3.9 Fish

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

There are no figures in this section.

3.9 Fish

FISH SYNOPSIS

The United States Department of the Navy considered all potential stressors, and the following have been analyzed for fish:

- Acoustic (sonar and other active acoustic sources; underwater explosives; swimmer defense airguns; weapons firing, launch, and impact noise; vessel noise; and aircraft noise)
- Energy (electromagnetic devices)
- Physical disturbance and strike (vessels, in-water devices, military expended materials, and seafloor devices)
- Entanglement (fiber optic cables and guidance wires, and decelerators/parachutes)
- Ingestion (munitions and military expended materials other than munitions)
- Secondary (impacts associated with sediments and water quality)

Preferred Alternative (Alternative 1)

- Acoustic: Pursuant to the Endangered Species Act (ESA), the use of sonar and other non-impulse acoustic sources may affect but is not likely to adversely affect ESA-listed scalloped hammerhead sharks. The use of explosives and other impulse acoustic sources may affect and is likely to adversely affect ESA-listed scalloped hammerhead sharks.
- Energy: Pursuant to the ESA, the use of electromagnetic devices may affect but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.
- Physical Disturbance and Strike: Pursuant to the ESA, the use of vessels and in-water devices, military expended materials, and seafloor devices would have no effect on ESA-listed scalloped hammerhead sharks.
- Entanglement: Pursuant to the ESA, the use of fiber optic cables, guidance wires, and parachutes may affect but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.
- Ingestion: Pursuant to the ESA, the potential for ingestion of military expended materials may affect but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.
- Secondary: Pursuant to the ESA, secondary stressors may affect, but are not likely to adversely affect, ESA-listed scalloped hammerhead sharks.
- Pursuant to the Essential Fish Habitat (EFH) requirements, the use of sonar and other active acoustic sources, explosives, and electromagnetic devices may have a minimal and temporary adverse effect on the fishes that occupy water column EFH.

3.9.1 INTRODUCTION

This section analyzes the potential impacts of the Proposed Action on fish found in the Mariana Islands Training and Testing (MITT) Study Area (Study Area) and provides a synopsis of the United States (U.S.) Department of the Navy's (Navy's) determinations of the impacts of the Proposed Action on fish. Section 3.9.1 (Introduction) introduces the Endangered Species Act (ESA) species and taxonomic groups that occur in the Study Area. Section 3.9.2 (Affected Environment) discusses the baseline affected environment. The complete analysis of environmental consequences is in Section 3.9.3 (Environmental Consequences) and the potential impacts of the Proposed Action on fish are summarized in Section 3.9.4 (Summary of Potential Impacts on Fish).

For this Environmental Impact Statement (EIS)/Overseas EIS (OEIS), marine fishes are evaluated as groups of species characterized by either distribution, morphology (body type), or behavior relevant to the stressor being evaluated in Section 3.9.3 (Environmental Consequences). Activities are evaluated for their potential effect on all fishes in general.

Marine fish species that are regulated under Magnuson-Stevens Fishery Conservation and Management Act are discussed in Section 3.9.1.3 (Federally Managed Species). Additional general information on the biology, life history, distribution, and conservation of marine fishes can be found on the following websites, as well as many others:

- National Marine Fisheries Services (NMFS), Office of Protected Resources (including ESA-listed species distribution maps)
- Regional Fishery Management Councils
- International Union for Conservation of Nature
- EFH Text Descriptions

Fishes are not distributed uniformly throughout the Study Area but are closely associated with a variety of habitats. Some species, such as large sharks, salmon, tuna, and billfishes, range across thousands of square miles; others, such as gobies and reef fishes, have small home ranges and restricted distributions (Helfman et al. 2009). The movements of some open-ocean species may never overlap with coastal fishes that spend their lives within several hundred feet of the shore. The distribution and specific habitats in which an individual of a single fish species occurs may be influenced by its developmental stage, size, sex, reproductive condition, and other factors. There are approximately 1,106 marine fish species in the coastal zone of the Study Area (Myers and Donaldson 2003).

For analyses of impacts on those habitats included as EFH within the Study Area, refer to Sections 3.3 (Marine Habitats), 3.7 (Marine Vegetation), and 3.8 (Marine Invertebrates).

3.9.1.1 Endangered Species Act Species

There is only one marine fish species, scalloped hammerhead shark (*Sphyrna* lewini), in the Study Area that is listed as threatened under the ESA (Table 3.9-1 and Section 3.9.2.3, Scalloped Hammerhead Shark). Two species are listed as a candidate that may be listed as threatened or endangered in the future, and one species is listed as a species of concern. The NMFS has some concerns regarding status and threats for species of concern, but insufficient information is available to indicate a need to list the species under the ESA. Species of concern status does not carry any procedural or substantive protections under the ESA. Marine fishes listed under the ESA as threatened, candidate species, and species of concern are listed in Table 3.9-1. All the species listed in Table 3.9-1 have been on decline because of impacts from fishing (including night spear fishing, bycatch, and illegal fishing activities) and habitat degradation.

Table 3.9-1: Endangered Species Act Listed and Special Status Fish Species in the Mariana Islands Training and Testing Study Area

Species Name and Regulatory Status			Presence in Study Area	
Common Name	**Scientific Name**	**Endangered Species Act Status**	**Open Ocean**	**Coastal Ocean**
Scalloped hammerhead shark	*Sphyrna lewini*	Threatened (Indo-West Pacific Distinct Population Segment)	Yes	Yes
Humpheaded wrasse	*Cheilinus undulatus*	Candidate Species	No	Yes
Great hammerhead shark	*Sphyrna mokarran*	Candidate Species	Yes	Yes
Bumphead parrotfish	*Bolbometopon muricatum*	Species of Concern	No	Yes

3.9.1.2 Taxonomic Groups

Groups of marine fish are provided in Table 3.9-2 and are described further in Section 3.9.2 (Affected Environment). These fish groups are based on the organization presented in Helfman et al. (1997), Moyle and Cech (1996), and Nelson (2006). These groupings are intended to organize the extensive and diverse list of fish that occur in the Study Area, as a means to structure the analysis of potential impacts to fish with similar ecological niches, behavioral characteristics, and habitat preferences. Exceptions to these generalizations exist within each group, and are noted wherever appropriate in the analysis of potential impacts.

Table 3.9-2: Major Taxonomic Groups of Marine Fishes within the Mariana Islands Training and Testing Study Area

Major Marine Fish Groups[1]		Vertical Distribution Within Study Area	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
Jawless fishes (order Myxiniformes and order Petromyzontiformes)	Primitive fishes with an eel-like body shape that feed on dead fishes or are parasitic on other fishes	Water column, seafloor	Seafloor
Sharks, skates, rays, and chimaeras (class Chondrichthyes)	Cartilaginous (non-bony) fishes, many of which are open-ocean predators	Surface, water column, seafloor	Surface, water column, seafloor
Eels and bonefishes (order Anguilliformes, order Elopiformes)	Undergo a unique willow leaf-shaped larval stage with a small head and often an elongated body; very different from other fishes	Surface, water column, seafloor	Surface, water column, seafloor
Herrings (order Clupeiformes)	Commercially valuable schooling plankton eaters such as herrings, sardines, menhaden, and anchovies	Surface, water column	Surface, water column
Dragonfishes and lanternfishes (orders Stomiiformes and Myctophiformes)	Largest group of deepwater fishes, some have adaptations for low-light conditions	Water column, seafloor	Water column, seafloor
Greeneyes, lizardfishes, lancetfishes, and telescopefishes (order Aulopiformes)	Have both primitive and advanced features of marine fishes; includes both coastal and estuarine species, as well as deepsea fish that occur in midwaters and along the bottom.	Seafloor	Water column, seafloor
Cods (orders Gadiformes and Ophidiiformes)	Are associated with bottom habitats, also includes some deepwater groups. Most have a distinctive barbel (a slender tactile organ) below the mouth.	Water column, seafloor	Water column, seafloor
Toadfishes and anglerfishes (orders Batrachoidiformes and Lophiiformes)	Includes the sound-producing toadfishes and the anglerfishes, a classic lie-in-wait predator	Seafloor	Seafloor
Mullets, silversides, and needlefishes (orders Mugiliformes, Atheriniformes, and Beloniformes)	Small-sized nearshore/coastal fishes (within 3 nm of shoreline), primarily feed on organic debris; also includes the surface-oriented flyingfishes	Surface	Surface, water column, seafloor
Oarfishes, squirrelfishes, dories (orders Lampridiformes, Beryciformes, Zeiformes)	Primarily open-ocean or deepwater fishes, except for squirrelfishes (reef-associated)	Surface, water column, seafloor	Surface, water column, seafloor

Table 3.9-2: Major Taxonomic Groups of Marine Fishes within the Mariana Islands Training and Testing Study Area (continued)

Major Marine Fish Groups[1]		Vertical Distribution Within Study Area	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
Pipefishes and seahorses (order Gasterosteiformes)	Small mouth with tubular snout and armor like scales; males care for young in nests or pouches	-	Surface, water column, seafloor
Scorpionfishes (order Scorpaeniformes)	Bottom dwelling with modified pectoral fins to rest on the bottom. Many are venomous.	Seafloor	Seafloor
Snappers, drums, and croakers (families Sciaenidae and Lutjanidae)	Important gamefishes and common predators in all marine waters; sciaenids produce sounds with their swim bladders	Surface, water column, seafloor	Surface, water column, seafloor
Groupers and seabasses (order Perciformes,[2] with representative families; Serranidae)	Important gamefish with vulnerable conservation status; in some species, individuals change from female to male as they mature.	Water column, seafloor	Surface, water column, seafloor
Wrasses, damselfishes (family Pomacentridae), and parrotfishes (families Labridae and Scaridae)	Primarily reef-associated fish; in some species, individuals change from female to make as they mature.	-	Surface, water column, seafloor
Gobies and blennies (families Gobiidae and Blennidae)	Gobies are the largest and most diverse family of marine fish, mostly found in bottom habitats of coastal areas.	Surface, water column, seafloor	Surface, water column, seafloor
Jacks, tunas, mackerels, and billfish (order Perciformes,[2] with representative families: Carangidae, Scombridae, Xiphiidae, and Istiophoridae)	Highly migratory predators found near the surface; commercially valuable fisheries.	Surface, water column, seafloor	Surface, water column
Flounders (order Pleuronectiformes)	Flatfish lack swim bladders, are well camouflaged, and occur in bottom habitats throughout the world.	Seafloor	Seafloor
Triggerfishes, puffers, and molas (order Tetraodontiformes)	Unique body shapes and characteristics to deter predators (e.g., spines); includes ocean sunfish, the largest bony fish	Surface, water column, seafloor	Surface, water column, seafloor

[1] Taxonomic groups are based on the following commonly accepted references (Moyle and Cech 1996; Helfman et al. 1997; Nelson 2006).
[2] Order Perciformes includes approximately 40 percent of all bony fish and includes highly diverse fish. Representative families are included here to reflect this diversity.
Notes: nm = nautical miles, Study Area = Mariana Islands Training and Testing Study Area

3.9.1.3 Federally Managed Species

The fisheries of the United States are managed within a framework of overlapping international, federal, state, interstate, and tribal authorities. Individual states and territories generally have jurisdiction over fisheries in marine waters within 3 nautical miles (nm) (12 nm for territories) of their coast. Federal jurisdiction includes fisheries in marine waters inside the U.S. Exclusive Economic Zone, which encompasses the area from the outer boundary of state or territorial waters out to 200 nm offshore of any U.S. coastline, except where intersected closer than 200 nm by bordering countries (National Oceanic and Atmospheric Administration 1996).

The Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act (see Section 3.0.1.1, Federal Statutes) led to the formation of eight fishery management councils that share authority with NMFS to manage and conserve the fisheries in federal waters. Essential Fish Habitat is also identified and managed under this act. For analyses of impacts on those habitats included as EFH within the Study Area, refer to Sections 3.3 (Marine Habitats), 3.7 (Marine Vegetation), and 3.8 (Marine Invertebrates). Together with NMFS, the councils maintain fishery management plans for species or species groups to regulate commercial and recreational fishing within their geographic regions. The Study Area is under the jurisdiction of the Western Pacific Regional Fishery Management Council.

Federally managed marine fish species are listed in Table 3.9-3. These species are also given consideration as recreationally and commercially important species in the analysis of impacts in Section 3.9.3 (Environmental Consequences). The analysis of impacts on commercial and recreational fisheries is provided in Section 3.12 (Socioeconomic Resources).

