurious (TTS) Level B harassment. Most odontocete species have some calculated level of estimated TTS exposure. However, the majority of exposures are associated with pygmy and dwarf sperm whale (combined total of 286 exposures). Similar to the preceding discussion of auditory injury, auditory fatigue is a reduction in hearing ability resulting from overstimulation to sounds that may result from damage or distortion of the tympanic membrane and hair cells, hair cell death, changes in cochlear blood flow, and cochlear nerve swelling. The distinction between PTS and TTS is based on whether there is complete recovery of hearing sensitivity following a sound exposure. If the animal's hearing ability eventually returns to pre-exposure levels, the threshold shift is considered temporary. Studies of terrestrial mammals show that large amounts of TTS (approximately 40 dB measured 24 hours after exposure) can result in permanent neural degeneration, despite the hearing thresholds returning to normal. As with PTS, animals are most susceptible to auditory fatigue within their most sensitive hearing range. The greater the degree of threshold shift, the smaller the ocean space within which an animal can detect biologically relevant sounds. In this document, the threshold resulting in the highest exposure estimates was used to determine takes. Similar to the discussion of PTS, the SEL metrics resulted in higher exposure estimates compared with peak SPL metrics and were conservatively used for impacts analysis.

Approximately 219 additional marine mammals could potentially be exposed to acoustic levels corresponding to applicable behavioral thresholds during Long Range Strike WSEP missions. Most odontocete species have some calculated level of estimated behavioral impact, including the ESA-listed sei whale (one estimated exposure). However, similar to the results for TTS, most exposures are associated with the pygmy and dwarf sperm whale. Behavioral harassment occurs at distances beyond the range of structural damage and hearing threshold shift. Numerous behavioral responses can result from physiological responses. An animal may react to a stimulus based on a number of factors in addition to the severity of the physiological response. An animal's previous experience with the same or a similar sound, the context of the exposure, and the presence of other stimuli contribute to determining its reaction. Behavioral responses fall into two major categories: alterations in natural behavior patterns and avoidance. These types of reactions are not mutually exclusive, and overall reactions may be combinations of behaviors or a sequence of behaviors. Severity of behavioral reactions can vary substantially, from minor and brief reorientations of the animal to investigate the sound to severe reactions such as aggression or prolonged flight. The type and severity of the behavioral response will determine the energetic cost to the animal. Possible behavioral responses to a detonation include panic, startle, departure from an area, and disruption of activities such as feeding or breeding, among others.

The magnitude and type of effect, as well as the speed and completeness of recovery, affect the long-term consequences to individual animals and populations. Animals that recover quickly and completely from explosive effects will not likely suffer reductions in their health or reproductive success or experience changes in their habitat utilization. In such cases, no population-level effects would be expected. Animals that do not recover quickly and fully could suffer reductions in their health and reproductive success, they could be permanently displaced or change how they utilize the environment, or they could die. Frequent disruptions to natural behavior patterns may not allow an animal to fully recover between exposures, which increases the probability of causing long-term consequences to individuals. Long-term consequences to individuals can lead to population-level consequences.

Consideration of "negligible impact" is required by NMFS to authorize incidental take of marine mammals. An activity has a negligible impact on a species or stock when it is determined that the total taking is not likely to reduce annual rates of adult survival or recruitment (offspring survival, birth rates). Potential impacts associated with the proposed actions consist of Level A harassment (PTS) and Level B harassment (TTS and behavioral effects). Behavioral reactions of marine mammals to sound are known to occur but are difficult to predict. Behavioral studies indicate that reactions to sounds, if any, are highly contextual and vary between species and individuals within a species (Moretti et al., 2010; Southall et al., 2011; Thompson et al, 2010; Tyack, 2009b; Tyack et al., 2011). Depending on the context, marine mammals often change their activity when exposed to disruptive levels of sound. For example, when sound becomes potentially disruptive, cetaceans at rest become active and feeding or socializing cetaceans or pinnipeds often interrupt these events by diving or swimming away. Recent studies on the effects of active sonar (a non-impulsive sound) on marine mammals have been undertaken within the PMRF. Martin et al. (2015) found that the number of minke whale calls detected on the range's hydrophones decreased with the use of active sonar (during the time frame of 2011 to 2013). Blainville's beaked whales underwent fewer dives during sonar use compared with periods without sonar use, and there is some indication that individuals moved toward the edges of the range (Martin et al., 2016). Conversely, Baird et al. (2014) investigated movements of satellite-tagged bottlenose dolphins, short-finned pilot whales, and rough-toothed dolphins exposed to active sonar and found no indication of large-scale movement away from the sound, although the authors note some limitations in the study. If sound disturbance occurs around a haulout site, pinnipeds may move back and forth between water and land or eventually abandon the site. When attempting to understand behavioral disruption by anthropogenic sound, a key consideration is whether the exposures have biologically significant consequences for the individual or population (National Research Council, 2005).

If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be important to the individual. For example, researchers have found during a study of dolphins' response to whale watching vessels in New Zealand that when animals can cope with constraint and easily feed or move elsewhere, there is little effect on survival (Lusseau and Bejder, 2007). On the other hand, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period and they do not have an alternate equally desirable area, impacts on the marine mammal could be negative because the disruption has biological consequences. Biological parameters or key elements having greatest importance to a marine mammal relate to its ability to mature, reproduce, and survive.

The importance of the disruption and degree of consequence for individual marine mammals is often dependent on the frequency, intensity, and duration of the disturbance. Isolated acoustic disturbances such as underwater detonations are expected to have minimal consequences and no lasting consequences on marine mammal populations. Marine mammals regularly cope with occasional disruption of their activities by predators, adverse weather, and other natural phenomena. It is reasonable to assume that they can tolerate occasional or brief disturbances by anthropogenic sound without significant consequences. A prolonged disturbance, as might occur if a stationary and noisy activity were established near a concentrated area, is a more important concern.

The following points provide a context for evaluating the potential to impact individual marine mammals or marine mammal populations:

- Estimated mortality impacts are zero.
- Most acoustic harassment effects are within the non-injurious TTS or behavioral effects zones (Level B harassment); the estimated number of animals potentially affected by Level A harassment (injury) is relatively small (36 total exposures for four species).
- The take numbers presented in Section 6 and summarized in the preceding paragraphs are likely conservative (overestimates) because they do not take into account the mitigation measures described in Section 11. These measures are expected to substantially decrease the potential for explosive and acoustic impacts, especially within the injury zone.

8.0 IMPACT ON SUBSISTENCE USE

Potential marine mammal impacts resulting from the proposed activities will be limited to individuals located in the Study Area and that have no subsistence requirements. Therefore, no impacts on the availability of species or stocks for subsistence use are considered.

9.0 IMPACTS TO MARINE MAMMAL HABITAT AND THE LIKELIHOOD OF RESTORATION

The primary sources of marine mammal habitat impact are acoustic and pressure waves resulting from live weapon detonations. However, neither the sound nor overpressure constitutes a long-term physical alteration of the water column or ocean floor. Further, these effects are not expected to substantially affect prey availability, are of limited duration, and are intermittent in time. Therefore, it is not anticipated that marine mammals will stop utilizing the waters of the Study Area, either temporarily or permanently, as a result of mission activities.

Other factors that could potentially affect marine mammal habitat include the introduction of metals, explosives and explosion by-products, other chemical materials, and debris into the water column and substrate due to the use of munitions and effect to prey distribution. The effects of metals, explosives and explosion by-products, other chemical materials, and debris are analyzed in the associated Long Range Strike WSEP EA/OEA, prepared in accordance with the National Environmental Policy Act. Based on the review in the EA/OEA, there would be no significant effects to marine mammals resulting from loss or modification of marine mammal habitat including water and sediment quality. Refer to the EA/OEA for more detailed discussion of these components.

Marine mammals in the Study Area feed on various fish and invertebrates. Physical effects from pressure and acoustic waves generated by surface detonations could affect these prey species near the detonation point, potentially decreasing their availability to marine mammals. In particular, the rapid oscillation between high- and low-pressure peaks has the potential to burst the swim bladders and other gas-containing organs of fish (Keevin and Hemen, 1997). Sublethal effects, such as changes in behavior of fish, have been observed on several occasions as a result of noise produced by explosives (National Research Council, 2003; Wright, 1982). The abundances of various fish and invertebrates near the detonation point could be altered for a few hours before animals from surrounding areas repopulate the area; however, these populations would be replenished as waters near the detonation point are mixed with adjacent waters. Munition fragments resulting from testing activities could potentially result in minor long-term changes to benthic habitat. Similar to an artificial reef structure, such materials could be colonized over time by benthic organisms that prefer hard substrate and could provide structure that could attract some species of fish.

10.0 IMPACTS TO MARINE MAMMALS FROM LOSS OR MODIFICATION OF HABITAT

Based on the discussions in Section 9, the proposed activities are not expected to have any habitat-related effects, such as from water quality, sediment quality, and prey availability, that could cause significant or long-term consequences for individual marine mammals or their populations. No permanent loss or modification of habitat would occur, and there would be no indirect impacts to marine mammals from temporarily altered habitat conditions. There will be no long-term impacts on marine mammals resulting from loss or modification of marine mammal habitat.

11.0 MEANS OF AFFECTING THE LEAST PRACTICABLE ADVERSE IMPACTS

The potential takes discussed in Section 6 represent the maximum expected number of animals that could be exposed to particular acoustic and pressure thresholds. The impact estimates do not take into account measures that will be employed to minimize impacts to marine species. Unlike standard operating procedures, which are established for reasons other than environmental benefit, mitigation measures are modifications to the proposed activities that are implemented for the sole purpose of reducing a specific potential environmental impact on a particular resource. The procedures discussed in this section are, in general, routinely implemented for test events in the PMRF as a result of previous U.S. Navy environmental compliance documents, ESA biological opinions, MMPA incidental harassment authorizations or letters of authorization, or other formal or informal consultations with regulatory agencies. The Air Force has worked with PMRF personnel to ensure mitigation measures are adequate and meet NMFS' expectations based on requirements identified for past similar actions conducted in the PMRF and BSURE areas. The overall approach to assessing potential mitigation measures in the BSURE area is based on two principles: (1) mitigations will be effective at reducing potential impacts on the resource, and (2) mitigation is consistent with mission objectives, range procedures, and safety measures.

For missions involving air-to-surface weapon employment in the BSURE area, such as Long Range Strike WSEP activities, mitigation procedures consist of visual aerial surveys of the impact area for the presence of protected marine species (marine mammals and sea turtles). During aerial observation, Navy test range personnel may survey the area from an S-61N helicopter or C-62 aircraft that is based at the PMRF land facility (typically when missions are located relatively close to shore). Alternatively, when missions are located farther offshore, surveys may be conducted from mission aircraft (typically jet aircraft such as F-15E, F-16, or F-22) or a U.S. Coast Guard C-130 aircraft.

Protected species surveys typically begin within one hour of weapon release and as close to the impact time as feasible, given human safety requirements. Survey personnel must depart the human hazard zone before weapon release, in accordance with Navy safety standards. Personnel would conduct aerial surveys within an area defined by a maximum 8-mile (13-km) radius around the impact point, with surveys typically flown in a star pattern. This survey distance is much larger than requirements already in place for similar actions at PMRF and what was accomplished for October 2016 missions. This expanded area would encompass the entire Behavioral threshold ranges (SEL) for all mid-frequency cetaceans, the entire PTS threshold ranges (SEL) for low-frequency cetaceans and phocids, approximately 23 percent of the TTS threshold ranges (SEL) for low-frequency cetaceans and phocids, and about 64 percent of the PTS threshold range (SEL) for high-frequnecy cetaceans (pygmy and dwarf sperm whales) (Table 6-1). The survey distance would not cover the behavioral harassment ranges for low- and high-frequency cetaceans and phocids. Given operational constraints, surveying these larger areas would not be feasible.

Observers would consist of aircrew operating the C-26, S-61N, and C-130 aircraft from PMRF and the Coast Guard. These aircrew are trained and experienced at conducting aerial marine mammal surveys and have provided similar support for other missions at PMRF. Aerial surveys are typically conducted at an altitude of about 200 feet, but altitude may vary somewhat depending on sea state and atmospheric conditions. If adverse weather conditions preclude the ability for aircraft to safely operate, missions would either be delayed until the weather clears or cancelled for the day. The C-26 and other aircraft would generally be operated at a slightly higher altitude than the helicopter. The observers will be provided with the GPS location of the impact area. Once the aircraft reaches the impact area, pre-mission surveys typically last for 30 minutes, depending on the survey pattern. The fixed-wing aircraft are faster than the helicopter and, therefore, protected species may be more difficult to spot. However, to compensate for the difference in speed, the aircraft may fly the survey pattern multiple times.

If a protected species is observed in the impact area, weapon release would be delayed until one of the following conditions is met: (1) the animal is observed exiting the impact area or (2) the impact area has been clear of any additional sightings for a period of 30 minutes. All weapons will be tracked and their water entry points will be documented. Post-mission surveys would begin immediately after the mission is complete and the Range Safety Officer declares the human safety area is reopened. Approximate transit time from the perimeter of the human safety area to the weapon impact area would depend on the size of the human safety area and vary between aircraft but is expected to be less than 30 minutes. Post-mission surveys would be conducted by the same aircraft and aircrew that conducted the pre-mission surveys and would follow the same patterns as pre-mission surveys but would focus on the area down current of the weapon impact area to determine if protected species were affected by the mission (observation of dead or injured animals). Post-mission surveys are conducted by aircraft at the impact point and surrounding area to determine if protected species were affected by the mission (observation of dead or injured animals). If an injury or mortality occurs to a protected species due to Long Range Strike WSEP missions, NMFS would be notified immediately.

NMFS has specified the following reporting and activity requirements:

- In the unanticipated event that Long Range Strike WSEP activities clearly cause the take of a marine mammal in a manner not authorized by NMFS, the 86 FWS will immediately cease activities and report the incident to the NMFS Office of Protected Resources and the Regional Stranding Coordinator. Activities will not resume until NMFS reviews the circumstances of the take and determines what further measures are necessary to minimize the likelihood of further prohibited take.
- If an injured or dead marine mammal is discovered, and the cause of injury or death is unknown and the injury or death occurred relatively recently, the 86 FWS will immediately report the incident to the NMFS Office of Protected Resources and the Regional Stranding Coordinator. Activities may continue while NMFS reviews the incident.
- If an injured or dead marine mammal is discovered, and the observer determines that the injury or death is not related to Long Range Strike WSEP activities, the 86 FWS will report the incident to the NMFS Office of Protected Resources and the Regional Stranding Coordinator within 24 hours and may provide photographs, video footage, or other documentation of the affected animal.

12.0 MINIMIZATION OF ADVERSE EFFECTS ON SUBSISTENCE USE

Subsistence use is the traditional exploitation of marine mammals by native peoples (i.e., for their own consumption) inhabiting Arctic regions. In terms of the Long Range Strike WSEP LOA application, none of the proposed activities occur in or near the Arctic. Based on discussions in Section 7, there are no anticipated impacts on any species or stocks migrating through the Study Area that might be available for subsistence use.

13.0 MONITORING AND REPORTING MEASURES

For Long Range Strike WSEP missions using live ordnance, the impact area will be visually surveyed for marine mammal presence prior to commencement of activities. Pre-mission surveys will be conducted from an S-61N helicopter, U.S. Coast Guard AC-130, jet aircraft, or C-62 aircraft. Post-mission surveys will also be carried out by the same aircraft. If any marine mammals are detected during pre-mission surveys, activities will be immediately halted until the area is clear of all marine mammals, as described in Section 11. During post-mission surveys, if an animal is found to have been injured or otherwise adversely impacted, NMFS will be notified. In addition to monitoring for marine species before and after missions, the following reporting measures will be implemented.

- A summary annual report of marine mammal observations and mission activities will be submitted to the NMFS Office of Protected Resources. This annual report would include the following information:
  - Date, time, and location of each mission
  - A summary of the pre- and post-mission activities related to mitigating the effects of mission activities on marine mammal populations
  - Results of the monitoring, including
    - Numbers, species, and any other relevant information regarding marine mammals observed and potentially exposed/taken during activities;
    - Description of the observed behaviors
    - Environmental conditions when observations were made
  - Assessment of the implementation and effectiveness of prescribed mitigation and monitoring measures
- If any dead or injured marine mammals are observed or detected prior to mission activities or injured or killed during mission activities
  - A report must be made to NMFS within 24 hours of discovery
  - Contact NMFS Office of Protected Resources and NMFS Pacific Islands Regional Office
  - Provide photographs, video footage, or other documentation of the sighting to NMFS.

Any unauthorized takes of marine mammals (i.e., mortality) must be immediately reported to NMFS and to the respective stranding network representative.

14.0 SUGGESTED MEANS OF COORDINATION

Annual reports of Long Range Strike WSEP mission activities will be submitted to NMFS. These reports will be made available to the public from NMFS on their website.

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16.0 LITERATURE CONSIDERED AND REFERENCES CITED

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APPENDIX A

ACOUSTIC MODELING METHODOLOGY

Long Range Strike WSEP

MMPA and ESA Acoustic Impact Modeling: Modeling Appendix

Submitted by:

Leidos

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APPENDIX A
MMPA AND ESA ACOUSTIC IMPACT MODELING

A.1 BACKGROUND AND OVERVIEW

A.1.1 Federal Regulations Affecting Marine Animals

All marine mammals are protected under the Marine Mammal Protection Act (MMPA). The MMPA prohibits, with certain exceptions, the take of marine mammals in U.S. waters and by U.S. citizens on the high seas and the importation of marine mammals and marine mammal products into the U.S.

The Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range and the conservation of their ecosystems. A species is considered endangered if it is in danger of extinction throughout all or a significant portion of its range. A species is considered threatened if it is likely to become an endangered species within the foreseeable future. Some marine mammals, already protected under MMPA, are also listed as either endangered or threatened under ESA and are afforded special protections. In addition, all sea turtles are protected under the ESA.

Actions involving sound in the water may have the potential to harass marine animals in the surrounding waters. Demonstration of compliance with the MMPA and ESA, using best available science, has been assessed using criteria and thresholds accepted or negotiated and is described here.