Table 3.9-3: Federally Managed Fish Species within the Mariana Islands Training and Testing Study Area, Listed under Each Fishery Management Unit

Western Pacific Regional Fishery Management Council	
Marianas Bottomfish Management Unit	
Common Name	**Scientific Name**
Amberjack	*Seriola dumerili*
Black trevally/jack	*Caranx lugubris*
Blacktip grouper	*Epinephelus fasciatus*
Blueline snapper	*Lutjanus kasmira*
Giant trevally/jack	*Caranx ignobilis*
Gray snapper	*Aprion virescens*
Lunartail grouper	*Variola louti*
Pink snapper	*Pristipomoides filamentosus*
Pink snapper	*Pristipomoides flavipinnis*
Red snapper/silvermouth	*Aphareus rutilans*
Red snapper/buninas agaga	*Etelis carbunculus*
Red snapper/buninas	*Etelis coruscans*
Redgill emperor	*Lethrinus rubrioperculatus*
Snapper	*Pristipomoides zonatus*
Yelloweye snapper	*Pristipomoides flavipinnis*
Yellowtail snapper	*Pristipomoides auricilla*
Marianas Coral Reef Ecosystem Management Unit	
Banded goatfish	*Parupeneus spp.*
Bantail goatfish	*Upeneus arge*
Barred flag-tail	*Kuhlia mugil*
Barred thicklip	*Hemigymnus fasciatus*
Bigeye	*Priacanthus hamrur*
Bigeye scad	*Selar crumenophthalmus*

Table 3.9-3: Federally Managed Fish Species within the Mariana Islands Training and Testing Study Area, Listed under Each Fishery Management Unit (continued)

Western Pacific Regional Fishery Management Council	
Marianas Coral Reef Ecosystem Management Unit (continued)	
Common Name	**Scientific Name**
Bignose unicornfish	*Naso vlamingii*
Bigscale soldierfish	*Myripristis berndti*
Black tongue unicornfish	*Naso hexacanthus*
Black triggerfish	*Melichthys niger*
Blackeye thicklip	*Hemigymnus melapterus*
Blackstreak surgeonfish	*Acanthurus nigricauda*
Blacktip reef shark	*Carcharhinus melanopterus*
Blotcheye soldierfish	*Myripristis murdjan*
Blue-banded surgeonfish	*Acanthurus lineatus*
Blue-lined squirrelfish	*Sargocentron tiere*
Bluespine unicornfish	*Naso unicornus*
Brick soldierfish	*Myripristis amaena*
Bronze soldierfish	*Myripristis adusta*
Cigar wrasse	*Cheilio inermis*
Clown triggerfish	*Balistoides conspicillum*
Convict tang	*Acanthurus triostegus*
Crown squirrelfish	*Sargocentron diadema*
Dash-dot goatfish	*Parupeneus barberinus*
Dogtooth tuna	*Gymnosarda unicolor*
Doublebar goatfish	*Parupeneus bifasciatus*
Engel's mullet	*Moolgarda engeli*
Floral wrasse	*Cheilinus chlorourus*
Forktail rabbitfish	*Siganus aregentus*
Fringelip mullet	*Crenimugil crenilabis*
Galapagos shark	*Carcharhinus galapagensis*
Giant moray eel	*Gymnothorax javanicus*
Glasseye	*Heteropriacanthus cruentatus*
Golden rabbitfish	*Siganus guttatus*
Gold-spot rabbitfish	*Siganus punctatissimus*
Gray unicornfish	*Naso caesius*
Great barracuda	*Sphyraena barracuda*
Grey reef shark	*Carcharhinus amblyrhynchos*
Heller's barracuda	*Sphyraena helleri*
Humphead parrotfish	*Bolbometopon muricatum*
Humpnose unicornfish	*Naso tuberosus*
Longface wrasse	*Hologynmosus doliatus*

Table 3.9-3: Federally Managed Fish Species within the Mariana Islands Training and Testing Study Area, Listed under Each Fishery Management Unit (continued)

Western Pacific Regional Fishery Management Council	
Marianas Coral Reef Ecosystem Management Unit (continued)	
Common Name	**Scientific Name**
Mackerel scad	*Decapterus macarellus*
Mimic surgeonfish	*Acanthurus pyroferus*
Multi-barred goatfish	*Parupeneus multifaciatus*
Napoleon wrasse	*Cheilinus undulates*
Orange-spot surgeonfish	*Acanthurus olivaceus*
Orangespine unicornfish	*Naso lituratus*
Orangestriped triggerfish	*Balistapus undulates*
Pacific longnose parrotfish	*Hipposcarus longiceps*
Parrotfish	*Scarus spp.*
Pearly soldierfish	*Myripristis kuntee*
Pinktail triggerfish	*Melichthys vidua*
Razor wrasse	*Xyrichtys pavo*
Red-breasted wrasse	*Cheilinus fasciatus*
Ring-tailed wrasse	*Oxycheilinus unifasciatus*
Ringtail surgeonfish	*Acanthurus blochii*
Rudderfish	*Kyphosus biggibus*
Rudderfish	*Kyphosus cinerascens*
Rudderfish	*Kyphosus vaigienses*
Saber or long jaw squirrelfish	*Sargocentron spiniferum*
Scarlet soldierfish	*Myripristis pralinia*
Scribbled rabbitfish	*Siganus spinus*
Side-spot goatfish	*Parupeneus pleurostigma*
Silvertip shark	*Carcharhinus albimarginatus*
Spotfin squirrelfish	*Neoniphon spp.*
Spotted unicornfish	*Naso brevirostris*
Stareye parrotfish	*Calotomus carolinus*
Striped bristletooth	*Ctenochaetus striatus*
Stripped mullet	*Mugil cephalus*
Surge wrasse	*Thalassoma purpureum*
Tailspot squirrelfish	*Sargocentron caudimaculatum*
Threadfin	*Polydactylus sexfilis*
Three-spot wrasee	*Halicoeres trimaculatus*
Titan triggerfish	*Balistoides viridescens*
Triple-tail wrasee	*Cheilinus trilobatus*
Twospot bristletooth	*Ctenochaetus binotatus*
Undulated moray eel	*Gymnothorax undulatus*
Vermiculate rabbitfish	*Siganus vermiculatus*

Table 3.9-3: Federally Managed Fish Species within the Mariana Islands Training and Testing Study Area, Listed under Each Fishery Management Unit (continued)

Western Pacific Regional Fishery Management Council	
Marianas Coral Reef Ecosystem Management Unit (continued)	
Common Name	**Scientific Name**
Violet soldierfish	*Myripristis violacea*
White-lined goatfish	*Parupeneus ciliatus*
White-spotted surgeonfish	*Acanthurus guttatus*
Whitebar surgeonfish	*Acanthurus leucopareius*
Whitecheek surgeonfish	*Acanthurus nigricans*
Whitemargin unicornfish	*Naso annulatus*
Whitepatch wrasse	*Xyrichtys aneitensis*
Whitetip reef shark	*Triaenodon obesus*
Whitetip soldierfish	*Myripristis vittata*
Yellow goatfish	*Mulloidichthys spp.*
Yellow tang	*Zebrasoma flavescens*
Yellowfin goatfish	*Mulloidichthys vanicolensis*
Yellowfin soldierfish	*Myripristis chryseres*
Yellowfin surgeonfish	*Acanthurus xanthopterus*
Yellowmarfin moray eel	*Gymnothorax flavimarginatus*
Yellowsaddle goatfish	*Parupeneus cyclostomas*
Yellowstripe goatfish	*Mylloidichthys flaviolineatus*
Guam and Northern Mariana Islands Pelagic Fisheries	
Dogtooth tuna	*Gymnosarda unicolor*
Double-lined mackerel	*Grammatorcynus bilineatus*
Kawakawa	*Euthynnus affinis*
Mahi	*Coryphaena hippurus*
Oilfish	*Ruvettus pretiosus*
Pacific blue marlin	*Makaira mazara*
Rainbow runner	*Elagatis bipinnulatus*
Skipjack tuna	*Katsuwonus pelamis*
Wahoo	*Acanthocybium solandri*
Yellowfin tuna	*Thunnus albacares*

3.9.2 Affected Environment

The distribution and abundance of fishes depends greatly on the physical and biological factors of the marine ecosystem, such as salinity, temperature, dissolved oxygen, population dynamics, predator and prey interaction oscillations, seasonal movements, reproduction and life cycles, and recruitment success (the success of an individual reaching a specific size or reproductive stage) (Helfman et al. 2009). A single factor is rarely responsible for the distribution of fish species; more often, a combination of factors is accountable. For example, open-ocean species optimize their growth, reproduction, and survival by tracking gradients of temperature, oxygen, or salinity (Helfman et al. 2009). Another major component in understanding species distribution is the location of highly productive regions, such as frontal zones (i.e., areas where two or more bodies of water with different oceanographic characteristics meet).

These areas concentrate various prey species and their predators and provide visual cues for the location of target species for commercial fisheries (National Marine Fisheries Service 2001).

Environmental variations, such as the Pacific decadal oscillation events (e.g., El Niño or La Niña), change the normal water temperatures in an area which affects the distribution, habitat range, and movement of open-ocean species (Adams et al. 2002; Sabarros et al. 2009; Bakun et al. 2010) within the Study Area. Pacific decadal oscillation events have caused the distribution of fisheries, such as that of the skipjack tuna (*Katsuwonus pelamis*), to shift by more than 620 miles (mi.) (997.8 kilometers [km]) (National Marine Fisheries Service 2001; Stenseth et al. 2002).

Currently 1,106 species of coastal zone fishes are known to occur around the Mariana Islands within the Study Area. The species found in the Study Area include widespread Indo-Pacific species (58 percent), circumtropical species (3.6 percent), Indo-west Pacific and west Pacific species (17.6 percent), west-central Pacific and Pacific Plate species (18.3 percent), and species confined to specific geographic areas, such as Micronesia, the Philippine plate and endemic to the Marianas (2.5 percent) (Myers and Donaldson 2003). Only 10 of the shallow water species found in the Study Area are endemic to the Mariana Islands (Myers and Donaldson 2003). Migratory open-ocean fishes, such as the larger tunas, the billfishes, and some sharks, are able to move across the great distance that separates the Mariana Islands from other islands or continents in the Pacific. Coral reef fish communities in the Mariana Islands tend to show a more consistent pattern of species throughout the year.

3.9.2.1 Hearing and Vocalization

Many researchers have investigated hearing and vocalizations in fish species (e.g., Astrup 1999; Hawkins and Johnstone 1978; Coombs and Popper 1979; Dunning et al. 1992; Astrup and Møhl 1993; Casper et al. 2003; Gregory and Clabburn 2003; Egner and Mann 2005; Casper and Mann 2006; Higgs et al. 2004; Iversen 1967; Iversen 1969; Jørgensen et al. 2005; Kenyon 1996; Meyer et al. 2010; Popper 1981; Popper and Tavolga 1981; Mann et al. 1997; Popper and Carlson 1998; Mann et al. 2001; Myrberg 2001; Ramcharitar et al. 2001; Nestler 2002; Sisneros and Bass 2003; Ramcharitar and Popper 2004; Ramcharitar et al. 2004; Mann et al. 2005; Wright et al. 2005; Ramcharitar et al. 2006; Remage-Healey et al. 2006; Song et al. 2006; Wright et al. 2007; Popper 2008).

All fish have two sensory systems to detect sound in the water: the inner ear, which functions very much like the inner ear in other vertebrates, and the lateral line, which consists of a series of receptors along the fish's body (Popper and Schilt 2008). The inner ear generally detects relatively higher-frequency sounds, while the lateral line detects water motion at low frequencies (below a few hundred Hertz [Hz]) (Hastings and Popper 2005).

Although hearing capability data only exist for fewer than 100 of the 32,000 fish species, current data suggest that most species of fish detect sounds from 50 to 1,000 Hz (low frequency), with few fish hearing sounds above 4,000 Hz (mid-frequency) (Popper 2008). It is believed that most fish have their best hearing sensitivity from 100 to 400 Hz (low frequency) (Popper 2003). Additionally, some clupeids (shad in the subfamily Alosinae) possess very high frequency hearing (i.e., able to detect sounds above 100,000 Hz) (Astrup 1999).

The inner ears of fish are directly sensitive to acoustic particle motion rather than acoustic pressure (for a more detailed discussion of particle motion versus pressure, see Section 3.0.4, Acoustic and Explosives Primer). Although a propagating sound wave contains both pressure and particle motion components, particle motion is most significant at low frequencies (less than a few hundred Hz) and closer to the sound source. However, a fish's gas-filled swim bladder can enhance sound detection by converting acoustic pressure into localized particle motion, which may then be detected by the inner ear. Fish with swim bladders generally have better sensitivity and better high-frequency hearing than fish without swim bladders (Popper and Fay 2010). Some fish also have specialized structures such as small gas bubbles or gas-filled projections that terminate near the inner ear. These fish have been called "hearing specialists," while fish that do not possess specialized structures have been referred to as "generalists" (Popper et al. 2003). In reality many fish species possess a continuum of anatomical specializations that may enhance their sensitivity to pressure (versus particle motion), and thus higher frequencies and lower intensities (Popper and Fay 2010).

Past studies indicated that hearing specializations in marine fish were quite rare (Popper 2003; Amoser and Ladich 2005). However, more recent studies have shown that there are more fish species than originally investigated by researchers, such as deep sea fish, that may have evolved structural adaptations to enhance hearing capabilities (Buran et al. 2005; Deng et al. 2011). Marine fish families Holocentridae (squirrelfish and soldierfish), Pomacentridae (damselfish), Gadidae (cod, hakes, and grenadiers), and Sciaenidae (drums, weakfish, and croakers) have some members that can potentially hear mid-frequency sound up to a few kilohertz (kHz). There is also evidence, based on the structure of the ear and the relationship between the ear and the swim bladder, that at least some deep-sea species, including myctophids, may have hearing specializations and thus be able to hear higher frequencies (Popper 1977; Popper 1980; Deng et al. 2011), although it has not been possible to do actual measures of hearing on these fish from great depths.

Several species of reef fish tested have shown sensitivity to mid-frequencies (i.e., over 1000 Hz). The hearing of the shoulderbar soldierfish (*Myripristis kuntee*) has a mid-frequency auditory range extending toward 3 kHz (Coombs and Popper 1979), while other species tested in this family have been demonstrated to lack this mid-frequency hearing ability (e.g., Hawaiian squirrelfish [*Adioryx xantherythrum*] and saber squirrelfish [*Sargocentron spiniferum*]). Some damselfish can hear frequencies of up to 2 kHz, but with best sensitivity well below 1 kHz (Kenyon 1996; Egner and Mann 2005; Wright et al. 2005; Wright et al. 2007).

Sciaenid research by Ramcharitar et al. (2006) investigated the hearing sensitivity of weakfish (*Cynoscion regalis*). Weakfish were found to detect frequencies up to 2 kHz. The sciaenid with the greatest hearing sensitivity discovered thus far is the silver perch (*Bairdiella chrysoura*), which has responded to sounds up to 4 kHz (Ramcharitar et al. 2004). Other species tested in the family Sciaenidae have been demonstrated to lack this mid-frequency sensitivity.

It is possible that the Atlantic cod (*Gadus morhua,* Family: Gadidae) is also able to detect high-frequency sounds (Astrup and Mohl 1993). However, in Astrup and Mohl's (1993) study it is feasible that the cod was detecting the stimulus using touch receptors that were over driven by very intense fish-finding sonar emissions (Astrup 1999; Ladich and Popper 2004). Nevertheless, Astrup and Mohl (1993) indicated that cod have high frequency thresholds of up to 38 kHz at 185 to 200 decibels (dB) referenced to (re) 1 micropascal (μPa), which likely only allows for detection of odontocete's clicks at distances no greater than 33 to 98 feet (ft.) (10.06 to 29.9 meters [m]) (Astrup 1999).Experiments on several species of the Clupeidae (i.e., herrings, shads, and menhadens) have obtained responses to frequencies between 40 kHz and 180 kHz (Astrup 1999); however, not all clupeid species tested have demonstrated this very high-frequency hearing. Mann et al. (1998) reported that the American shad can detect sounds from 0.1 to 180 kHz with two regions of best sensitivity: one from a low-frequency region (0.2 to 0.8 kHz), and the other from a mid-to high-frequency region (25 kHz to 150 kHz). This shad species has relatively high thresholds (about 145 dB re 1 µPa), which should enable the fish to detect odontocete clicks at distances up to about 656 ft. (199.9 m) (Mann et al. 1997). Likewise, other members of the subfamily Alosinae, including Alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and Gulf menhaden (*Brevoortia patronus*), have upper hearing thresholds exceeding 100 to 120 kHz. In contrast, the Clupeidae bay anchovy (*Anchoa mitchilli*), scaled sardine (*Harengula jaguana*), and Spanish sardine (*Sardinella aurita*) did not respond to frequencies over 4 kHz (Mann et al. 2001; Gregory and Clabburn 2003). Mann et al. (2005) found hearing thresholds of 0.1 kHz to 5 kHz for Pacific herring (*Clupyea pallasii*).

Two other groups to consider are the jawless fish (Superclass: Agnatha—lamprey) and the cartilaginous fish (Class: Chondrichthyes—the sharks, rays, and chimeras). While there are some lampreys in the marine environment, virtually nothing is known about their hearing capability. They do have ears, but these are relatively primitive compared to the ears of other vertebrates, and it is unknown whether they can detect sound (Popper and Hoxter 1987). While there have been some studies on the hearing of cartilaginous fish, these have not been extensive. However, available data suggest detection of sounds from 20 to 1000 Hz, with best sensitivity at lower ranges (Myrberg 2001; Casper et al. 2003; Casper and Mann 2006; Casper and Mann 2009). It is likely that elasmobranchs only detect low-frequency sounds because they lack a swim bladder or other pressure detector.

Most other marine species investigated to date lack mid-frequency hearing (i.e., greater than 1,000 Hz). This notably includes sturgeon species tested to date that could detect sound up to 400 or 500 Hz (Meyer et al. 2010; Lovell et al. 2005) and Atlantic salmon that could detect sound up to about 500 Hz (Hawkins and Johnstone 1978; Kane et al. 2010).

Bony fish can produce sounds in a number of ways and use them for a number of behavioral functions (Ladich 2008). Over 30 families of fish are known to use vocalizations in aggressive interactions, whereas over 20 families known to use vocalizations in mating (Ladich 2008). Sound generated by fish as a means of communication is generally low-frequency below 500 Hz (Slabbekoorn et al. 2010). The air in the swim bladder is vibrated by the sound producing structures (often muscles that are integral to the swim bladder wall) and radiates sound into the water (Zelick et al. 1999). Sprague and Luczkovich (2004) calculated that silver perch (*Bidyanus bidyanus*) can produce drumming sounds ranging from 128 to 135 dB re 1 µPa. Female midshipman fish (genus Porichthys) apparently use the auditory sense to detect and locate vocalizing males during the breeding season (Sisneros and Bass 2003).

3.9.2.2 General Threats

This section covers the existing condition of marine fish as a resource and presents some of the major threats to that resource within the Study Area. Human impacts are widespread throughout the world's oceans, such that very few habitats remain unaffected by human influence (Halpern et al. 2008). These stressors have shaped the condition of marine fish populations, particularly those species with large body sizes and late maturity ages, because these species are especially vulnerable to habitat losses and fishing pressure (Reynolds et al. 2005). This trend is evidenced by the world's shark species, which make up 60 percent of the marine fishes of conservation concern (International Union for Conservation of Nature 2009). Furthermore, the conservation status of only 3 percent of the world's marine fish species has been evaluated, so the threats to the remaining species are largely unknown at this point (Reynolds et al. 2005).

Overfishing is the most serious threat that has led to the listing of ESA-protected marine species (Kappel 2005; Crain et al. 2009), with habitat loss also contributing to extinction risk (Jonsson et al. 1999; Musick et al. 2000; Dulvy et al. 2003; Cheung et al. 2007; Limburg and Waldman 2009). Approximately 30 percent of the fishery stocks managed by the United States are overfished (U.S. Fish and Wildlife Service and National Marine Fisheries Service 2009). Overfishing occurs when fish are harvested in quantities above a sustainable level. Overfishing impacts both targeted species and non-targeted species (or "bycatch" species) that are often important in marine food webs. Bycatch may also include seabirds, turtles, and marine mammals. In recent decades marine fisheries have targeted species lower on the food chain as the abundance of higher-level predators has decreased; some entire marine food webs have collapsed as a result (Pauly and Palomares 2005; Crain et al. 2009). Other factors, such as fisheries-induced evolution and intrinsic vulnerability to overfishing, have been shown to reduce the abundance of some populations (Kuparinen and Merila 2007). Fisheries-induced evolution is a change in genetic composition of the population, such as a reduction in the overall size of fish and individual growth rates resulting from intense fishing pressure. Intrinsic vulnerability describes certain life history traits (e.g., large body size, late maturity age, low growth rate), which increases the susceptibility of a species to overfishing (Cheung et al. 2007).

Pollution primarily impacts coastal fish near the sources of pollution. However, global oceanic circulation patterns result in a considerable amount of marine pollutants and debris scattered throughout the open ocean (Crain et al. 2009). Pollutants in the marine environment that may impact marine fish include organic contaminants (e.g., pesticides, herbicides, polycyclic aromatic hydrocarbons, flame retardants, and oil from run-off), inorganic chemicals (e.g., heavy metals), and debris (e.g., plastics and waste from dumping at sea) (Pew Oceans Commission 2003). High chemical pollutant levels in marine fish may cause behavioral changes, physiological changes, or genetic damage in some species (Pew Oceans Commission 2003; van der Oost et al. 2003; Goncalves et al. 2008; Moore 2008). Bioaccumulation of metals and organic pollutants is also a concern, particularly in terms of human health, because people consume top predators with potentially high pollutant loads. Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism directly from contaminated water or sediment through the gills or skin, from ingesting food containing the substance (Newman 1998), or from ingestion of the substance itself (Moore 2008).

Entanglement in abandoned commercial and recreational fishing gear has also caused pollution-related declines for some marine fishes; some species are more susceptible to entanglement by marine debris than others (Musick et al. 2000).

Other human-caused stressors on marine fish are invasive species, climate change, aquaculture, energy production, vessel movement, and underwater noise:

- Non-native fish pose threats to native fish when they are introduced into an environment lacking natural predators and then compete with, and prey upon, native marine fish for resources (Whitfield et al. 2007; Crain et al. 2009), such as lionfish in the southeastern United States and the Caribbean.
- Global climate change is contributing to a shift in fish distribution from lower to higher latitudes (Glover and Smith 2003; Brander 2007; Limburg and Waldman 2009; Brander 2010; Dufour et al. 2010; Wilson et al. 2010).
- The threats of aquaculture operations on wild fish populations are reduced water quality, competition for food, predation by escaped or released farmed fish, spread of disease, and reduced genetic diversity (Ormerod 2003; Kappel 2005; Hansen and Windsor 2006). The National Oceanic and Atmospheric Administration is developing an aquaculture policy aimed at

promoting sustainable marine aquaculture (National Oceanic and Atmospheric Administration 2011).

- Energy production and offshore activities associated with power-generating facilities result in direct and indirect fish injury or mortality from two primary sources; including cooling water withdrawal that results in entrainment mortality of eggs and larvae and impingement mortality of juveniles and adults (U.S. Environmental Protection Agency 2004), and offshore wind energy development that results in acoustic impacts (Madsen et al. 2006).
- Vessel strikes pose threats to some large, slow-moving fish at the surface, although this is not considered a major threat to most marine fish (Kappel 2005). However, some species such as whale sharks, basking sharks, ocean sunfish, and manta rays have been struck by vessels (The Hawaii Association for Marine Education and Research Inc. 2005; Rowat et al. 2007; Stevens 2007; National Marine Fisheries Service 2010).
- Underwater noise is a threat to marine fish. However, the physiological and behavioral responses of marine fish to underwater noise (Popper 2003; Codarin et al. 2009; Slabbekoorn et al. 2010; Wright et al. 2010) have been investigated for only a limited number of fish species (Popper and Hastings 2009a, b). In addition to vessels, other sources of underwater noise include pile-driving activity (Feist et al. 1992; California Department of Transportation 2001; Nedwell et al. 2003; Popper et al. 2006; Carlson et al. 2007; Mueller-Blenkle et al. 2010, Halvorsen et al. 2012a) and seismic activity (Popper and Hastings 2009a). Information on fish hearing is provided in Section 3.9.2.1 (Hearing and Vocalization), with further discussion in Section 3.9.3.1 (Acoustic Stressors).

3.9.2.3 Scalloped Hammerhead Shark (*Sphyrna lewini*)

3.9.2.3.1 Status and Management

In August 2011, NMFS received a petition to list the scalloped hammerhead shark as threatened or endangered under the ESA and to designate critical habitat concurrently with the listing (National Marine Fisheries Service 2011). In 2013, based on the best scientific and commercial information available, including the status review report (Miller et al. 2013), and other information available since completion of the status review report, NMFS determined that the species is comprised of six distinct population segments (DPSs) that qualify as species under the ESA: Northwest (NW) Atlantic and Gulf of Mexico (GOM) DPS, Central and Southwest (SW) Atlantic DPS, Eastern Atlantic DPS, Indo-West Pacific DPS, Central Pacific DPS, and Eastern Pacific DPS. After reviewing the best available scientific and commercial information on the DPSs, NMFS determined that two DPSs warrant listing as endangered, the Eastern Atlantic and Eastern Pacific DPSs; two DPSs warrant listing as threatened, the Central and SW Atlantic and Indo-West Pacific DPSs; and two DPSs do not warrant listing at this time, the NW Atlantic and GOM DPS, and the Central Pacific DPS. The Indo-West Pacific DPS is the only one located within the Study Area.

3.9.2.3.2 Habitat and Geographic Range

The scalloped hammerhead shark is circumglobal, occurring in all temperate to tropical waters (Duncan and Holland 2006) from the surface to depths of 512 m (1,600 feet [ft.]) and possibly deeper (Miller et al. 2014). It typically inhabits nearshore waters of bays and estuaries where water temperatures are at least 22 degrees (°) Celsius (C) (72° Fahrenheit [F]) (Castro 1983; Compagno 1984, Ketchum et al. 2014). The scalloped hammerhead shark remains close to shore during the day and moves to deeper waters at night to feed (Bester 1999). A genetic marker study suggests that females typically remain close to coastal habitats, while males are more likely to disperse across larger open ocean areas (Daly-Engel et al. 2012).

3.9.2.3.3 Population and Abundance

NMFS data and information provided in the listing petition suggest that the scalloped hammerhead shark has undergone substantial declines throughout its range (National Marine Fisheries Service 2011). Specific information for scalloped hammerhead shark in the Indo-West Pacific region is unavailable as only data for overall shark population estimates are available. In its 2013 status review, NMFS used two models to estimate the overall population of scalloped hammerhead sharks as ranging from approximately 142,000 to 169,000 individuals in 1981 and between 24,000 and 28,000 individuals in 2005 (Miller et al. 2014).

3.9.2.3.4 Predator and Prey Interactions

Scalloped hammerhead sharks follow daily vertical movement patterns within their home range (Holland et al. 1993; Klimley and Nelson 1984) and feed primarily at night (Compagno 1984). They are a high trophic level predator and feed opportunistically on all types of teleost fish, cephalopods, crustaceans, and rays (Bethea et al. 2011; Compagno 1984; Torres-Rojas et al. 2010; Torres-Rojas et al. 2014; Vaske et al. 2009).

3.9.2.3.5 Species-Specific Threats

The primary threat to the scalloped hammerhead shark is direct take, especially by the foreign commercial shark fin market (National Marine Fisheries Service 2011). Scalloped hammerhead sharks are a principal component of the total shark bycatch in the swordfish and tuna longline fishery and are particularly susceptible to overfishing and bycatch in gillnet fisheries because of schooling habits (Food and Agriculture Organization of the United Nations 2012). Longline mortality for this species is estimated between 91 and 94 percent (National Marine Fisheries Service 2011).

3.9.2.4 Jawless Fishes (Orders Myxiniformes and Petromyzontiformes)

Hagfish (Myxiniformes) are the most primitive fish group (Nelson 2006). In fact, recent taxonomic revisions suggest that Myxiniformes are not fish at all but are a “sister” group to all vertebrates (Nelson 2006). However, jawless fish are generally thought of as fish and are therefore included in this section. Hagfish occur exclusively in marine habitats and are represented by 70 species worldwide in temperate marine locations. This group feeds on dead or dying fishes and have very limited external features often associated with fishes, such as fins and scales (Helfman et al. 2009). The members of this group are important scavengers that recycle nutrients back through the ecosystem.

No lampreys have been recorded in the Study Area, and only one species of hagfish has been recorded at depths greater than 650 ft. (200 m) (Myers and Donaldson 2003).

3.9.2.5 Sharks, Rays, and Chimaeras (Class Chondrichthyes)

The cartilaginous (non-bony) marine fishes of the class Chondrichthyes are distributed throughout the world’s oceans, occupying all areas of the water column (Paxton and Eschmeyer 1998). This group is mainly predatory and contains many of the apex predators found in the ocean (e.g., great white shark, mako shark, and tiger shark) (Helfman et al. 1997). The whale shark and basking shark are notable exceptions as filter-feeders. Sharks and rays have some unique features among marine fishes; no swim bladder; protective toothlike scales; unique sensory systems (electroreception, mechanoreception); and some species bear live young in a variety of life history strategies (Moyle and Cech 1996). The subclass Elasmobranchii contains more than 850 marine species, including sharks, rays and skates, spread across nine orders (Nelson 2006). Very little is known about the subclass Holocephali, which contains 58 marine species of chimaeras (Nelson 2006).