Sections of the MMPA (16 USC 1361 et seq.) direct the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity, other than commercial fishing, within a specified geographical region. Through a specific process, if certain findings are made and regulations are issued, or if the taking is limited to harassment, notice of a proposed authorization is provided to the public for review.

Authorization for incidental takings may be granted if the National Marine Fisheries Service (NMFS) finds that the taking will have no more than a negligible impact on the species or stock(s), will not have an immitigable adverse impact on the availability of the species or stock(s) for subsistence uses, and that the permissible methods of taking and requirements pertaining to the mitigation, monitoring, and reporting of such taking are set forth.

NMFS has defined “negligible impact” in 50 CFR 216.103 as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

Subsection 101(a)(5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. The National Defense Authorization Act of 2004 (NDAA) (Public Law 108-136) removed the small numbers limitation and amended the definition of “harassment” as it applies to a military readiness activity to read as follows:

> (i) *any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or*
> (ii) *any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B Harassment].*

The primary potential impact to marine mammals from underwater acoustics is Level A and Level B harassment, as defined by the MMPA from noise. Potential impacts to sea turtles from underwater acoustic exposure are primarily behavioral responses and impairment, with some potential for injury, and a very small potential for mortality.

A.1.2 Development of Animal Impact Criteria

A.1.2.1 Marine Mammals

For explosions of ordnance planned for use in the Long Range Strike WSEP mission area, in the absence of any mitigation or monitoring measures, there is a small chance that a marine mammal could be injured or killed when exposed to the energy generated from an explosive force. Analysis of noise impacts is based on criteria and thresholds initially presented in U.S. Navy Environmental Impact Statements for ship shock trials of the Seawolf submarine and the Winston Churchill (DDG 81), and subsequently adopted by NMFS.

Mortality

Lethal impact determinations currently incorporate species-specific thresholds that are based on the level of impact that would cause extensive lung injury from which one percent of exposed animals would not recover (Finneran and Jenkins, 2012). The threshold represents the expected onset of mortality, where 99 percent of exposed animals would be expected to survive. The lethal exposure level of blast noise, associated with the positive impulse pressure of the blast, is expressed as Pascal-seconds (Pa·s) and is determined using the Goertner (1982) modified positive impulse equation. This equation incorporates sound propagation, source/animal depths, and the mass of a newborn calf of the affected species. The Goertner equation used in the acoustic model to develop mortality impact analysis, is as follows:

$$I_M(M,D) = 91.4M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/2}$$

$I_M(M,D)$ mortality threshold, expressed in terms of acoustic impulse (Pa·s)

M Animal mass (Table D-1)

D Water depth (m)

Level A Harassment

Non-lethal injurious impacts (Level A Harassment) are defined in those documents as onset of slight lung injury, gastro-intestinal (GI) tract damage, and permanent (auditory) threshold shift (PTS).

The criteria for onset of slight lung injury were established using partial impulse because the impulse of an underwater blast wave was the parameter that governed damage during a study using mammals, not peak pressure or energy (Yelverton, 1981). Goertner (1982) determined a way to calculate impulse values for injury at greater depths, known as the Goertner "modified" impulse pressure. Those values are valid only near the surface because as hydrostatic pressure increases with depth, organs like the lung, filled with air, compress. Therefore the "modified" impulse pressure thresholds vary from the shallow depth starting point as a function of depth.

The shallow depth starting points for calculation of the "modified" impulse pressures are mass-dependent values derived from empirical data for underwater blast injury (Yelverton, 1981). During the calculations, the lowest impulse and body mass for which slight, and then extensive, lung injury found during a previous study (Yelverton et al., 1973) were used to determine the positive impulse that may cause lung injury. The Goertner model is sensitive to mammal weight such that smaller masses have lower thresholds for positive impulse so injury and harassment will be predicted at greater distances from the source for them. The equation used for determination of slight lung injury is:

$$I_S(M,D) = 39.1 M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/2},$$

where *M* is animal mass (in kilograms [kg]), *D* is animal depth (m), and the units of I_s are Pa-s. Following Finneran and Jenkins (2012), the representative mass for each species is taken to be that of an average newborn calf or pup for that species.

The criterion for slight injury to the GI tract was found to be a limit on peak pressure and independent of the animal's size (Goertner, 1982). A threshold of 103 psi (237 dB re 1 μPa) is used for all marine mammals. This level at which slight contusions to the GI tract were reported from small charge tests (Richmond et al., 1973).

Two thresholds are used for PTS, one based on sound exposure level (SEL) and the other on the sound pressure level (SPL) of an underwater blast. Thresholds follow the approach of the NMFS 2016 Technical Guidance (NMFS, 2016). The threshold producing either the largest Zone of Influence (ZOI) or higher exposure levels is then used as the more protective of the dual thresholds. In previous assessments Type I and Type II weighting functions (Finneran and Jenkins, 2012) have been applied for each functional hearing group as appropriate. Following recent guidance from NMFS (NMFS, 2016), the newer TAP Phase 3 weighting functions are utilized within this assessment. PTS thresholds for each functional hearing group are as follows:

<u>Low-Frequency (LF) Cetaceans</u>

- SEL (Type II weighted): 183 decibels referenced to 1 micropascal-squared – seconds (dB re 1 $\mu Pa^2 \cdot s$)
- Peak SPL (unweighted): 219 decibels referenced to 1 micropascal (dB re 1 μPa)

<u>Mid-Frequency (MF) Cetaceans</u>

- SEL (Type II weighted): 185 dB re 1 $\mu Pa^2 \cdot s$
- Peak SPL (unweighted): 230 dB re 1 μPa

<u>High-Frequency (HF) Cetaceans</u>

- SEL (Type II weighted): 155 dB re 1 $\mu Pa^2 \cdot s$
- Peak SPL (unweighted): 202 dB re 1 μPa

<u>Phocids (In-Water)</u>

- SEL (Type I weighted) of 185 dB re 1 $\mu Pa^2 \cdot s$
- Peak SPL (unweighted) of 218 dB re 1 μPa

<u>Level B Harassment</u>

Level B (non-injurious) harassment includes temporary (auditory) threshold shift (TTS), a slight, recoverable loss of hearing sensitivity. Similar to PTS, the 2016 NMFS Technical Guidance details two criteria to be evaluated for TTS exposure the cumulative sound exposure level (SEL, weighted), and the peak sound pressure level (SPL, unweighted). NMFS applies the more conservative of these two. For species where no data exist, TTS thresholds are based on the most closely related species for which data are available. The TTS thresholds for each functional hearing group are as follows:

<u>LF Cetaceans</u>

- SEL (Type-II weighted) of 168 dB re 1 μPa²·s
- Peak SPL (unweighted) of 213 dB re 1 μPa

<u>MF Cetaceans</u>

- SEL (Type II weighted) of 170 dB re 1 μPa²·s
- Peak SPL (unweighted) of 224 dB re 1 μPa

<u>HF Cetaceans</u>

- SEL (Type II weighted) of 140 dB re 1 μPa²·s
- Peak SPL (unweighted) of 196 dB re 1 μPa

<u>Phocids (In-Water)</u>

- SEL (Type I weighted) of 170 dB re 1 μPa²·s
- Peak SPL (unweighted) of 212 dB re 1 μPa

<u>Level B Behavioral Harassment</u>

For multiple successive explosions, the acoustic criterion for non-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment but occurring at lower sound energy levels than those that may cause TTS. The threshold for behavioral disturbance is set 5 dB below the Phase 3 weighted total SEL-based TTS threshold. This is based on observations of behavioral reactions in captive dolphins and belugas occurring at exposure levels approximately 5 dB below those causing TTS after exposure to pure tones (Schlundt et al., 2000). The behavioral impacts thresholds for all functional hearing groups of marine mammals exposed to multiple, successive detonations are:

<u>LF Cetaceans</u>

- SEL (Type II weighted) of 163 dB re 1 μPa²·s

<u>MF Cetaceans</u>

- SEL (Type II weighted) of 165 dB re 1 μPa²·s

<u>HF Cetaceans</u>

- SEL (Type II weighted) of 135 dB re 1 μPa²·s

<u>Phocids (In-Water)</u>

- SEL (Type I weighted) of 165 dB re 1 μPa²·s

Table A-1 summarizes the current threshold levels for marine mammals used to analyze explosives identified for use in the Long Range Strike WSEP mission area. The mammal species of interest for Long Range Strike WSEP are spread across four functional hearing groups, three for cetaceans – low frequency (LF), mid-frequency (MF) and high frequency (HF) – and one for in-water phocids.