Sharks and rays occupy relatively shallow temperate and tropical waters throughout the world. More than half of these species occur in less than 655 ft. (199.6 m) of water, and nearly all are found at depths less than 6,560 ft. (1,999.5 m) (Nelson 2006). Sharks and rays are found in all open-ocean areas and coastal waters of the Study Area (Paxton and Eschmeyer 1998). While most sharks occur in the water column, many rays occur on or near the seafloor. In May 2007, a whale shark was sighted in the Study Area, halfway between Saipan and Farallon de Medinilla (FDM) (Vogt 2008). A manta ray was observed off of Guam in March 2012 during a cetacean survey (HDR EOC 2012). Chimaeras are cool-water benthic marine fishes that are found on seafloors at depths between 260 and 8,500 ft. (79.2 and 2,590.8 m) (Nelson 2006). They may occur in the open-ocean portions of the Study Area (Paxton and Eschmeyer 1998).

3.9.2.6 Eels and Bonefishes (Orders Anguilliformes and Elopiformes)

These fishes have a unique larval stage, called leptocephalus, in which leptocephali grow to much larger sizes during an extended larval period as compared to most other fishes. The eels (Anguilliformes) have an elongated snakelike body; most of the 780 eel species do not inhabit the deep ocean. Eels generally feed on other fishes or small bottom-dwelling invertebrates, but will also take larger organisms (Helfman et al. 1997). Moray eels, snake eels, and conger eels are well represented by many species that occur in the Study Area (Paxton and Eschmeyer 1998). The order Elopiformes include two distinct groups with very different forms: the bonefishes, predators of shallow tropical waters; and the little-known spiny eels, elongated seafloor feeders which feed on decaying organic matter in deep ocean areas (Paxton and Eschmeyer 1998).

Eels are found in all marine habitat types, although most inhabit shallow subtropical or tropical marine habitats (Paxton and Eschmeyer 1998) in the Study Area. The bonefishes and spiny eels occur in deep ocean waters, ranging from 400 to 16,000 ft. (121.9 to 4,876.8 m) within the open-ocean area of the Study Area, throughout the Pacific on the seafloor and in the water column, and bonefish are also found in near-shore habitats (Paxton and Eschmeyer 1998).

3.9.2.7 Sardines and Anchovies (Order Clupeiformes)

Many of the 364 species of the order Clupeiformes are found primarily in the Indo-west Pacific or the western Atlantic. These sardine and anchovy species are one of the most well-defined orders of fishes because of their importance to commercial fisheries (Nelson 2006). This group of fishes swims together (school) to help conserve energy and minimize predation (Brehmer et al. 2007). Herrings account for a large portion of the total worldwide fish catch (United Nations Environment Programme 2005; United Nations Environment Programme 2009). Sardine and anchovies are also an important part of marine food webs because they are the targeted prey for many marine species, including other fishes, birds, and mammals. The clupeids feed on decaying organic matter and plankton (Moyle and Cech 1996).

Clupeiformes are often concentrated in large schools near the surface. They are common in the coastal waters of the Study Area (Paxton and Eschmeyer 1998; Myers and Donaldson 2003).

3.9.2.8 Hatchetfish and Lanternfishes (Orders Stomiiformes and Myctophiformes)

The orders Stomiiformes and Myctophiformes comprise one of the largest groups of the world's deepwater fishes—more than 500 total species, many of which are not very well described in the scientific literature (Nelson 2006). The ecological role of many of these species is also not well understood (Helfman et al. 2009) These fishes are known for their unique body forms (e.g., slender bodies, or disc-like bodies, often possessing light-producing capabilities) and adaptations that likely present some advantages within the deepwater habitats in which they occur (e.g., large mouths, sharp teeth, and sensitive lateral line [sensory] systems) (Haedrich 1996; Koslow 1996; Marshall 1996; Rex and Etter 1998; Warrant and Locket 2004).

Overall the hatchetfish and lanternfishes occur in deep ocean waters, ranging from 3,280 to 16,000 ft. (999.7 to 4,876.8 m), making diurnal migrations within the open ocean area of the Study Area (Froese and Pauly 2010; Paxton and Eschmeyer 1998).

3.9.2.9 Greeneyes, Lizardfishes, Lancetfishes, and Telescopefishes (Order Aulopiformes)

Fishes of the order Aulopiformes are a diverse group that possess both primitive (adipose [fatty] fin, rounded scales) and advanced (unique swim bladder and jawbone) features of marine fishes (Paxton and Eschmeyer 1998). They are common in estuarine and coastal waters to the deep ocean. The lizardfish (Synodontidae), Bombay ducks (Harpadontidae) primarily occur in coastal waters to the outer shelf, where they rest on the bottom and are well camouflaged with the substrate (Paxton and Eschmeyer 1998). Lancetfish (Alepisauridae) are primarily mid-water column fish, but are known from the surface to deep water. Telescopefish are primarily found in deep waters from 1,640 to 3,280 ft. (499.9 to 999.7 m), but they can also be found at shallower depths and may approach the surface at night (Paxton and Eschmeyer 1998).

In general, greeneyes, lizardfishes, and lancetfishes occur in the coastal waters of the Study Area. Telescopefishes and bathysaurids occur primarily in the deeper waters associated with the open-ocean areas of the Study Area (Paxton and Eschmeyer 1998).

3.9.2.10 Cods and Cusk-eels (Orders Gadiformes and Ophidiiformes)

The order Ophidiiformes includes cusk-eels and brotulas, which have long eel-like tapering bodies and are distributed in deepwater areas throughout tropical and temperate oceans (Paxton and Eschmeyer 1998). The characteristics of ophidiiforms are similar to those of the other deepwater groups. Other fishes of this order are also found in shallow waters on coral reefs. In addition, there are several cusk-eel species which are pelagic or found on the continental shelves and slopes.

Cods are generally found near the seafloor and feed on bottom-dwelling organisms. They do not occur in the Study Area (Paxton and Eschmeyer 1998). Cusk-eels occur near the seafloor of the coastal waters and in the open-ocean areas of the Study Area (Paxton and Eschmeyer 1998).

3.9.2.11 Toadfishes and Anglerfishes (Orders Batrachoidiformes and Lophiiformes)

The order Batrachoidiformes includes only the toadfish family. Some species of toadfishes produce and detect sounds by vibrating the swimbladder. They spawn in and around bottom structures and invest a substantial amount of parental care by defending their nests (Moyle and Cech 1996, Paxton and Eschmeyer 1998). The order Lophiiformes includes all of the world’s anglerfishes, goosefishes, frogfishes, batfishes, and deepwater anglerfishes, most of which occur in seafloor habitats of all oceans. Some deepwater anglerfish use highly modified “lures” to attract prey (Koslow 1996; Helfman et al. 2009). The males of these species are small and parasitic, spending their life attached to the side of the female (Helfman et al. 2009). The anglerfishes can be broken into two groups: (1) those that dwell in the deep water (10 families), and (2) those that live on the bottom or attached to drifting seaweed in shallow water (5 families). Toadfish are not found within the Study Area; however, anglerfish are found in the Study Area at depths ranging from 65.5 to 328 ft. (20 to 100 m) (Paxton and Eschmeyer 1998).

3.9.2.12 Mullets, Silversides, Needlefish, and Killifish (Orders Mugiliformes, Atheriniformes, Beloniformes, and Cyprinodontiformes)

Mugiliformes (mullets) contain 71 marine species that occupy coastal marine and estuarine waters of all tropical and temperate oceans. There has been disagreement in the taxonomic classification of this group; some have included this group within the super order Athinerimorpha (Nelson 2006), while others have placed it as a suborder within the Perciformes (Moyle and Cech 1996). Mullets feed on decaying organic matter in estuaries and possess a filter-feeding mechanism with a gizzard-like digestive tract. They feed on the bottom by scooping up food and retaining it in their very small gill rakers (Moyle and Cech 1996). Most species within these groups are important prey for predators in all estuarine habitats within the Study Area.

Most of these fishes are found in tropical or temperate marine waters and occupy shallow habitats near the water surface. An exception to this nearshore distribution includes the flyingfishes and halfbeaks, which occur in the oceanic or shallow seacoast regions where light penetrates, in tropical to warm-temperate regions. The silversides are a small inshore species often found in intertidal habitats. The Cyprinodontiformes include the killifishes that are often associated with intertidal coastal zones and salt marsh habitats and are highly tolerant of pollution. These fishes are found in all coastal waters and open ocean areas of the Study Area (Froese and Pauly 2010; Paxton and Eschmeyer 1998).

3.9.2.13 Oarfishes, Squirrelfishes, and Dories (Orders Lampridiformes, Beryciformes, and Zeiformes)

There are only 19 species in the order Lampridiformes—the oarfishes (Nelson 2006). They exhibit diverse body shapes, and some have a protruding mouth, which allows for a suction feeding technique while feeding on plankton. Other species, including the crestfish, possess grasping teeth used to catch prey. They occur only in the mid-water column of the open ocean, but are rarely observed (Nelson 2006). Fishes in the order Beryciformes are primarily either deepwater or nocturnal species, many of which are poorly described. There are a few shallow water exceptions, including squirrelfishes, which are distributed throughout reef systems in tropical and subtropical marine regions (Nelson 2006). Squirrelfishes are relied upon by some communities who catch their own food (Froese and Pauly 2010). They possess specialized eyes and large mouths and primarily feed on bottom-dwelling crustaceans (Goatley and Bellwood 2009). Very little is known about the order Zeiformes, or dories, which includes some very rare families, many containing only a single species (Paxton and Eschmeyer 1998). Even general information on their biology, ecology, and behavior is limited.

Squirrelfishes are common in coral reef systems in the Study Area. Most of the Lampridiformes and Zeiformes are confined to seafloor regions in all coastal waters of the Study Area, as well as the open-ocean areas at depths of 130 to 330 ft. (39.6 to 100.6 m) (Paxton and Eschmeyer 1994; Moyle and Cech 1996).

3.9.2.14 Pipefishes and Seahorses (Order Gasterosteiformes)

Gasterosteiformes include sticklebacks, pipefishes, and seahorses. Most of these species are found in brackish water (a mixture of seawater and freshwater) throughout the world (Nelson 2006) and occur in surface, water column, and seafloor habitats. Small mouths on a long snout and armorlike scales are characteristic of this group. Most of these species exhibit a high level of parental care, either through nest building (sticklebacks) or brooding pouches (seahorses have a pouch where eggs develop), which results in relatively few young being produced (Helfman et al. 1997). This group also includes the trumpetfishes and cornetfishes, ambush predators, with a large mouth used to capture smaller lifestages of fishes.

This group is associated with tropical and temperate reef systems. They are found in the coastal waters of the Study Area (Paxton and Eschmeyer 1998).

3.9.2.15 Scorpionfishes (Order Scorpaeniformes)

The order Scorpaeniformes is a diverse group of more than 1,400 marine species, all with bony plates or spines near the head. This group contains the scorpionfishes, waspfishes, rockfishes, velvetfishes, pigfishes, sea robins, gurnards, sculpins, snailfishes, and lumpfishes (Paxton and Eschmeyer 1998). Many of these fishes are adapted for inhabiting the seafloor of the marine environment (e.g., modified pectoral fins or suction discs), where they feed on smaller crustaceans and fishes. Sea robins are capable of generating sounds with their swimbladders and are among the noisiest of all fish species within the Study Area (Moyle and Cech 1996).

Scorpionfishes are widely distributed in open-ocean and coastal habitats, at all depths, throughout the world. They occur in all waters of the Study Area. Most occur in depths less than 330 ft. (100.6 m), but others are found in deepwater habitat, down to 7,000 ft. (2,133.6 m) (Paxton and Eschmeyer 1998).

3.9.2.16 Snappers, Drums, and Croakers (Families Sciaenidae and Lutjanidae)

The families Sciaenidae and Lutjanidae include mainly predatory coastal marine fishes, including the recreationally important snappers, drums, and croakers. These fishes are sometimes distributed in schools as juveniles then become more solitary as they grow larger. They feed on fishes and crustaceans. Drums and croakers (Sciaenidae) produce sounds via their swimbladders, which generate a drumming sound. The snappers (Lutjanidae) are generally associated with seafloor habitats and tend to congregate near structured habitats, including natural/artificial reefs and oil platforms (Moyle and Cech 1996). Other representative groups include the brightly colored and diverse forms of reef-associated cardinalfishes, butterflyfishes, angelfishes, dottybacks, and goatfishes (Paxton and Eschmeyer 1998).

Like the scorpionfishes, the drums, snappers, snooks, and temperate basses are widely distributed in open-ocean and coastal habitats throughout the world. They occur in all waters of the Study Area, but are particularly concentrated, and exhibit the most varieties, in depths less than 330 ft. (100.6 m), often associated with reef systems (Paxton and Eschmeyer 1994; Froese and Pauly 2010).

3.9.2.17 Groupers and Sea Basses (Family Serranidae)

The Serranidae are primarily nearshore marine fishes that support recreational and commercial fisheries. Seabasses and groupers are nocturnal predators found primarily within reef systems. They generally possess specialized eyes and large mouths and feed mostly on bottom-dwelling fishes and crustaceans (Goatley and Bellwood 2009). Some groupers and seabasses take advantage of feeding opportunities in the low-light conditions of twilight when countershaded fishes become conspicuous and easier for these predators to locate (Rickel and Genin 2005). Other groupers are active during the daytime and exhibit a variety of opportunistic predatory strategies, such as ambush (Wainwright and Richard 1995) to benefit from mistakes made by prey species. Many of the serranids begin life as females and then become male as they grow larger (Moyle and Cech 1996). This group occurs in all coastal waters of the Study Area, but are mostly concentrated in depths less than 100 ft. (30.5 m) within the Study Area (Moyle and Cech 1996; Paxton and Eschmeyer 1998; Froese and Pauly 2010).

3.9.2.18 Wrasses, Parrotfish, and Damselfishes (Families Labridae, Scaridae, and Pomacentridae)

The suborder Labroidei contains many nearshore marine reef or structure-associated fishes, including the diverse wrasses (Labridae), parrotfishes (Scaridae), and damselfishes (Pomacentridae). Most of the wrasses are conspicuous, brightly colored, coral reef fishes, but others are found in temperate waters. Most are active during the daytime and exhibit a variety of opportunistic predatory strategies, such as ambush (Wainwright and Richard 1995) to capitalize on mistakes made by prey species. Parrotfishes provide important ecological functions to the reef system by grazing on coral and processing sediments (Goatley and Bellwood 2009). Similar to the Serranidae, many wrasses and parrotfishes begin life as females but change into males as they grow larger and exhibit with a variety of reproductive strategies found among the species and between populations (Moyle and Cech 1996). Damselfishes are noted for their territoriality and are brightly colored. This group occurs in all coastal waters of the Study Area, but are mostly concentrated in depths less than 100 ft. (30.5 m) within the Study Area (Moyle and Cech 1996; Paxton and Eschmeyer 1998; Froese and Pauly 2010). This group includes the ESA candidate species, the humpheaded wrasse (Section 3.9.1.1, Endangered Species Act Species).

3.9.2.19 Gobies, Blennies, and Surgeonfishes (Suborders Gobiodei, Blennioidei, and Acanthuroidei)

The seafloor-dwelling gobies (suborder Gobiodei) include Gobiidae, the largest family of marine fishes (Nelson 2006); they exhibit modified pelvic fins that allow them to adhere to various bottom surfaces (Helfman et al. 2009). Fishes of the suborder Blennioidei primarily occupy the intertidal zones throughout the world, including the clinid blennies and the combtooth blennies of the family Blenniidae (Moyle and Cech 1996; Mahon et al. 1998; Nelson 2006). The blennies and gobies primarily feed on seafloor debris. The suborder Acanthuroidei contains the surgeonfishes, moorish idols, and rabbitfishes of tropical reef systems. They have elongated small mouths used to scrape algae from coral. These grazers provide an important function to the reef system by controlling the growth of algae on the reef (Goatley and Bellwood 2009). Some of these species are adapted to target particular prey species; for example, the elongated snouts of butterflyfishes allow them to bite off exposed parts of invertebrates (Leysen et al. 2010).

These fishes occur in all coastal waters of the Study Area, but are mostly concentrated, and exhibit the most varieties, in depths less than 100 ft. (30.5 m) within the Study Area (Moyle and Cech 1996; Paxton and Eschmeyer 1998; Froese and Pauly 2010).

3.9.2.20 Jacks, Tunas, Mackerels, and Billfishes (Families Carangidae, Xiphiidae, and Istiophoridae and Suborder Scombroidei)

The suborder Scombroidei contains some of the most voracious open-ocean predators: the jacks, mackerels, barracudas, billfishes, and tunas (Estrada et al. 2003; Sibert et al. 2006). Many jacks are known to feed nocturnally (Goatley and Bellwood 2009) and in the low light of twilight (Rickel and Genin 2005) by ambushing their prey (Sancho 2000). The open-ocean, highly migratory tunas, mackerels, and billfishes are extremely important to fisheries; they constitute a large component of the total annual worldwide catch by weight, with tunas and swordfish as the most important species (United Nations Environment Programme 2005; United Nations Environment Programme 2009). One unique adaptation found in these fishes is ram ventilation (Wegner et al. 2006). Ram ventilation uses the motion of the fish through the water to increase respiratory efficiency in large, fast-swimming open-ocean fishes (Wegner et al. 2006). Many fishes in this group have large-scale migrations that allow for feeding in highly productive areas, which vary by season (Pitcher 1995).

These fishes occupy the open-ocean areas that comprise the largest area of ocean but make up only about 5 percent of the total marine fishes (Helfman et al. 1997; Froese and Pauly 2010). They are mostly found near the surface, or the upper portion of the water column, located within all coastal waters and open-ocean areas of the Study Area (Paxton and Eschmeyer 1998; Froese and Pauly 2010).

3.9.2.21 Flounders (Order Pleuronectiformes)

The order Pleuronectiformes includes flatfishes (flounders, dabs, soles, and tonguefishes) that are found in all marine seafloor habitats throughout the world (Nelson 2006). Fishes in this group have eyes on either the left side or the right side of the head and are not symmetrical like other fishes (Saele et al. 2004). All flounder species are ambush predators, feeding mostly on other fishes and bottom-dwelling invertebrates (Drazen and Seibel 2007; Froese and Pauly 2010).

This group is widely distributed on the seafloor of open-ocean and coastal habitats throughout the world. They occur in all waters of the Study Area, but are particularly concentrated, and exhibit the most varieties, in depths less than 330 ft. (100.6 m), often associated with sand bottoms within the Study Area (Paxton and Eschmeyer 1998; Froese and Pauly 2010).

3.9.2.22 Triggerfish, Puffers, and Molas (Order Tetraodontiformes)

The fishes in the order Tetraodontiformes are the most advanced group of modern bony fishes. This order includes the triggerfishes, filefishes, puffers, and ocean sunfishes (Nelson 2006). Like the flounders, this group exhibits body shapes unique among marine fishes, including modified spines or other structures advantageous in predator avoidance. The unique body shapes also require the use of a tail swimming style because some species lack the muscle structure and body shape of other fishes. Most of these fishes are active during the daytime and exhibit a variety of strategies for catching prey, such as ambushing their prey (Wainwright and Richard 1995). The ocean sunfishes (*Mola* species) are the largest bony fish and the most prolific vertebrate species, with females producing more than 300 million eggs in a breeding season (Moyle and Cech 1996). The ocean sunfishes occur very close to the surface. They are slow swimming and feed on a variety of plankton (including jellyfish), crustaceans, and fishes (Froese and Pauly 2010). Their only natural predators are sharks, orcas, and sea lions (Helfman et al. 1997).

Most species within this group are associated with reef systems. This group is widely distributed in tropical and temperate bottom or mid-water column habitats (open-ocean and coastal) throughout the world. They occur in all waters of the Study Area, but are particularly concentrated, and exhibit the most varieties, in depths less than 330 ft. (100.6 m), often associated with reefs or structured seafloor habitats (Paxton and Eschmeyer 1998; Froese and Pauly 2010). One major exception is for the molas (ocean sunfishes), which occur at the surface in all open-ocean areas (Helfman et al. 1997).

3.9.3 Environmental Consequences

This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact marine fishes known to occur within the Study Area. Chapter 2 presents the baseline and proposed training and testing activity locations for each alternative (including number of activities and ordnance expended). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors applicable to marine fish in the Study Area and analyzed below include the following:

- Acoustic (sonar and other active acoustic sources; underwater explosives; swimmer defense airguns; weapons firing, launch, and impact noise; vessel noise; and aircraft noise)
- Energy (electromagnetic devices)
- Physical disturbance and strike (vessels, in-water devices, military expended materials, seafloor devices)
- Entanglement (fiber optic cables and guidance wires, decelerators/parachutes)

- Ingestion (munitions and military expended materials other than munitions)
- Secondary (impacts associated with sediments and water quality)

Each of these components was carefully analyzed for potential impacts on fishes within the stressor categories contained in this section. The specific analysis of the training and testing activities considers these components within the context of geographic location and overlap of marine fish resources. In addition to the analysis here, the details of all training and testing activities, stressors, components that cause the stressor, and geographic overlap within the Study Area are included in Chapter 2 (Description of Proposed Action and Alternatives).

3.9.3.1 Acoustic Stressors

The following sections analyze potential impacts on fish from proposed activities that involve acoustic stressors (non-impulse and impulse).

3.9.3.1.1 Analysis Background and Framework

This section is largely based on a technical report prepared for the Navy: *Effects of Mid- and High-Frequency Sonars on Fish* (Popper 2008). Additionally, Popper and Hastings (2009a) provide a critical overview of some of the most recent research regarding potential effects of anthropogenic sound on fish.

Studies of the effects of human-generated sound on fish have been reviewed in numerous places (e.g., National Research Council 1994; National Research Council 2003; Popper 2003; Popper et al. 2004; Hastings and Popper 2005; Popper 2008; Popper and Hastings 2009a, b). Most investigations, however, have been in the gray literature (non peer-reviewed reports). See Hastings and Popper (2005), Popper (2008), and Popper and Hastings (2009a, b) for extensive critical reviews of this material.

Fish have been exposed to short-duration, high-intensity signals such as those that might be found near high-frequency sonar, pile driving, or a seismic airgun survey. Such studies examined short-term effects that could result in death to the exposed fish, as well as hearing loss and long-term consequences. Recent experimental studies have provided additional insight into the issues (e.g., Govoni et al. 2003; McCauley et al. 2003; Popper et al. 2005; Popper et al. 2007; Doksaeter et al. 2009; Kane et al. 2010).

3.9.3.1.1.1 Direct Injury

<u>Non-Impulse Acoustic Sources</u>

Potential direct injuries from non-impulse sound sources, such as sonar, are unlikely because of the relatively lower peak pressures and slower rise times than potentially injurious sources such as explosives. Non-impulse sources also lack the strong shock wave such as that associated with an explosion. Therefore, direct injury is not likely to occur from exposure to non-impulse sources such as sonar, vessel noise, or subsonic aircraft noise. The theories of sonar-induced acoustic resonance, neurotrauma, and lateral line system injury are discussed below, although these phenomena are difficult to recreate under real-world conditions and are therefore unlikely to occur.

Two unpublished reports examined the effects of mid-frequency sonar-like signals (1.5–6.5 kHz) on larval and juvenile fish of several species (Jørgensen et al. 2005; Kvadsheim and Sevaldsen 2005). In the first study, Kvadsheim and Sevaldsen (2005) showed that intense sonar activities in herring spawning areas affected less than 0.3 percent of the total juvenile stock. The second study, Jørgensen et al. (2005) exposed larval and juvenile fish to various sounds to investigate potential effects on survival, development, and behavior. The study used herring (*Clupea harengus*) (standard length 2–5 centimeters

[cm] [0.8–2 inches {in.}]), Atlantic cod (*Gadus morhua*) (standard length 2 and 6 cm [0.8 and 2.3 in.]), saithe (*Pollachius virens*) (4 cm [1.6 in.]), and spotted wolffish (*Anarhichas minor*) (4 cm [1.6 in.]) at different developmental stages. The researchers placed the fish in plastic bags 10 ft. (3 m) from the sound source and exposed them to between 4 and 100 pulses of 1-second duration of pure tones at 1.5, 4, and 6.5 kHz. The fish in only two groups out of the 82 tested exhibited any adverse effects. These two groups were both composed of herring and were tested with sound pressure levels of 189 dB re 1 µPa, which resulted in a post-exposure mortality of 20 to 30 percent. In the remaining 80 groups tested, 42 of which were replicates of herring only, there were no observed effects on growth (length and weight) or the survival of fish that were kept as long as 34 days post exposure. While statistically significant losses were documented in the two groups impacted, the researchers only tested that particular sound level once, so it is not known if this increased mortality was due to the level of the test signal or to other unknown factors.

High sound pressure levels may cause bubbles to form from micronuclei in the blood stream or other tissues of animals, possibly causing embolism damage (Ketten 1998). Fish have small capillaries where these bubbles could be caught and lead to the rupturing of the capillaries and internal bleeding. It has also been speculated that this phenomena could also take place in the eyes of fish due to potentially high gas saturation within the fish's eye tissues (Popper and Hastings 2009a).

As reviewed in Popper and Hastings (2009a), Hastings (1990, 1995) found 'acoustic stunning' (loss of consciousness) in blue gouramis (*Trichogaster trichopterus*) following an 8-minute exposure to a 150 Hz pure tone with a peak sound pressure level of 198 dB re 1 µPa. This species of fish has an air bubble in the mouth cavity directly adjacent to the animal's braincase that may have caused this injury. Hastings (1990, 1995) also found that goldfish exposed to 2 hours of continuous wave sound at 250 Hz with peak pressures of 204 dB re 1 µPa, and fathead minnows exposed to 0.5 hour of 150 Hz continuous wave sound at a peak level of 198 dB re 1 µPa, did not survive.

The only study on the effect of exposure of the lateral line system to continuous wave sound (conducted on one freshwater species, the Oscar [*Astronatus ocellatus*]) suggests no effect on these sensory cells by intense pure tone signals (Hastings et al. 1996).

Explosives and Other Acoustic Sources

The greatest potential for direct, non-auditory tissue effects is primary blast injury and barotrauma following exposure to high amplitude impulse sources, such as explosions. Primary blast injury refers to those injuries that result from the initial compression of a body exposed to a blast wave. Primary blast injury is usually limited to gas-containing structures (e.g., swim bladder and gut) and the auditory system. Barotrauma refers to injuries caused when large pressure changes occur across tissue interfaces, normally at the boundaries of gas-filled tissues such as the swim bladder of fish.

An underwater explosion generates a shock wave that produces a sudden, intense change in local pressure as it passes through the water (U.S. Department of the Navy 1998, 2001c). Pressure waves extend to a greater distance than other forms of energy produced by the explosion (i.e., heat and light) and are therefore the most likely source of negative effects to marine life from underwater explosions (Craig 2001; Scripps Institution of Oceanography 2005; U.S. Department of the Navy 2006).

The shock wave from an underwater explosion is lethal to fish at close range, causing massive organ and tissue damage and internal bleeding (Keevin and Hempen 1997). At greater distance from the detonation point, the extent of mortality or injury depends on a number of factors including fish size, body shape, orientation, and species (Wright 1982; Keevin and Hempen 1997). At the same distance from the source, larger fish are generally less susceptible to death or injury, elongated forms that are round in cross-section are less at risk than deep-bodied forms, and fish oriented sideways to the blast suffer the greatest impact (Yelverton et al. 1975; Wiley et al. 1981; O'Keefe and Young 1984; Edds-Walton and Finneran 2006). Species with gas-filled organs have higher mortality than those without them (Goertner et al. 1994), which includes most fish found in the Study Area.