Table A-1. Explosives Threshold Levels for Marine Mammals

Functional Hearing Group	Mortality*	Level A Harassment			Level B Harassment	
		Slight Lung Injury*	GI Tract Injury	PTS	TTS	Behavioral
LF Cetaceans	$91.4M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/2}$	$39.1M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/2}$	Unweighted SPL: 237 dB re 1 μPa	Weighted SEL: 183 dB re 1 μPa²·s Unweighted SPL: 219 dB re 1 μPa	Weighted SEL: 168 dB re 1 μPa²·s Unweighted SPL: 213 dB re 1 μPa (23 psi PP)	Weighted SEL: 163 dB re 1 μPa²·s
MF Cetaceans			Unweighted SPL: 237 dB re 1 μPa	Weighted SEL: 185 dB re 1 μPa²·s Unweighted SPL: 230 dB re 1 μPa	Weighted SEL: 170 dB re 1 μPa²·s Unweighted SPL: 224 dB re 1 μPa (23 psi PP)	Weighted SEL: 165 dB re 1 μPa²·s

Table A-1. Explosives Threshold Levels for Marine Mammals, Cont'd

Functional Hearing Group	Mortality*	Level A Harassment			Level B Harassment	
		Slight Lung Injury*	GI Tract Injury	PTS	TTS	Behavioral
HF Cetaceans			Unweighted SPL: 237 dB re 1 μPa	Weighted SEL: 155 dB re 1 $\mu Pa^2 \cdot s$	Weighted SEL: 140 dB re 1 $\mu Pa^2 \cdot s$	Weighted SEL: 135 dB re 1 $\mu Pa^2 \cdot s$
				Unweighted SPL: 202 dB re 1 μPa	Unweighted SPL: 196 dB re 1 μPa (1 psi PP)	
Phocids (in water)			Unweighted SPL: 237 dB re 1 μPa	Weighted SEL: 185 dB re 1 $\mu Pa^2 \cdot s$	Weighted SEL: 170 dB re 1 $\mu Pa^2 \cdot s$	Weighted SEL: 165 dB re 1 $\mu Pa^2 \cdot s$
				Unweighted SPL: 218 dB re 1 μPa	Unweighted SPL: 212 dB re 1 μPa (6 psi PP)	

M = Animal mass based on species (kilograms); *D* = Water depth (meters); dB re 1 μPa = decibels referenced to 1 micropascal; dB re 1 $\mu Pa^2 \cdot s$ = decibels referenced to 1 micropascal-squared – seconds; GI = gastrointestinal; PTS = permanent threshold shift; SEL = sound exposure level; TTS = temporary threshold shift; SPL = sound pressure level; PP = peak pressure
*Expressed in terms of acoustic impulse (pascal – seconds [Pa·s])

A.1.2.2 Sea Turtles

The weapons impact zone will be located in an area that is inhabited by species listed as threatened or endangered under the ESA (16 USC §§ 1531-1543), including sea turtles. Operation of sound sources, that is, transmission of acoustic signals in the water column, could potentially cause harm or harassment to listed species.

Until recently, there were no acoustic energy or pressure impact thresholds defined specifically for ESA-listed sea turtles and, in the absence of such information, the thresholds used for marine mammal analysis were typically applied. However, NMFS has recently undertaken a more detailed investigation of the effects of underwater detonations on turtles and provided the following summary of potential behavioral responses at various peak dB levels (Table A-2).

Table A-2. Range of Sea Turtle Behavioral Responses at Multiple Underwater Noise Levels

dB Level (Peak) Range	Response Category	Number of Animals Potentially Affected
110 – 160	Discountable effects; minor response possible but within the range of normal behaviors.	Very few
>160 – 200	Some swimming and diving response, becoming stronger and more frequent at higher dB levels.	Few at 160 dB; most at 200 dB
>200 – 220	Strong avoidance response.	Some to all at 220 dB
>220	Intolerable.	All individuals

dB = decibel

Although there has been recent effort to address turtle-specific thresholds, there are currently no experimental or modeling data sufficient to support development of physiological thresholds. However, NMFS has recently endorsed sea turtle criteria and thresholds for impulsive sources (including detonations) to be used in impact analysis. In some cases, turtle-specific data are not available and marine mammal criteria are therefore used. Similar to marine mammal analysis, criteria and thresholds are provided for mortality (extensive lung injury), non-lethal injury (slight lung or GI tract injury), onset of PTS and TTS, and behavioral effects (Finneran and Jenkins, 2012).

Table A-3. Criteria and Thresholds Used for Sea Turtle Exposure Impulsive Impact Analysis

Impulsive Sound Exposure Impact	Threshold Value
Onset Mortality (1% mortality based on extensive lung injury)*	$91.4M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/2}$
Onset Slight Lung Injury*	$39.1M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/2}$
Onset Slight Gastrointestinal Tract Injury	237 dB re 1 µPa SPL (104 psi)
Onset Permanent Threshold Shift	187 dB re 1 μPa^2-s SEL (T^2)
	230 dB re 1 µPa Peak SPL
Onset Temporary Threshold Shift	172 dB re 1 μPa^2-s SEL (T^2)
	224 dB re 1 µPa Peak SPL
Behavioral Effects	175 dB re 1 µPa unweighted RMS

D = depth of animal (meters); dB = decibel; dB re 1 µPa = decibels referenced to 1 micropascal; dB re 1 $\mu Pa^2 \cdot s$ = decibels referenced to 1 micropascal-squared second; M = animal mass based on species (kilograms); RMS = root mean square; SEL = sound exposure level; SPL = sound pressure level; T = turtle auditory weighting
*Expressed in terms of acoustic impulse (pascal seconds [Pa-s])

A.2 Explosive Acoustic Sources

A.2.1 Acoustic Characteristics of Explosive Sources

The acoustic sources to be deployed during Long Range Strike WSEP missions are categorized as broadband explosives. Broadband explosives produce significant acoustic energy across several frequency decades of bandwidth. Propagation loss is sufficiently sensitive to frequency as to require model estimates at several frequencies over such a wide band.

Explosives are impulsive sources that produce a shock wave that dictates additional pressure-related metrics (peak pressure and positive impulse). Detailed descriptions of the sources in the Long Range Strike WSEP mission area are provided in this subsection.

Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. Three source parameters influence the effect of an explosive: the weight of the explosive material, the type of explosive material, and the detonation depth. The net explosive weight (or NEW) accounts for the first two parameters. The NEW of an explosive is the weight of TNT required to produce an equivalent explosive power.

A.2.2 Animal Harassment Effects of Explosive Sources

The harassments expected to result from these sources are computed on a per-event basis, where an event lasts for 24 hours and takes into account multiple explosives that would detonate within that time period. Within that 24-hour time period it is assumed that the animal population remains constant or, in other words, animals exposed to sounds at the beginning of the 24-hour period would also be exposed to any sounds occurring at the end of the period. A new animal population is assumed for each consecutive 24-hour period. In some cases, this can be a more conservative approach than assuming each detonation, or burst of detonations, is received by a new population of animals. It is important to note that only energy metrics are affected by the accumulation of energy over a 24-hour period. Pressure metrics (e.g., peak pressure and positive impulse) do not accumulate. Rather, a maximum is taken over all of the detonations specified within the 24-hour period. A more detailed description of pressure and energy considerations resulting from munition bursts is provided in Section A.2.3 below.

Explosives are modeled as detonating at depths ranging from the water surface to 10 feet below the surface, as provided by government-furnished information. Impacts from above surface detonations were considered negligible and not modeled.

For sources that are detonated at shallow depths, it is frequently the case that the explosion may breach the surface with some of the acoustic energy escaping the water column. We model surface detonations as occurring 1 foot below the water surface. The source levels have not been adjusted for possible venting nor does the subsequent analysis attempt to take this into account.

A.2.3 Zone of Influence: Per-Detonation Versus Net Explosive Weight Combination

It may useful to consider why and when it is appropriate to treat rounds within a burst as separate events, rather than combining the NEW of all rounds and treating it as a single, larger event. The basic information necessary to address this issue is provided below, where pressure-based metrics are considered separately from energy-level metrics.

Peak Pressure and Positive Impulse

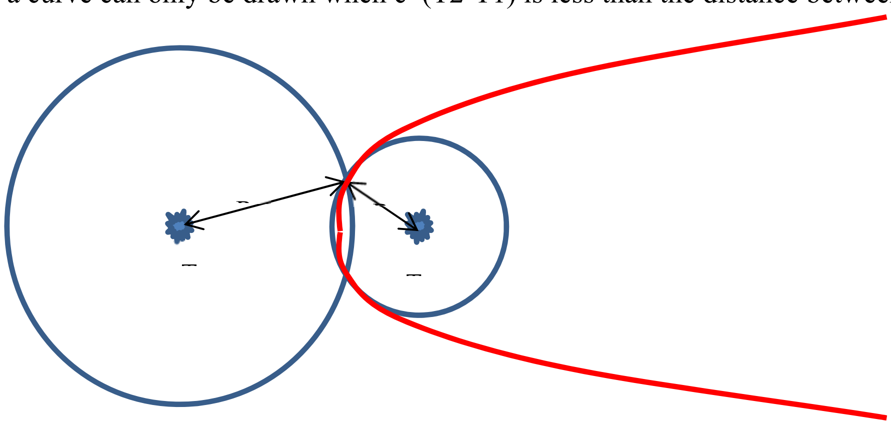
Peak pressures add if two (or more) impulses reach the same point at the same time. Since explosive rounds go off at different times and locations, this will only be true for a small set of points. This problem is mathematically the same as the passive sonar problem of localizing a sound source based on the time difference of arrival (TDOA) of a signal reaching two receivers (R1 and R2). The red curve in the figure (half of a hyperbola) represents the set of all points where:

R1 – R2 = c*(T2 – T1), for

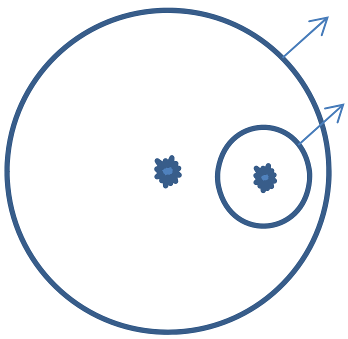
c = the speed of sound in water, and

T1 and T2 being the detonation times of the two rounds.

Such a curve can only be drawn when c*(T2-T1) is less than the distance between the two explosions. If,



for instance, 30 rounds/second are fired (and the difference in impact time is assumed to be roughly the distance in firing time), then the peak impact pressure from the first round will have traveled 1,500 meters/second * 1/30 second = 50 meters. If the second round hits less than 50 meters from the first round, the impact wave from the second round will never catch the impact wave from the first.



In the first case (loose grouping), the pressures will only add along a curve with very narrow width and negligible volume. The pressure on this curve is less than twice the pressure of the closest round, as it will be the pressure at R2 and at (R2+c*dT). In the second case (tight grouping), the pressures will never add.

If this logic is extended to a many-shot burst, the logic becomes even more persuasive. For the impulse peak from a third shot to interact with the peaks from the first two using the 30 rounds/second assumption, it would have to impact the water more than 100 meters away from the impact of the first round and more than 50 meters away from the impact of the second round. Even in that case, there would be at most two places in the ocean where the curve from the 1st and 3rd impacts would meet the curve from 2nd and 3rd explosions (and the travel distances would have to be 50 meters longer for one and 100 meters longer for the other). In summary:

- There would be 0 to 4 directions where a curve (a hyperbola approaches an asymptotic line far from the source) of negligible thickness, and volume would have less than two times the pressure from the closest source.
- There would be 0 to 2 very small points with no extent in range or bearing where one would see less than three times the pressure from the closest source.
- In every other part of the ZOI, the impulse from each round would be received separately by any animal present.

For the 4th round and any subsequent round, another curve could be added, if it was far enough away from the previous shots so that their peak had not already passed the impact point. However, this new curve would intersect with the previous two curves at a different location than where the first two curves intersected. No matter how many rounds are fired, there would not be any point in the ocean where more than three peaks arrive at the same time. These points would have almost no volumetric extent, and required range increases from the closest source of N*dt*c, where *N* is the difference in shot number and *dt* is the time between shots.

If the rate of fire is increased, there is a decrease in the additional required separation in order to have any coherent increase in pressure or positive impulse. However, the end result is that almost all of the ocean experiences only one pressure peak at a time.

If the rounds are far enough apart in space and close enough in time, there will be curves where sequential rounds add coherently; however,

- They will not occupy any significant volume, and
- They will be less than a factor of 2 above the pressure or positive impulse of the nearest source.

Contrast this with the alternative assumption that pressures from separate rounds are added. This models the event as if all rounds went off exactly at the same place and exactly at the same time. That is the only way that travelling pressure peaks from separate rounds would go through space together and add pressures at all points. This is not realistic and would overestimate pressure and positive impulse metrics by a factor equal to the number of rounds in the burst, which could be 10 or 20 dB in pressure levels.

Energy Metrics

Energy metrics accumulate the integral of the power density of each explosion over the duration of the impulse. Thus, even though the peaks from separate explosions arrive at different times, the energy from all of their arrivals will be added. If you fire a number of rounds close together in a burst (N_{burst}), the energy from all of the rounds will add and the sound exposure level will be $10*\log10(N_{burst})$ higher than if a single shot had been fired. The area affected, A_{burst}, would be larger than the area affected by a single shot (A_1), because additional transmission loss would be needed to reduce the larger energy level to a given threshold.

The alternative assumption is that each round sees a fresh population and the area affected by N single bullets is $N*A_1$. The single-shot assumption is more conservative as long as $A_{burst} < N*A_1$.

For this LOA Request, the total energy for all weapon released as part of a representative mission day was calculated to assess impacts from the accumulated energy resulting from multiple weapon releases within a 24-hour period. Given the large degree in uncertainty in what could be released on any mission day, the total number of each munition proposed to be released per year was divided by the annual number of mission days. Since there would be a total of five mission days per year during the time frame of 2017–2021 the analysis assumes the following munitions and quantities would be released daily as the representative mission day: one JASSM, six JDAMs, six SDB-Is, six SDB-IIs, and two HARMs. Total annual numbers of munitions released would not exceed what is listed in Table 1-2.

A.3 ENVIRONMENTAL CHARACTERIZATION

A.3.1 Important Environmental Parameters for Estimating Animal Harassment

Propagation loss ultimately determines the extent of the ZOI for a particular source activity. In turn, propagation loss as a function of range depends on a number of environmental parameters including:

- Water depth
- Sound speed variability throughout the water column
- Bottom geo-acoustic properties
- Surface roughness, as determined by wind speed

Due to the importance that propagation loss plays in anti-submarine warfare, the Navy has, over the last four to five decades, invested heavily in measuring and modeling these environmental parameters. The result of this effort is the following collection of global databases containing these environmental parameters, which are accepted as standards for Navy modeling efforts. Table A-4 contains the version of the databases used in the modeling for this report.

Table A-4. Navy Standard Databases Used in Modeling

Parameter	Database	Version
Water Depth	Digital Bathymetry Data Base Variable Resolution	DBDBV 6.0
Ocean Sediment	Re-packed Bottom Sediment Type	BST 2.0
Wind Speed	Surface Marine Gridded Climatology Database	SMGC 2.0
Temperature/Salinity Profiles	Generalized Digital Environment Model	GDEM 3.0

The sound speed profile directs the sound propagation in the water column. The spatial variability of the sound speed field is generally small over operating areas of typical size. The presence of a strong oceanographic front is a noteworthy exception to this rule. To a lesser extent, variability in the depth and strength of a surface duct can be of some importance. If the sound speed minimum occurs within the water column, more sound energy can travel further without suffering as much loss (ducted propagation). But if the sound speed minimum occurs at the surface or bottom, the propagating sound interacts more with these boundaries and may become attenuated more quickly. In the mid-latitudes, seasonal variation often provides the most significant variation in the sound speed field. For this reason, both summer and winter profiles are modeled to demonstrate the extent of the difference.

Losses of propagating sound energy occur at the boundaries. The water-sediment boundary defined by the bathymetry can vary by a large amount. In a deep water environment, the interaction with the bottom may matter very little. In a shallow water environment the opposite is true and the properties of the sediment become very important. The sound propagates through the sediment, as well as being reflected by the interface. Soft (low-density) sediment behaves more like water for lower frequencies and the sound has relatively more transmission and relatively less reflection than a hard (high-density) bottom or thin sediment.

The roughness of the boundary at the water surface depends on the wind speed. Average wind speed can vary seasonally but could also be the result of local weather. A rough surface scatters the sound energy and increases the transmission loss. Boundary losses affect higher frequency sound energy much more than lower frequencies.

A.3.2 Characterizing the Acoustic Marine Environment

The environment for modeling impact value is characterized by a frequency-dependent bottom definition, range-dependent bathymetry and sound velocity profiles (SVP), and seasonally varying wind speeds and SVPs. The bathymetry database is on a grid of variable resolution.

The SVP database has a fixed spatial resolution storing temperature and salinity as a function of time and location. The low-frequency bottom loss is characterized by standard definition of geo-acoustic parameters for the given sediment type for the area. The high-frequency bottom loss class is fixed to match expected loss for the sediment type. The area of interest can be characterized by the appropriate sound speed profiles, set of low-frequency bottom loss parameters, high-frequency bottom loss class, and HFEVA very-high-frequency sediment type for modeled frequencies in excess of 10 kilohertz (kHz).

Generally, seasonal variation is sampled by looking at summer and winter cases that tend to capture extremes in both the environmental variability as well as animal populations. Calculations were made for both seasons, even though events are expected to be at the end of the summer season.

Impact volumes in the operating area are then computed using propagation loss estimates and the explosives model derived for the representative environment.