Two aspects of the shock wave appear most responsible for injury and death to fish: the received peak pressure and the time required for the pressure to rise and decay (Dzwilewski and Fenton 2002). Higher peak pressure and abrupt rise and decay times are more likely to cause acute pathological effects (Wright and Hopky 1998). Rapidly oscillating pressure waves might rupture the kidney, liver, spleen, and sinus and cause venous hemorrhaging (Keevin and Hempen 1997). They can also generate bubbles in blood and other tissues, possibly causing embolism damage (Ketten 1998). Oscillating pressure waves might also burst gas-containing organs. The swim bladder, the gas-filled organ used by many pelagic fish and coastal fish to control buoyancy, is the primary site of damage from explosives (Yelverton et al. 1975; Wright 1982). Gas-filled swim bladders resonate at different frequencies than surrounding tissue and can be torn by rapid oscillation between high- and low-pressure waves. Swim bladders are a characteristic of bony fishes and are not present in sharks and rays.

Studies that have documented fish killed during planned underwater explosions indicate that most fish that die do so within 1 to 4 hours, and almost all die within a day (Hubbs and Rechnizer 1952; Yelverton et al. 1975). Fitch and Young (1948) found that the type of fish killed changed when blasting was repeated at the same marine location within 24 hours of previous blasting. They observed that most fish killed on the second day were scavengers, presumably attracted by the victims of the previous day's blasts. However, fishes collected during these types of studies have mostly been recovered floating on the water's surface. Gitschlag et al. (2000) collected both floating fish and those that were sinking or lying on the bottom after explosive removal of nine oil platforms in the northern Gulf of Mexico. They found that 3 to 87 percent (46 percent average) of the specimens killed during a blast might float to the surface. Other impediments to accurately characterizing the magnitude of fish mortality included currents and winds that transported floating fishes out of the sampling area and predation by seabirds or other fishes.

There have been few studies of the impact of underwater explosions on early life stages of fish (eggs, larvae, juveniles). Fitch and Young (1948) reported the demise of larval anchovies exposed to underwater blasts off California, and Nix and Chapman (1985) found that anchovy and smelt larvae died following the detonation of buried charges. Similar to adult fish, the presence of a swim bladder contributes to shock wave-induced internal damage in larval and juvenile fish (Settle et al. 2002). Shock wave trauma to internal organs of larval pinfish and spot from shock waves was documented by Govoni et al. (2003). These were laboratory studies, however, and have not been verified in the field.

It has been suggested that impulse sounds, such as those produced by seismic airguns, may cause damage to the cells of the lateral line in fish larvae and juveniles when in proximity (5 m [16 ft.]) to the sound source (Booman et al. 1996).

3.9.3.1.1.2 Hearing Loss

Exposure to high intensity sound can cause hearing loss, also known as a noise-induced threshold shift, or simply a threshold shift (Miller 1974). A Temporary Threshold Shift (TTS) is a temporary, recoverable loss of hearing sensitivity. A TTS may last several minutes to several weeks and the duration may be related to the intensity of the sound source and the duration of the sound (including multiple exposures). A Permanent Threshold Shift (PTS) is non-recoverable, results from the destruction of tissues within the auditory system, and can occur over a small range of frequencies related to the sound exposure. As with TTS, the animal does not become deaf but requires a louder sound stimulus (relative to the amount of PTS) to detect a sound within the affected frequencies; however, in this case, the effect is permanent.

Permanent hearing loss has not been documented in fish. The sensory hair cells of the inner ear in fish can regenerate after they are damaged, unlike in mammals where sensory hair cells loss is permanent (Lombarte et al. 1993; Smith et al. 2006). As a consequence, any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (e.g., Smith et al. 2006).

Non-Impulse Acoustic Sources

Studies of the effects of long-duration sounds with sound pressure levels below 170 to 180 dB re 1 µPa indicate that there is little to no effect of long-term exposure on species that lack notable anatomical hearing specialization (Scholik and Yan 2001; Amoser and Ladich 2003; Smith et al. 2004a, b; Wysocki et al. 2007). The longest of these studies exposed young rainbow trout (*Onorhynchus mykiss*), to a level of noise equivalent to one that fish would experience in an aquaculture facility (e.g., on the order of 150 dB re 1 µPa) for about nine months. The investigators found no effect on hearing (i.e., TTS) as compared to fish raised at 110 dB re 1 µPa.

In contrast, studies on fish with hearing specializations (i.e., greater sensitivity to lower sound pressures and higher frequencies) have shown that there is some hearing loss after several days or weeks of exposure to increased background sounds, although the hearing loss seems to recover (e.g., Scholik and Yan 2002; Smith et al. 2004a; Smith et al. 2006). Smith et al. (2004b, 2006) exposed goldfish to noise at 170 dB re 1 µPa and found a clear relationship between the amount of hearing loss (TTS) and the duration of exposure until maximum hearing loss occurred after 24 hours of exposure. A 10-minute exposure resulted in a 5 dB TTS, whereas a 3-week exposure resulted in a 28 dB TTS that took over 2 weeks to return to pre-exposure baseline levels (Smith et al. 2004a) (note: recovery time was not measured by investigators for shorter exposure durations).

Similarly, Wysocki and Ladich (2005) investigated the influence of noise exposure on the auditory sensitivity of two freshwater fish with notable hearing specializations, the goldfish and the lined Raphael catfish (*Platydoras costatus*), and on a freshwater fish without notable specializations, the pumpkinseed sunfish (*Lepomis gibbosus*). Baseline thresholds showed greatest hearing sensitivity around 500 Hz in the goldfish and catfish and at 100 Hz in the sunfish. For the goldfish and catfish, continuous white noise of approximately 130 dB re 1 µPa at 1 m resulted in a significant TTS of 23 to 44 dB. In contrast, the auditory thresholds in the sunfish declined by 7 to 11 dB. The duration of exposure and time to recovery was not addressed in this study. Scholik and Yan (2001) demonstrated TTS in fathead minnows (*Pimephales promelas*). After a 24-hour exposure to white noise (300–2,000 Hz) at 142 dB re 1 µPa, recovery took as long as 14 days post-exposure.

Some studies have suggested that there may be some loss of sensory hair cells due to high intensity sources; however, none of these studies concurrently investigated effects on hearing. Enger (1981) found loss of ciliary bundles of the sensory cells in the inner ears of Atlantic cod (*Gadus morhua*) following 1 to 5 hours of exposure to pure tone sounds between 50 and 400 Hz with a sound pressure level of 180 dB re 1 µPa. Hastings (1995) found auditory hair-cell damage in a species with notable anatomical hearing specializations, the goldfish, exposed to 250 Hz and 500 Hz continuous tones with maximum peak levels of 204 dB re 1 µPa and 197 dB re 1 µPa, respectively, for about two hours. Similarly, Hastings et al. (1996) demonstrated damage to some sensory hair cells in oscars (*Astronotus ocellatus*) following a one hour exposure to a pure tone at 300 Hz with a peak pressure level of 180 dB re 1 µPa. In none of the studies was the hair cell loss more than a relatively small percent (less than a maximum of 15 percent) of the total sensory hair cells in the hearing organs.

Studies have also examined the effects of the sound exposures from Surveillance Towed Array Sensor System Low-Frequency Active sonar on fish hearing (Popper et al. 2007; Kane et al. 2010). Hearing was measured both immediately post exposure and for several days thereafter. Maximum received sound pressure levels were 193 dB re 1 µPa for 324 or 628 seconds. Catfish and some specimens of rainbow trout showed 10 to 20 dB of hearing loss immediately after exposure to the low-frequency active sonar when compared to baseline and control animals; however, another group of rainbow trout showed no hearing loss. Recovery in trout took at least 48 hours, but studies were not completed. The different results between rainbow trout groups is difficult to understand, but may be due to developmental or genetic differences in the various groups of fish. Catfish hearing returned to, or close to, normal within about 24 hours after exposure to low-frequency active sonar. Furthermore, examination of the inner ears of the fish during necropsy (note: maximum time fish were held post exposure before sacrifice was 96 hours) revealed no differences from the control groups in ciliary bundles or other features indicative of hearing loss (Kane et al. 2010). More recently, Halvorsen et al. (2013) exposed three fish species, largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and yellow perch (*Perca flavescens*) to low–frequency sonar with received sound pressure levels of approximately 195 dB re 1 µPa. The two species without hearing specializations, largemouth bass and yellow perch, showed no loss in hearing sensitivity from sound exposure neither immediately after the test nor after 24 hours. Channel catfish, which do have anatomical specializations allowing them greater sensitivity to higher frequencies, did show a small threshold shift up to 24 hours after the experiment.

The study of mid-frequency active sonar by the same investigators also examined potential effects on fish hearing and the inner ear (Kane et al. 2010; Halvorsen et al. 2012b). Out of the four species tested (rainbow trout, channel catfish, largemouth bass, and yellow perch) only one group of channel catfish, tested in December, showed any hearing loss after exposure to mid-frequency active sonar. The signal consisted of a 2-second-long, 2.8–3.8 kHz frequency sweep followed by a 3,300 Hz tone of 1-second duration. The stimulus was repeated five times with a 25-second interval. The maximum received sound pressure level was 210 dB re 1 µPa. These animals, which have the widest hearing range of any of the species tested, experienced approximately 10 dB of threshold shift that recovered within 24 hours. Channel catfish tested in October did not show any hearing loss. The investigators speculated that the difference in hearing loss between catfish groups might have been due to the difference in water temperature of the lake where all of the testing took place (Seneca Lake, New York) between October and December. Alternatively, the observed hearing loss differences between the two catfish groups might have been due to differences between the two stocks of fish (Halvorsen et al. 2012b). Any effects on hearing in channel catfish due to sound exposure appear to be transient (Kane et al. 2010; Halvorsen et al. 2012b). Investigators observed no damage to ciliary bundles or other features indicative of hearing loss in any of the other fish tested including the catfish tested in October (Kane et al. 2010).

Popper et al. (2014) summarized in a technical report the outcome of a working group session that evaluated the sound detection capabilities for a wide range of fishes and sea turtles, which were organized into broad groups based on how they detect sound. The technical report presents sound exposure guidelines for assessing how a variety of natural and anthropogenic sound sources may affect fish and sea turtle species. Sivle et al. (2015) reported on possible population-level effects to Atlantic herring (*Clupae harengus*) from active naval sonar. The herring were exposed to source levels up 235 dB re 1 μPa at 1 m for durations exceeding 24 hours with frequencies of 1 – 2 kHz. The authors concluded that the use of naval sonar poses little risk to populations of herring even when the herring are aggregated during sonar exposure. In a related study, herring were exposed to both low-frequency (1-2 kHz) and mid-frequency (6-7 kHz) sonar as well as killer whale feeding calls (Sivle et al. 2012). The results were similar to Sivle et al. (2015) in that the herring did not respond to either the low- or mid-frequency sonar, but did show obvious avoidance behavior (diving) when exposed to the killer whale feeding sounds, which were at lower received sound pressure levels than the sonar (150 dB re 1 μPa for the killer whale calls, 176 dB re 1 μPa for the low-frequency sonar, and 162 dB re 1 μPa for the mid-frequency sonar).

Explosives and Other Impulse Acoustic Sources

Popper et al. (2005) examined the effects of a seismic airgun array on a fish with hearing specializations, the lake chub (*Couesius plumbeus*), and two species that lack notable specializations, the northern pike (*Esox lucius*) and the broad whitefish (*Coregonus nasus*) (a salmonid). In this study the average received exposure levels were a mean peak pressure level of 207 dB re 1 μPa; sound pressure level of 197 dB re 1 μPa; and single-shot sound exposure level of 177 decibels referenced to 1 micropascal squared second (dB re 1 μPa^2-s). The results showed temporary hearing loss for both lake chub and northern pike to both 5 and 20 airgun shots, but not for the broad whitefish. Hearing loss was approximately 20 to 25 dB at some frequencies for both the northern pike and lake chub, and full recovery of hearing took place within 18 hours after sound exposure. Examination of the sensory surfaces of the ears by an expert on fish inner ear structure showed no damage to sensory hair cells in any of the fish from these exposures (Song et al. 2008).

McCauley et al. (2003) showed loss of a small percent of sensory hair cells in the inner ear of the pink snapper (*Pagrus auratus*) exposed to a moving airgun array for 1.5 hours. Maximum received levels exceeded 180 dB re 1 μPa^2-s for a few shots. The loss of sensory hair cells continued to increase for up to at least 58 days post exposure to 2.7 percent of the total cells, with disproportionate damage (approximately 15 percent of hair cells) in the caudal portion of the ear. It is not known if this hair cell loss would result in hearing loss since fish have tens or even hundreds of thousands of sensory hair cells in the inner ear (Popper and Hoxter 1984; Lombarte and Popper 1994) and only a small portion were affected by the sound. The question remains as to why McCauley et al. (2003) found damage to sensory hair cells while Popper et al. (2005) did not. There are many differences between the studies, including species, precise sound source, and spectrum of the sound that it is hard to speculate.

Hastings et al. (2008) exposed the pinecone soldierfish (*Myripristis murdjan*), a fish with anatomical specializations to enhance their hearing; and three species without notable specializations: the blue green damselfish (*Chromis viridis*), the saber squirrelfish (*Sargocentron spiniferum*), and the bluestripe seaperch (*Lutjanus kasmira*) to an airgun array. Fish in cages in 5 m (16 ft.) of water were exposed to multiple airgun shots with a cumulative sound exposure level of 190 dB re 1 μPa^2-s. The authors found no hearing loss in any fish following exposures.

3.9.3.1.1.3 Auditory Masking

Auditory masking refers to the presence of a noise that interferes with a fish's ability to hear biologically relevant sounds. Fish use sounds to detect predators and prey, and for schooling, mating, and navigating, among other uses (Myrberg 1980; Popper et al. 2003). Masking of sounds associated with these behaviors could have impacts to fish by reducing their ability to perform these biological functions.