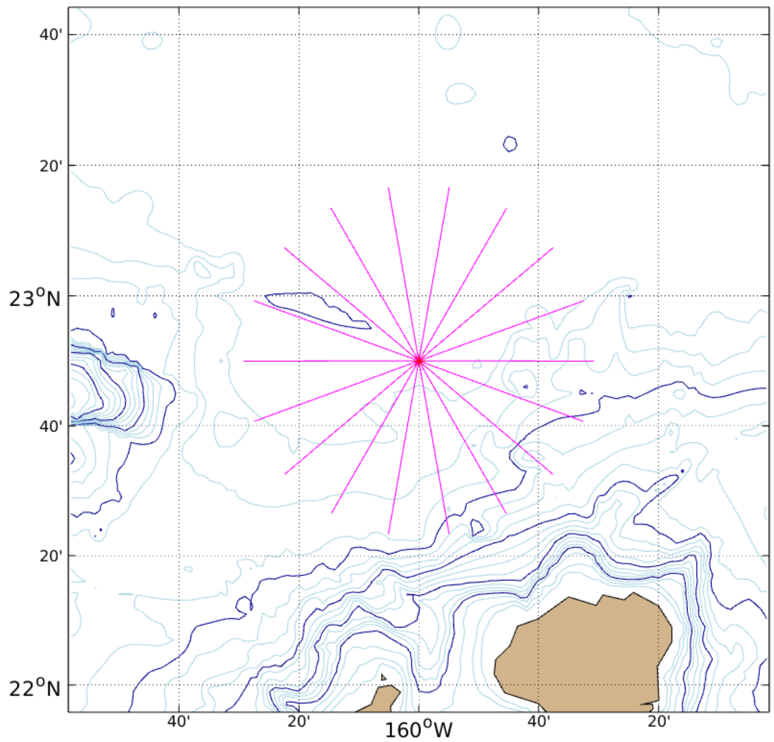
A.3.3 Description of the BSURE Training Range Area Environment

The Long Range Strike mission area is located to the northwest of the Hawaiian island of Kauai, in the northern part of the BSURE tracking range. The bottom is characterized as clay according to the Bottom Sediments Type Database. Environmental values were extracted from unclassified Navy standard databases in a radius of 75 kilometers around the center point at

N 22° 50.0' W 160° 00'

The Navy standard database for bathymetry has a resolution of 0.05 minutes in the Pacific Ocean; see Figure A-1. Mean and median depths from DBDBV in the extracted area are 4,351 and 4,550 meters, respectively. Minimum and maximum depths are 1,135 and 4,848 meters, respectively.

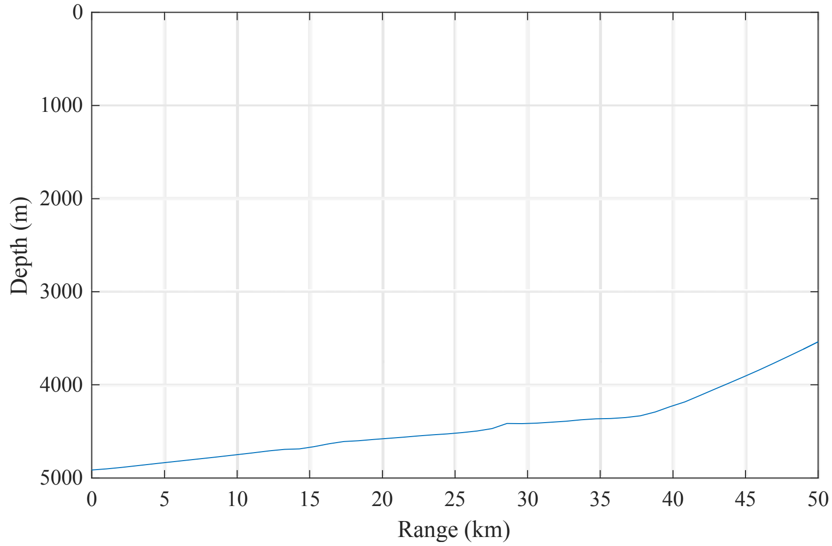
Figure A-1. Bathymetry (in 250-Meter Contours) for the BSURE Range and Long Range Strike WSEP Mission Area



The seasonal variability in wind speed was modeled as 7.7 knots in the summer and 7.1 knots in the winter.

Example input of range-dependent bathymetry is depicted in Figure A-2 for the due-north bearing.

Figure A-2. Bathymetry Along 150° Radial to the SW from Center Point



A.4 MODELING IMPACT ON MARINE ANIMALS

Many underwater actions include the potential to injure or harass marine animals in the neighboring waters through noise emissions. The number of animals exposed to potential harassment in any such action is dictated by the propagation field and the characteristics of the noise source.

Estimating the number of animals that may be injured or otherwise harassed in a particular environment entails the following steps.

- For the relevant environmental acoustic parameters, transmission loss (TL) estimates are computed, sampling the water column over the appropriate depth and range intervals. TL calculations are also made over disjoint one-third octave bands for a wide range of frequencies with dependence in range, depth, and azimuth for bathymetry and sound speed. TL computations were sampled with 40-degree spacing in azimuth.
- The weighted total accumulated energy within the waters where the source detonates is sampled over a volumetric grid. At each grid point, the received energy from each source emission is modeled as the effective energy source level reduced by the appropriate propagation loss from the location of the source at the time of the emission to that grid point and summed. For the peak pressure or positive impulse, the appropriate metric is similarly modeled for each emission. The maximum value of that metric over all frequencies and emissions is stored at each grid point.
- The impact volume for a given threshold is estimated by summing the incremental volumes represented by each grid point sampled in range and depth for which the appropriate metric exceeds that threshold and accumulated over all modeled bearings. Histograms representing impact volumes as a function of (possibly depth-dependent) thresholds are stored in a spreadsheet for dynamic changes of thresholds.
- Finally, the number of harassments is estimated as the inner-product of the animal density, the impact area, and number of events per year.

This section describes in detail the process of computing impact areas.

A.4.1 Calculating Transmission Loss

Transmission loss (TL) was pre-computed for both seasons for 30 non-overlapping frequency bands. The 30 bands had one-third octave spacing around center frequencies from 50 Hertz (Hz) to approximately 40.637 kHz. In the previous report, TL was computed at only seven frequencies. The broadband nature of the sources has been well covered in this report. The TL was modeled using the Navy Standard GRAB V3 propagation loss model (Keenan, 2000) with CASS v4.3. GRAB is well suited to modeling transmission losses over the wide frequency band of interest.

The TL results were interpolated onto a variable range grid with logarithmic spacing. The increased spatial resolution near the source provided greater fidelity for estimates.

The TL was calculated from the source depth to an array of output depths. The output depths were the mid-points of depth intervals matching GDEM's depth sampling. For water depths from surface to 10-meter depth, the depth interval was 2 meters. Between 10-meter and 100-meter water depth, the depth interval was 5 meters. For water depths between 100 meters and 2,400 meters, the depth interval was 10 meters. The output depths represent possible locations of the animals and are used with the animal depth distribution to better estimate animal impact. The depth grid is used to make the surface image interference correction and to capture the depth-dependence of the positive impulse threshold.

A.4.2 Computing Impact Volumes

This section and the next provide a detailed description of the approach taken to compute impact volumes for explosives. The impact volume associated with a particular activity is defined as the area of water in which some acoustic metric exceeds a specified threshold. The product of this impact volume with a volumetric animal density yields the expected value of the number of animals exposed to that acoustic metric at a level that exceeds the threshold. The acoustic metric can either be an energy term (weighted or un-weighted energy flux density, either in a limited frequency band or across the full band) or a pressure term (such as peak pressure or positive impulse). The thresholds associated with each of these metrics define the levels at which half of the animals exposed will experience some degree of harassment (ranging from behavioral change to mortality).

Impact volume is particularly relevant when trying to estimate the effect of repeated source emissions separated in either time or space. Impact range, which is defined as the maximum range at which a particular threshold is exceeded either for a single source emission or accumulation of source emissions over a 24-hour period, defines the range to which marine mammal activity is monitored in order to meet mitigation requirements.

The effective energy source level is modeled directly for the sources to be used at the Long Range Strike WSEP impact area. The energy source level is comparable to the model used for other explosives (Arons (1954), Weston (1960), McGrath (1971), Urick (1983), Christian and Gaspin (1974)). The energy source level over a one-third octave band with a center frequency of f for a source with a net explosive weight of w pounds is given by:

$$\text{ESL} = 10 \log_{10} (0.26 f) + 10 \log_{10} (2\, p_{max}^2 / [1/\theta^2 + 4 \pi^2 f^2]) + 197 \text{ dB}$$

where the peak pressure for the shock wave at 1 meter is defined as

$$p_{max} = 21600 \, (w^{1/3} / 3.28)^{1.13} \text{ psi} \qquad \text{(B-1)}$$

and the time constant is defined as:

$$\theta = [(0.058)\,(w^{1/3})\,(3.28 / w^{1/3})^{0.22}] / 1000 \text{ sec} \qquad \text{(B-2)}$$

For each explosive source, the amount of acoustic energy injected into the water column is calculated, conservatively assuming that all explosive energy is converted into acoustic energy. The propagation loss for each frequency, expressed as a pressure term, modulates the sound energy found at each point on the grid of depth (uniform spacing) and range (logarithmic spacing). If a threshold is exceeded at a point, the impact volume at an annular sector is added to the total impact volume. The impact volume at a point is calculated exactly using the depth, range, and azimuthal intervals associated with that particular point in the water column.

A.4.3 Effects of Metrics on Impact Volumes

The impact of explosive sources on marine wildlife is measured by three different metrics, each with its own thresholds. The energy metric, the peak pressure metric, and the “modified” positive impulse metric are discussed in this section. The energy metric, using the TAP Phase 3 weighting functions as shown in the NMFS Technical Guidance (NMFS, 2016), is accumulated after the explosive detonation. The other two metrics, peak pressure and positive impulse, are not accumulated but rather the maximum levels are taken.

Energy Metric

The energy flux density is sampled at several frequencies in one-third-octave bands. The total weighted energy flux at each range/depth combination is obtained by summing the product of the TAP Phase 3 weighting function, $W_{II}(f)$, and the energy flux density at each frequency. The Phase 3 weighting function in dB is given by:

$$W(f) = C + 10log\left\{\frac{\left(f/f_1\right)^{2a}}{\left[1+\left(f/f_1\right)^{a}\right]^{2}\left[1+\left(f/f_2\right)^{2}\right]^{b}}\right\}$$

where *W(f)* is the weighting function in dB for a given frequency *f*.

The component lower cutoff frequencies, f_1 , upper frequency f_2, low- and high- frequency exponents *a* and *b*, and weighting function gain *C*, are given in Table A-3.

Table A-3. TAP Phase 3 Weighting Parameters used for Marine Mammals

Functional Hearing Group	C(dB)	f_1(kHz)	f_2(kHz)	a	b
LF cetaceans	0.13	0.2	19	1.0	2
MF cetaceans	1.20	8.8	110	1.6	2
HF cetaceans	1.36	12	140	1.8	2
Phocid pinnipeds	0.75	1.9	30	1.0	2

Note that because the weightings are in dB, we will actually weight each frequency's EFD by $10^{(W_{II}(f)/10)}$, sum the EFDs over frequency, and then convert the weighted total energy to back to dB, with level = 10 $\log_{10}$(total weighted EFD). Also, note that accumulating the EFD across frequency is equivalent to summing the energy in time over the pulse duration, both of which lead to the cumulative sound exposure level metric with units of μPa^2-s. Single-impulse SEL levels are then accumulated over a pre-determined set of munition detonations that are likely to occur within a single 24-hour period.

Peak Pressure Metric

The peak pressure metric is a simple, straightforward calculation at each range/animal depth combination. First, the transmission pressure ratio, modified by the source level in a one-third-octave band, is summed across frequency. This averaged transmission ratio is normalized by the total broadband source level. Peak pressure at that range/animal depth combination is then simply the product of:

- The square root of the normalized transmission ratio of the peak arrival,
- The peak pressure at a range of 1 meter (given by equation B-1), and
- The similitude correction (given by $r^{-0.13}$, where *r* is the slant range).

If the peak pressure for a given grid point is greater than the specified threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

"Modified" Positive Impulse Metric

The modeling of positive impulse follows the work of Goertner (Goertner, 1982). The Goertner model defines a "partial" impulse as

$$I = \int_0^{T_{min}} p(t)dt \,,$$

where $p(t)$ is the pressure wave from the explosive as a function of time t, defined so that $p(t) = 0$ for $t < 0$. This similitude pressure wave is modeled as

$$p(t) = p_{max}\, e^{-t/\theta}$$

where p_{max} is the peak pressure at 1 meter (see, equation B-1), and θ is the time constant defined in equation A-2.

The upper limit of the "partial" impulse integral is

$$T_{min} = \min\, \{T_{cut}, T_{osc}\}$$

where T_{cut} is the time to cutoff and T_{osc} is a function of the animal lung oscillation period. When the upper limit is T_{cut}, the integral is the definition of positive impulse. When the upper limit is defined by T_{osc}, the integral is smaller than the positive impulse and thus is just a "partial" impulse. Switching the integral limit from T_{cut} to T_{osc} accounts for the diminished impact of the positive impulse upon the animals lungs that compress with increasing depth and leads to what is sometimes call a "modified" positive impulse metric.

The time to cutoff is modeled as the difference in travel time between the direct path and the surface-reflected path in an isovelocity environment. At a range of r, the time to cutoff for a source depth z_s and an animal depth z_a is

$$T_{cut} = 1/c\ \{\, [r^2 + (z_a + z_s)^2]^{1/2} - [r^2 + (z_a - z_s)^2]^{1/2}\, \}$$

where c is the speed of sound.

The animal lung oscillation period is a function of animal mass M and depth z_a and is modeled as

$$T_{osc} = 1.17\, M^{1/3}\, (1 + z_a/33)^{-5/6}$$

where M is the animal mass (in kg) and z_a is the animal depth (in feet).

The modified positive impulse threshold is unique among the various injury and harassment metrics in that it is a function of depth and the animal weight. So instead of the user specifying the threshold, it is computed as $K\,(M)^{1/3}\,(1 + z_a/33)^{1/2}$. The coefficient K depends upon the level of exposure. For the onset of slight lung injury, K is 39.1; for the onset of extensive lung hemorrhaging (1 percent mortality), K is 91.4.

Although the thresholds are a function of depth and animal weight, sometimes they are summarized as their value at the sea surface for a typical dolphin calf (with an average mass of 12.2 kg). For the onset of slight lung injury, the threshold at the surface is approximately 13 psi-msec; for the onset of extensive lung hemorrhaging (1 percent mortality), the threshold at the surface is approximately 31 psi-msec.

As with peak pressure, the "modified" positive impulse at each grid point is compared to the derived threshold. If the impulse is greater than that threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

A.5 ESTIMATING ANIMAL HARASSMENT

A.5.1 Distribution of Animals in the Environment

Species densities are usually reported by marine biologists as animals per square kilometer. This gives an estimate of the number of animals below the surface in a certain area, but does not provide any information about their distribution in depth. The impact volume vector specifies the volume of water ensonified above the specified threshold in each depth interval. A corresponding animal density for each of those depth intervals is required to compute the expected value of the number of exposures. The two-dimensional area densities do not contain this information, so three-dimensional densities must be constructed by using animal depth distributions to extrapolate the density at each depth.

The following bottlenose dolphin (summer profile) example demonstrates the method used to account for three-dimensional analysis by merging the depth distributions with user-specifiable surface densities. Bottlenose dolphins are distributed with:

- 19.2% in 0-10 meters,
- 76.8% in 10-50 meters,
- 1.7% in 50-100 meters, and
- 2.3% in 100-165 meters.

The impact volume vector is sampled at 30 depths over the maximally 165 meter water column. Since this is a finer resolution than the depth distribution, densities are apportioned uniformly over depth intervals. For example, 19.2% of bottlenose dolphins are in the 0-10 meter interval, so approximately

- 3.84% are in 0-2 meters,
- 3.84% are in 2-4 meters,
- 3.84% are in 4-6 meters,
- 3.84% are in 6-8 meters, and
- 3.84% are in 8-10 meters.

Similarly, 76.8% are in the 10-50 m interval, so approximately

- 9.60% are in 10 - 15 meters,
- 9.60% are in 15 - 20 meters,
- 9.60% are in 20 - 25 meters,
- etc.

The animal densities and depth distributions used in this study are provided in Appendix B.

A.5.2 Harassment Estimates

Impact volumes for all depth intervals are scaled by their respective depth densities, divided by their depth interval widths, summed over the entire water column and finally converted to square kilometers to create impact areas. The spreadsheet allows a user-specifiable surface density in animals per square kilometer, so the product of these quantities yields expected number of animals in ensonified water where they could experience harassment.

Since the impact volume vector is the volume of water at or above a given threshold per mission day scenario (e.g. representative mission day with multiple detonations occurring in a 24 hour time period, or clusters of munitions explosions), the final harassment count for each animal is the harassment count for the representative mission day multiplied by the number of mission days proposed annually.

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APPENDIX B

MARINE MAMMALS DEPTH DISTRIBUTIONS

MARINE MAMMALS DEPTH DISTRIBUTIONS USED IN ACOUSTIC MODELING

Source: Watwood, S. L., and D. M. Buonantony, 2012. Dive Distribution and Group Size Parameters for Marine Species Occurring in Navy Training and Testing Areas in the North Atlantic and North Pacific Oceans. NUWC-NPT Technical Document12,085. 12 March 2012.

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling

Species	Depth Category (m = meters)	Percentage of Time at Depth
Humpback whale	0–10 m	39.55
	10–20 m	26.51%
	20–30 m	11.66%
	30–40 m	4.25%
	40–50 m	3.04%
	50–60 m	2.47%
	60–70 m	2.14%
	70–80 m	1.66%
	80–90 m	1.97%
	90–100 m	1.55%
	100–110 m	1.39%
	110–120 m	1.31%
	120–130 m	0.92%
	130–140 m	0.72%
	140–150 m	0.20%
	150–160 m	0.23%
	160–170 m	0.15%
	170–180 m	0.09%
Blue whale	0–15 m	43.078%
	15–30 m	29.621%
	30–45 m	9.376%
	45–60 m	2.334%
	60–75 m	2.342%
	75–90 m	2.341%
	90–105 m	2.264%
	105–120 m	2.094%
	120–135 m	1.859%
	135–150 m	1.528%
	150–165 m	1.187%
	165–180 m	0.819%
	180–195 m	0.532%
	195–210 m	0.312%
	210–225 m	0.172%
	225–240 m	0.084%
	240–255 m	0.035%
	255–270 m	0.013%
	270–285 m	0.005%
	285–300 m	0.002%
	300–315 m	0.001%
Fin whale	0–15 m	46.460%