Any noise (i.e., unwanted or irrelevant sound, often of an anthropogenic nature) detectable by a fish can prevent the fish from hearing biologically important sounds including those produced by prey or predators (Myrberg 1980; Popper et al. 2003). Auditory masking may take place whenever the noise level heard by a fish exceeds ambient noise levels, the animal's hearing threshold, and the level of a biologically relevant sound. Masking is found among all vertebrate groups, and the auditory system in all vertebrates, including fish, is capable of limiting the effects of masking noise, especially when the frequency range of the noise and biologically relevant signal differ (Fay 1988; Fay and Megela-Simmons 1999).

The frequency of the sound is an important consideration for fish because many marine fish are limited to detection of the particle motion component of low frequency sounds at relatively high sound intensities (Amoser and Ladich 2005). The frequency of the acoustic stimuli must first be compared to the animal's known or suspected hearing sensitivity to establish if the animal can potentially detect the sound.

One of the problems with existing fish auditory masking data is that the bulk of the studies have been done with goldfish, a freshwater fish with well-developed anatomical specializations that enhance hearing abilities. The data on other species are much less extensive. As a result, less is known about masking in marine species, many of which lack the notable anatomical hearing specializations. However, Wysocki and Ladich (2005) suggest that ambient sound regimes may limit acoustic communication and orientation, especially in animals with notable hearing specializations.

Tavolga (1974a, b) studied the effects of noise on pure-tone detection in two species without notable anatomical hearing specializations, the pin fish (*Lagodon rhomboids*) and the African mouth-Breeder (*Tilapia macrocephala*), and found that the masking effect was generally a linear function of masking level, independent of frequency. In addition, Buerkle (1968, 1969) studied five frequency bandwidths for Atlantic cod in the 20 to 340 Hz region and showed masking across all hearing ranges. Chapman and Hawkins (1973) found that ambient noise at higher sea states in the ocean has masking effects in cod, *Gadus morhua* (L.), haddock, *Melanogrammus aeglefinus* (L.), and pollock, *Pollochinus pollachinus* (L.), and similar results were suggested for several sciaenid species by Ramcharitar and Popper (2004).Thus, based on limited data, it appears that for fish, as for mammals, masking may be most problematic in the frequency region near the signal.

There have been a few field studies that may suggest masking could have an impact on wild fish. Gannon et al. (2005) shows that bottlenose dolphins (*Tursiops truncatus*) move toward acoustic playbacks of the vocalization of Gulf toadfish (*Opsanus beta*). Bottlenose dolphins employ a variety of vocalizations during social communication including low-frequency pops. Toadfish may be able to best detect the low-frequency pops since their hearing is best below 1 kHz, and there is some indication that toadfish have reduced levels of calling when bottlenose dolphins approach (Remage-Healey et al. 2006). Silver perch have also been shown to decrease calls when exposed to playbacks of dolphin whistles mixed with other biological sounds (Luczkovich et al. 2000). Results of the Luczkovich et al. (2000) study, however, must be viewed with caution because it is not clear what sound may have elicited the silver perch response (Ramcharitar et al. 2006). Astrup (1999) and Mann et al. (1998) hypothesize that high frequency detecting species (e.g., clupeids) may have developed sensitivity to high frequency sounds to avoid predation by odontocetes. Therefore, the presence of masking noise may hinder a fish's ability to detect predators and therefore increase predation.

Of considerable concern is that human-generated sounds could mask the ability of fish to use communication sounds, especially when the fish are communicating over some distance. In effect, the masking sound may limit the distance over which fish can communicate, thereby having an impact on important components of their behavior. For example, the sciaenids, which are primarily inshore species, are one of the most active sound producers among fish, and the sounds produced by males are used to "call" females to breeding sights (Ramcharitar et al. 2001) reviewed in Ramcharitar (2006). If the females are not able to hear the reproductive sounds of the males, there could be a significant impact on the reproductive success of a population of sciaenids. Since most sound production in fish used for communication is generally below 500 Hz (Slabbekoorn et al. 2010), sources with significant low-frequency acoustic energy could affect communication in fish.

Also potentially vulnerable to masking is navigation by larval fish, although the data to support such an idea are still exceedingly limited. There is indication that larvae of some reef fish (species not identified in study) may have the potential to navigate to juvenile and adult habitat by listening for sounds emitted from a reef (either due to animal sounds or non-biological sources such as surf action) (e.g., Higgs 2005). In a study of an Australian reef system, the sound signature emitted from fish choruses was between 0.8 and 1.6 kHz (Cato 1978) and could be detected by hydrophones 3 to 4 nm from the reef (McCauley and Cato 2000). This bandwidth is within the detectable bandwidth of adults and larvae of the few species of reef fish, such as the damselfish, *Pomacentrus partitus,* and bicolor damselfish, *Eupomacentrus partitus,* that have been studied (Myrberg 1980; Kenyon 1996). At the same time, it has not been demonstrated conclusively that sound, or sound alone, is an attractant of larval fish to a reef, and the number of species tested has been very limited. Moreover, there is also evidence that larval fish may be using other kinds of sensory cues, such as chemical signals, instead of, or alongside of, sound (Atema et al. 2002).

3.9.3.1.1.4 Physiological Stress and Behavioral Reactions

As with masking, a fish must first be able to detect a sound above its hearing threshold for that particular frequency and the ambient noise before a behavioral reaction or physiological stress can occur. There are little data available on the behavioral reactions of fish, and almost no research conducted on any long-term behavioral effects or the potential cumulative effects from repeated exposures to loud sounds (Popper and Hastings 2009a).

Stress refers to biochemical and physiological responses to increases in background sound. The initial response to an acute stimulus is a rapid release of stress hormones into the circulatory system, which may cause other responses such as elevated heart rate and blood chemistry changes. Although an increase in background sound has been shown to cause stress in humans, only a limited number of studies have measured biochemical responses by fish to acoustic stress (e.g., Smith et al. 2004b; Remage-Healey et al. 2006; Wysocki et al. 2006; Wysocki et al. 2007) and the results have varied. There is evidence that a sudden increase in sound pressure level or an increase in background noise levels can increase stress levels in fish (Popper and Hastings 2009a). Exposure to acoustic energy has been shown to cause a change in hormone levels (physiological stress) and altered behavior in some species such as the goldfish (*Carassius auratus*) (Pickering 1981; Smith et al. 2004a, b), but not all species tested to date, such as the rainbow trout (*Oncorhynchus mykiss*) (Wysocki et al. 2007).

Behavioral effects to fish could include disruption or alteration of natural activities such as swimming, schooling, feeding, breeding, and migrating. Sudden changes in sound level can cause fish to dive, rise, or change swimming direction. There is a lack of studies that have investigated the behavioral reactions of unrestrained fish to anthropogenic sound. Studies of caged fish have identified three basic behavioral reactions to sound: startle, alarm, and avoidance (Pearson et al. 1992; McCauley et al. 2000; Scripps Institution of Oceanography and National Science Foundation 2008). Changes in sound intensity may be more important to a fish's behavior than the maximum sound level. Sounds that fluctuate in level tend to elicit stronger responses from fish than even stronger sounds with a continuous level (Schwartz 1985).

Non-Impulse Acoustic Sources

Remage-Healey et al. (2006) found elevated cortisol levels, a stress hormone, in Gulf toadfish (*Opsanus beta*) exposed to low frequency bottlenose dolphin sounds. Additionally, the toadfish' call rates dropped by about 50 percent, presumably because the calls of the toadfish, a primary prey for bottlenose dolphins, give away the fish's location to the dolphin. The researchers observed none of these effects in toadfish exposed to an ambient control sound (i.e., low-frequency snapping shrimp "pops").

Smith et al. (2004b) found no increase in corticosteroid, a stress hormone, in goldfish (*Carassius auratus*) exposed to a continuous, band-limited noise (0.1 to 10 kHz) with a sound pressure level of 170 dB re 1 µPa for 1 month. Wysocki et al. (2007) exposed rainbow trout (*Onorhynchus mykiss*) to continuous band-limited noise with a sound pressure level of about 150 dB re 1 µPa for 9 months with no observed stress effects. Growth rates and effects on the trout's immune system were not significantly different from control animals held at sound pressure level of 110 dB re 1 µPa.

Gearin et al. (2000) studied responses of adult sockeye salmon (*Oncorhynchus nerka*) and sturgeon (*Acipenser* sp.) to pinger sounds produced by acoustic devices designed to deter marine mammals from gillnet fisheries. The pingers produced sounds with broadband energy with peaks at 2 kHz or 20 kHz. They found that fish did not exhibit any reaction or behavior change to the pingers, which demonstrated that the alarm was either inaudible to the salmon and sturgeon, or that neither species was disturbed by the mid-frequency sound (Gearin et al. 2000). Based on hearing threshold data, it is highly likely that the salmonids did not hear the sounds.

Culik et al. (2001) did a very limited number of experiments to determine the catch rate of herring (*Clupea harengus*) in the presence of pingers producing sounds that overlapped with the frequency range of hearing for herring (base frequency of 2.7 kHz with harmonics to 19 kHz). They found no change in catch rates in gill nets with or without the higher frequency (greater than 20 kHz) sounds present, although there was an increase in the catch rate with the signals from 2.7 kHz to 19 kHz (a different source than the higher frequency source). The results could mean that the fish did not "pay attention" to the higher frequency sound or that they did not hear it, but that lower frequency sounds may be attractive to fish. At the same time, it should be noted that there were no behavioral observations on the fish, and so how the fish actually responded when they detected the sound is not known.

Doksæter et al. (2009) studied the reactions of wild, overwintering herring to Royal Netherlands Navy experimental mid-frequency active sonar and killer whale feeding sounds. The behavior of the fish was monitored using upward looking echosounders. The received levels from the 1 to 2 kHz and 6 to 7 kHz sonar signals ranged from 127 to 197 dB re 1 µPa and 139 to 209 dB re 1 µPa, respectively. Escape reactions were not observed upon the presentation of the mid-frequency active sonar signals; however, the playback of the killer whale sounds elicited an avoidance reaction. The authors concluded that these mid-frequency sonar could be used in areas of overwintering herring without substantially affecting the fish.

There is evidence that elasmobranchs respond to human-generated sounds. Myrberg and colleagues did experiments in which they played back sounds and attracted a number of different shark species to the sound source (e.g., Myrberg et al. 1969; Myrberg et al. 1972; Nelson and Johnson 1972; Myrberg et al. 1976). The results of these studies show that sharks were attracted to low-frequency sounds (below several hundred Hz), in the same frequency range of sounds that might be produced by struggling prey. However, sharks are not known to be attracted by continuous signals or higher frequencies (which they presumably cannot hear since their best hearing sensitivity is around 20 Hz, and drops off above 1000 Hz [Casper and Mann 2006; Casper and Mann 2009]).

Studies documenting behavioral responses of fish to vessels show that Barents Sea capelin (*Mallotus villosus*) may exhibit avoidance responses to engine noise, sonar, depth finders, and fish finders (Jørgensen et al. 2004). Avoidance reactions are quite variable depending on the type of fish, its life history stage, behavior, time of day, and the sound propagation characteristics of the water (Schwartz 1985). Misund (1997) found that fish ahead of a ship, that showed avoidance reactions, did so at ranges of 160 to 490 ft. (49 to 150 m). When the vessel passed over them, some species of fish responded with sudden escape responses that included lateral avoidance or downward compression of the school.

In a study by Chapman and Hawkins (1973) the low-frequency sounds of large vessels or accelerating small vessels caused avoidance responses by herring. Avoidance ended within 10 seconds after the vessel departed. Twenty-five percent of the fish groups habituated to the sound of the large vessel and 75 percent of the responsive fish groups habituated to the sound of small boats.

Explosives and Other Impulse Acoustic Sources

Pearson et al. (1992) exposed several species of rockfish (*Sebastes* spp.) to a seismic airgun. The investigators placed the rockfish in field enclosures and observed the fish's behavior while firing the airgun at various distances for 10-minute trials. Dependent upon the species, rockfish exhibited startle or alarm reactions between peak to peak sound pressure level of 180 dB re 1 µPa and 205 dB re 1 µPa. The authors reported the general sound level where behavioral alterations became evident was at about 161 dB re 1 µPa for all species. During all of the observations, the initial behavioral responses only lasted for a few minutes, ceasing before the end of the 10-minute trial.

Similarly, Skalski et al. (1992) show a 52 percent decrease in rockfish (*Sebastes* sp.) caught with hook-and-line (as part of the study—fisheries independent) when the area of catch was exposed to a single airgun emission at 186 to 191 dB re 1 µPa (mean peak level) (See also Pearson et al. 1987; Pearson et al. 1992). They also demonstrate that fish would show a startle response to sounds as low as 160 dB re 1 µPa, but this level of sound did not appear to elicit decline in catch. Wright (1982) also observed changes in fish behavior as a result of the sound produced by an explosion, with effects intensified in areas of hard substrate.

Wardle et al. (2001) used a video system to examine the behaviors of fish and invertebrates on reefs in response to emissions from seismic airguns. The researchers carefully calibrated the airguns to have a peak level of 210 dB re 1 µPa at 16 m (52.5 ft.) and 195 dB re 1 µPa at 109 m (357.6 ft.) from the source. There was no indication of any observed damage to the marine organisms. They found no substantial or permanent changes in the behavior of the fish or invertebrates on the reef throughout the course of the study, and no marine organisms appeared to leave the reef.

Engås et al. (1996) and Engås and Løkkeborg (2002) examined movement of fish during and after a seismic airgun study by measuring catch rates of haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) as an indicator of fish behavior using both trawls and long-lines as part of the experiment. These investigators found a significant decline in catch of both species that lasted for several days after termination of airgun use. Catch rate subsequently returned to normal. The conclusion reached by the investigators was that the decline in catch rate resulted from the fish moving away from the airgun sounds at the fishing site. However, the investigators did not actually observe behavior, and it is possible that the fish just changed depth.