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling, Cont'd

Species	Depth Category (m = meters)	Percentage of Time at Depth
	15–30 m	10.738%
	30–45 m	9.105%
	45–60 m	4.033%
	60–75 m	2.684%
	75–90 m	2.466%
	90–105 m	2.231%
	105–120 m	2.148%
	120–135 m	1.947%
	135–150 m	1.762%
	150–165 m	1.633%
	165–180 m	1.592%
	180–195 m	1.712%
	195–210 m	2.107%
	210–225 m	2.663%
	225–240 m	2.834%
	240–255 m	2.217%
	255–270 m	1.125%
	270–285 m	0.361%
	285–300 m	0.081%
	300–315 m	0.011%
	315–330 m	0.001%
Sei whale and Bryde's whale	0–40 m	84.50%
	40–292 m	15.30%
Minke whale	0–25 m	79.70%
	25–65 m	20.30%
Sperm whale	0–50 m	30.689%
	50–100 m	3.220%
	100–150 m	3.372%
	150–200 m	3.587%
	200–250 m	3.757%
	250–300 m	3.893%
	300–350 m	4.057%
	350–400 m	4.434%
	400–450 m	4.668%
	450–500 m	5.167%
	500- 550 m	4.750%
	550–600 m	4.024%
	600–650 m	3.537%
	650–700 m	3.112%
	700–750 m	2.786%
	750–800 m	2.461%
	800–850 m	2.149%
	850–900 m	1.836%
	900–950 m	1.563%
	950–1000 m	1.316%
	100–1050 m	1.098%
	1050–1100 m	0.892%
	1100–1150 m	0.712%

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling, Cont'd

Species	Depth Category (m = meters)	Percentage of Time at Depth
	1150–1200 m	0.581%
	1200–1250 m	0.472%
	1250–1300 m	0.382%
	1300–1350 m	0.306%
	1350–1400 m	0.248%
	1400–1450 m	0.194%
	1450–1500 m	0.161%
	1500–1550 m	0.128%
	1550–1600 m	0.110%
	1600–1650 m	0.086%
	1650–1700 m	0.069%
	1700–1750 m	0.051%
	1570–1800 m	0.039%
	1800–1850 m	0.028%
	1850–1900 m	0.019%
	1900–1950 m	0.013%
	1950–2000 m	0.009%
	2000–2050 m	0.006%
	2050–2100 m	0.004%
	2100–2150 m	0.003%
	2150–2200 m	0.002%
	2200–2250 m	0.002%
	2250–2300 m	0.002%
	2300–2350 m	0.001%
	2350–2400 m	0.001%
Pygmy sperm whale and Dwarf sperm whale	0–17 m	74.40%
	17–35 m	5.20%
	35–53 m	2.20%
	53–101 m	3.80%
	101–149 m	2.80%
	149–197 m	1.80%
	197–299 m	3.40%
	299–401 m	2.60%
	401–599 m	2.90%
	599–797 m	0.90%
Killer whale	0–5 m	24%
	5–10 m	3.50%
	10–15 m	2.50%
	15–20 m	4.20%
	20–25 m	8%
	25–30 m	12%
	30–35 m	11%
	35–40 m	8.50%
	40–45 m	10.90%
	45–50 m	8.50%
	50–55 m	5%
	55–60 m	1.50%
	60–65 m	0.40%

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling, Cont'd

Species	Depth Category (m = meters)	Percentage of Time at Depth
False killer whale, Pygmy killer whale, and Melon-headed whale	0–1 m	24.7500%
	1–2 m	13.5000%
	2–10 m	16.5000%
	10–50 m	43.5000%
	50–100 m	1.1875%
	100–150 m	0.1375%
	150–600 m	0.4250%
Short-finned pilot whale and Fraser's dolphin	0–17 m	74.40%
	17–35 m	5.20%
	35–53 m	2.20%
	53–101 m	3.80%
	101–149 m	2.80%
	149–197 m	1.80%
	197–299 m	3.40%
	299–401 m	2.60%
	401–599 m	2.90%
	599–797 m	0.90%
Bottlenose dolphin	0–5 m	74.21%
	5–10 m	17.04%
	10–15 m	3.09%
	15–20 m	1.41%
	20–25 m	1.87%
	25–30 m	1.59%
	30–35 m	0.66%
	35–40 m	0.12%
	40–45 m	0.01%
Pantropical spotted dolphin, Striped dolphin, and Spinner dolphin	0–2 m	20.40%
	2–4 m	10.70%
	4–6 m	8.60%
	6–8 m	9.00%
	8–10 m	9.50%
	10–20 m	21.30%
	20–30 m	8.80%
	30–40 m	3.80%
	40–50 m	2.50%
	50–60 m	1.90%
	60–70 m	1.10%
	70–80 m	0.60%
	80–90 m	0.60%
	90–100 m	0.40%
	100–110 m	0.40%
	110–120 m	0.30%
	120–130 m	0.10%
	130–140 m	0.10%
	140–150 m	0.10%
	150–160 m	0.10%
	160–170 m	0.10%
Rough-toothed dolphin	0–10 m	77.99%

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling, Cont'd

Species	Depth Category (m = meters)	Percentage of Time at Depth
	10–25 m	16.24%
	25–50 m	3.81%
	50–75 m	0.93%
	75–100 m	0.29%
	100–150 m	0.11%
	150–200 m	0.01%
	200–300 m	0.01%
Risso's dolphin	0–1 m	24.7500%
	1–2 m	13.5000%
	2–10 m	16.5000%
	10–50 m	43.5000%
	50–100 m	1.1875%
	100–150 m	0.1375%
	150–600 m	0.4250%
Cuvier's beaked whale	0–50 m	49.76%
	50–100 m	6.38%
	100–150 m	5.91%
	150–200 m	5.03%
	200–250 m	3.92%
	250–300 m	2.95%
	300–350 m	2.16%
	350–400 m	1.63%
	400–450 m	1.41%
	450–500 m	1.36%
	500- 550 m	1.35%
	550–600 m	1.28%
	600–650 m	1.35%
	650–700 m	1.41%
	700–750 m	1.43%
	750–800 m	1.33%
	800–850 m	1.29%
	850–900 m	1.28%
	900–950 m	1.25%
	950–1000 m	1.13%
	100–1050 m	1.07%
	1050–1100 m	0.93%
	1100–1150 m	0.80%
	1150–1200 m	0.74%
	1200–1250 m	0.61%
	1250–1300 m	0.49%
	1300–1350 m	0.41%
	1350–1400 m	0.29%
	1400–1450 m	0.21%
	1450–1500 m	0.22%
	1500–1550 m	0.18%
	1550–1600 m	0.15%
	1600–1650 m	0.09%
	1650–1700 m	0.07%

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling, Cont'd

Species	Depth Category (m = meters)	Percentage of Time at Depth
	1700–1750 m	0.05%
	1570–1800 m	0.03%
	1800–1850 m	0.01%
	1850–1900 m	0.01%
Blaineville's beaked whale and Longman's beaked whale	0–20 m	43.447%
	20–40 m	8.743%
	40–60 m	7.116%
	60–80 m	5.665%
	80–100 m	4.134%
	100–120 m	2.793%
	120–140 m	1.740%
	140–160 m	1.127%
	160–180 m	0.772%
	180–200 m	0.597%
	200–220 m	0.500%
	220–240 m	0.470%
	240–260 m	0.460%
	260–280 m	0.455%
	280–300 m	0.454%
	300–320 m	0.454%
	320–340 m	0.456%
	340–360 m	0.458%
	360–380 m	0.458%
	380–400 m	0.460%
	400–420 m	0.461%
	420–440 m	0.465%
	440–460 m	0.478%
	460–480 m	0.492%
	480–500 m	0.505%
	500–520 m	0.520%
	520–540 m	0.528%
	540–560 m	0.553%
	560–580 m	0.576%
	580–600 m	0.589%
	600–620 m	0.605%
	620–640 m	0.642%
	640–660 m	0.697%
	660–680 m	0.715%
	680–700 m	0.708%
	700–720 m	0.694%
	720–740 m	0.727%
	740–760 m	0.739%
	760–780 m	0.741%
	780–800 m	0.758%
	800–820 m	0.781%
	820–840 m	0.775%
	840–860 m	0.694%
	860–880 m	0.624%

Table B-1. Marine Mammals Depth Distributions Used in Acoustic Modeling, Cont'd

Species	Depth Category (m = meters)	Percentage of Time at Depth
	880–900 m	0.601%
	900–920 m	0.566%
	920–940 m	0.512%
	940–960 m	0.444%
	960–980 m	0.384%
	980–1000 m	0.330%
	1000–1020 m	0.285%
	1020–1040 m	0.228%
	1040–1060 m	0.182%
	1060–1080 m	0.146%
	1080–1100 m	0.110%
	1100–1120 m	0.078%
	1120–1140 m	0.057%
	1140–1160 m	0.048%
	1160–1180 m	0.050%
	1180–1200 m	0.045%
	1200–1220 m	0.030%
	1220–1240 m	0.015%
	1240–1260 m	0.004%
	1260–1280 m	0.004%
	1280–1300 m	0.001%
	1300–1320 m	0.001%
	1320–1340 m	0.001%
	1340–1360 m	0.001%
Hawaiian monk seal	0–4 m	33.00%
	4–20 m	34.70%
	20–40 m	13.20%
	40–60 m	5.50%
	60–80 m	3.60%
	70–100 m	2.10%
	100–120 m	2.50%
	120–140 m	2.00%
	140–160 m	0.80%
	160–180 m	0.70%
	180–200 m	0.30%
	200–250 m	0.40%
	250–350 m	0.90%
	350–500 m	0.60%