The same research group showed, more recently, parallel results for several additional pelagic species including blue whiting and Norwegian spring spawning herring (Slotte et al. 2004). However, unlike earlier studies from this group, the researchers used fishing sonar to observe behavior of the local fish schools. They reported that fish in the area of the airguns appeared to go to greater depths after the airgun exposure compared to their vertical position prior to the airgun usage. Moreover, the abundance of animals 30 to 50 km (18.6 to 31.1 mi.) away from the ensonification increased, suggesting that migrating fish would not enter the zone of seismic activity.

Alteration in natural behavior patterns due to exposure to pile driving noise has not been well studied. However, one study (Mueller-Blenkle et al. 2010) demonstrates behavioral reactions of cod (*Gadus morhua*) and Dover sole (*Solea solea*) to pile driving noise. Sole showed a significant increase in swimming speed. Cod reacted, but not significantly, and both species showed directed movement away from the sources with signs of habituation after multiple exposures. For sole, reactions were seen with peak sound pressure levels of 144 to 156 dB re 1 µPa; and cod showed altered behavior at peak sound pressure levels of 140 to 161 dB re 1 µPa. For both species, this corresponds to a peak particle motion between 6.51×10^{-3} and 8.62×10^{-4} meters per second squared.

3.9.3.1.2 Impacts from Sonar and Other Active Acoustic Sources

Non-impulse sources from the Proposed Action include sonar and other active acoustic sources, vessel noise, and subsonic aircraft noise. Potential acoustic effects to fish from non-impulse sources may be considered in four categories, as detailed above in Section 3.9.3.1.1 (Analysis Background and Framework): (1) direct injury, (2) hearing loss, (3) auditory masking, and (4) physiological stress and behavioral reactions.

As discussed in Section 3.9.3.1.1.1 (Direct Injury), direct injury to fish as a result of exposure to non-impulse sounds is highly unlikely to occur. Therefore, direct injury as a result of exposure to non-impulse sound sources is not discussed further in this analysis.

Research discussed in Section 3.9.3.1.1.2 (Hearing Loss), indicates that exposure of fish to transient, non-impulse sources is unlikely to result in any hearing loss. Most sonar sources are outside of the hearing and sensitivity range of most marine fish, and noise sources such as vessel movement and aircraft overflight lack the duration and intensity to cause hearing loss. Furthermore, PTS has not been demonstrated in fish as they have been shown to regenerate lost sensory hair cells. Therefore, hearing loss as a result of exposure to non-impulse sound sources is not discussed further in this analysis.

3.9.3.1.2.1 No Action Alternative – Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.1 (Sonar and Other Active Acoustic Sources), training activities under the No Action Alternative include activities that produce in-water sound from the use of sonar and other active acoustic sources, and could occur throughout the Study Area. Sonar and other active acoustic sources proposed for use are transient in most locations as active sonar activities pass through the Study Area. Based on current research, only a few species of shad within the Clupeidae family (herrings) are known to be able to detect high-frequency sonar and other active acoustic sources (greater than 10,000 Hz). Other marine fish would probably not detect these sounds and would therefore experience no stress, behavioral disturbance, or auditory masking. Shad species, especially in nearshore and inland areas where mine warfare activities take place that often employ high-frequency sonar systems, could have behavioral reactions and experience auditory masking during these activities. However, mine warfare activities are typically limited in duration and geographic extent. Furthermore, sound from high-frequency systems may only be detectable above ambient noise regimes in these coastal habitats from within a few kilometers. Behavioral reactions and auditory masking if they occurred for some shad species are expected to be transient. Long-term consequences for the population would not be expected.

The fish species that are known to detect mid-frequencies (some sciaenids [drum], most clupeids [herring], and potentially deep-water fish such as myctophids [lanternfish]) do not have their best sensitivities in the range of the operational sonar (see Chapter 3, Affected Environment and Environmental Consequences, for more details). Thus, these fish may only detect the most powerful systems, such as hull-mounted sonar within a few kilometers; and most other, less powerful mid-frequency sonar systems, for a kilometer or less. Due to the limited time of exposure due to the moving sound sources, most mid-frequency active sonar used in the Study Area would not have the potential to substantially mask key environmental sounds or produce sustained physiological stress or behavioral reactions. Furthermore, although some species may be able to produce sound at higher frequencies (greater than 1 kHz), vocal marine fish, such as sciaenids, largely communicate below the range of mid-frequency levels used by most sonar. However, any such effects would be temporary and infrequent as a vessel operating mid-frequency sonar transits an area. As such, sonar use is unlikely to impact fish species. Long-term consequences for fish populations due to exposure to mid-frequency sonar and other active acoustic sources are not expected.

A large number of marine fish species, including cartilaginous fish, may be able to detect low-frequency sonar and other active acoustic sources. However, low-frequency active usage is rare, and most low-frequency training activities are conducted in deeper waters. The majority of fish species, including those that are the most highly vocal, exist within nearshore areas. Fish within a few tens of kilometers around a low-frequency active sonar could experience brief periods of masking, physiological stress, and behavioral disturbance while the system is used, with effects most pronounced closer to the source. However, overall effects would be localized and infrequent. Based on the lack of low-frequency sonar for training and the majority of sonar and other active acoustic sources that are outside the hearing range of scalloped hammerhead sharks, long-term consequences are not expected.

Vessel Noise

As discussed in Section 3.0.5.2.1.5 (Vessel Noise), training activities under the No Action Alternative include vessel movement. Military vessel traffic could occur anywhere within the Study Area; however, it would be concentrated near ports or naval installations and training ranges. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours up to 2 weeks.

Additionally, a variety of smaller craft would be operated within the Study Area. Small craft types, sizes and speeds vary. These activities would be spread across the coastal and open ocean areas designated within the Study Area. Vessel movements involve transit to and from ports to various locations within the Study Area, and many ongoing and proposed training and testing activities within the Study Area involve maneuvers by various types of surface ships, boats, and submarines (collectively referred to as vessels).

A detailed description of vessel noise associated with the proposed action is provided in Section 3.0.5.2.1.5 (Vessel Noise). Vessel noise has the potential to expose fish to sound and general disturbance, which could result in short-term behavioral or physiological responses (e.g., avoidance, stress, increased heart rate). Training and testing activities involving vessel movements occur intermittently and range in duration from a few hours up to a few weeks. These activities are widely dispersed throughout the Study Area. While vessel movements have the potential to expose fish occupying the water column to sound and general disturbance, potentially resulting in short-term behavioral or physiological responses, such responses would not be expected to compromise the general health or condition of individual fish. In addition, most activities involving vessel movements are infrequent and widely dispersed throughout the Study Area. The exception is for pierside activities, although these areas are located in inshore, these are industrialized areas that are already exposed to high levels of anthropogenic noise due to numerous waterfront users (e.g., industrial and marinas). Therefore, impacts from vessel noise would be temporary and localized. Long-term consequences for the population are not expected.

Aircraft Noise

As described in Section 3.0.5.2.1.6 (Aircraft Overflight Noise), training activities under the No Action Alternative include fixed and rotary wing aircraft overflights. Certain portions of the Study Area, such as areas near military airfields, installations, and ranges are used more heavily by military aircraft than other portions. These activities would be spread across the coastal and open ocean areas designated within the Study Area. A detailed description of aircraft noise as a stressor is provided in Section 3.0.5.2.1.6 (Aircraft Overflight Noise). Aircraft produce extensive airborne noise from either turbofan or turbojet engines. A severe but infrequent type of aircraft noise is the sonic boom, produced when the aircraft exceeds the speed of sound. Rotary wing aircraft (helicopters) produce low-frequency sound and vibration (Pepper et al. 2003). Most fixed-wing aircraft sorties would occur above 3,000 ft. (900 m). Exposure to fixed-wing aircraft noise would be brief (seconds) as an aircraft quickly passes overhead.

Fish may be exposed to aircraft-generated noise wherever aircraft overflights occur; however, sound is primarily transferred into the water from air in a narrow cone under the aircraft. Most of these sounds would occur near airbases and fixed ranges within each range complex. Some species of fish could respond to noise associated with low-altitude aircraft overflights or to the surface disturbance created by downdrafts from helicopters. Aircraft overflights have the potential to affect surface waters and, therefore, to expose fish occupying those upper portions of the water column to sound and general disturbance potentially resulting in short-term behavioral or physiological responses. If fish were to respond to aircraft overflights, only short-term behavioral or physiological reactions (e.g., temporarily swimming away and increased heart rate) would be expected. Therefore, long-term consequences for individuals would be unlikely and long-term consequences for the populations are not expected. The primary exposure to vessel and aircraft noise may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

Pursuant to the ESA, the use of sonar and other non-impulse acoustic sources during training activities under the No Action Alternative may affect, but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.

3.9.3.1.2.2 No Action Alternative – Testing Activities

Testing activities potentially using non-impulse acoustic sources under the No Action Alternative are restricted to the North Pacific Acoustic Lab Philippine Sea Experiment (Table 2.8-4). Research vessels, acoustic test sources, side scan sonar, ocean gliders, the existing moored acoustic topographic array and distributed vertical line array, and other oceanographic data collection equipment will be used to collect information on the ocean environment and sound propagation during the 2018 data collection period. Currently, the array is being used to passively collect oceanographic and acoustic data in the region. Therefore, impacts to fish due to non-impulse sound are expected to be limited to short-term, minor behavioral reactions. Long-term consequences for populations would not be expected. Based on the lack of low-frequency sonar for testing and the majority of sonar and other active acoustic sources that are outside the hearing range of scalloped hammerhead sharks, long-term consequences are not expected.

The primary exposure to vessel noise would occur around ports and air bases. Vessel noise has the potential to expose fish to sound and general disturbance, potentially resulting in short-term behavioral responses. However, as discussed above, any short-term behavioral reactions, physiological stress, or auditory masking is unlikely to lead to long-term consequences for individuals. Therefore, long-term consequences for populations are not expected. The primary exposure to vessel noise may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

Pursuant to the ESA, the use of sonar and other non-impulse acoustic sources during testing activities under the No Action Alternative may affect, but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.

3.9.3.1.2.3 Alternative 1 – Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Chapter 3 (Affected Environment and Environmental Consequences), the number of annual training activities that produce in-water sound from the use of sonar and other active acoustic sources under Alternative 1 would increase; however, the locations, types, and severity of impacts would not be discernable from those described above in Section 3.9.3.1.2.1 (No Action Alternative – Training). Under Alternative 1, there will be the additional use of low-frequency sonar. A large number of marine fish species may be able to detect low-frequency sonar and other active acoustic sources. However, low-frequency active usage is rare and most low-frequency active operations are conducted in deeper waters, usually beyond the continental shelf break. The majority of fish species, including those that are the most highly vocal, exist on the continental shelf and within nearshore, estuarine areas. Fish within several dozen kilometers around a low-frequency active sonar could experience brief periods of masking, physiological stress, and behavioral disturbance while the system is used, with effects most pronounced closer to the source. However, overall effects would be localized and infrequent. Based on the low level and short duration of potential exposure to low-frequency sonar and other active acoustic sources, long-term consequences for fish populations are not expected. Available data on cartilaginous fish hearing, such as the scalloped hammerhead, suggests the detection of sounds from 20 to 1,000 Hz, with sensitivity at lower ranges (Myrberg 2001; Casper et al. 2003; Casper and Mann 2006 and 2009). However, it is likely that elasmobranchs detect only low-frequency sounds because they lack a swim bladder or other pressure detectors. Based on the lack of low-frequency sonar for training and the majority of sonar and other active acoustic sources that are outside the hearing range of scalloped hammerhead sharks, long-term consequences are not expected.

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.5 (Vessel Noise), training activities, under Alternative 1 include an increase in the numbers of activities that involve vessels compared to the No Action Alternative; however, the locations and predicted impacts would not differ. Proposed training activities under Alternative 1 that involve vessel movement differ in number from training activities proposed under the No Action Alternative; however, the locations, types, and severity of impacts would not be discernable from those described above in Section 3.9.3.1.2.1 (No Action Alternative – Training).

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.6 (Aircraft Overflight Noise), training activities under Alternative 1 include an increase in the number of activities that involve aircraft as compared to the No Action Alternative; however, the training locations, types of aircraft, and types of activities would not differ. The number of individual predicted impacts associated with Alternative 1 aircraft overflight noise may increase; however, the locations, types, and severity of impacts would not be discernable from those described above in Section 3.9.3.1.2.1 (No Action Alternative – Training). The primary exposure to vessel and aircraft noise may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

Despite the increase in activity, the potential effects of training activities involving sonar and other active acoustic sources under Alternative 1 on fish species would be similar to those described above for training activities under the No Action Alternative, and are expected to be limited to short-term, minor behavioral reactions. Effects to fish populations would not occur as a result of non-impulse sounds associated with training activities under Alternative 1.

Pursuant to the ESA, the use of sonar and other non-impulse acoustic sources during training activities under Alternative 1 may affect, but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.

3.9.3.1.2.4 Alternative 1 – Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Tables 2.8-2 to 2.8-4, and Section 3.0.5.2.1 (Acoustic Stressors), the number of annual testing activities that produce sound from vessels and aircraft, and the use of sonar and other active acoustic sources, analyzed under Alternative 1 would increase over what was analyzed for the No Action Alternative. These activities would happen in the same general locations under Alternative 1 as described under the Alternative 1 – Training. The use of low-frequency sonar for testing activities may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

The primary exposure to vessel and aircraft noise would occur around ports and air bases. Vessel and aircraft overflight noise have the potential to expose fish to sound and general disturbance, potentially resulting in short-term behavioral responses. However, as discussed above, any short-term behavioral reactions, physiological stress, or auditory masking is unlikely to lead to long-term consequences for individuals. Therefore, long-term consequences for populations are not expected. The primary exposure to vessel and aircraft noise may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

The potential effects of testing activities involving sonar and other active acoustic sources under Alternative 1 on fish species would are expected to be limited to short-term, minor behavioral reactions. Effects to fish populations would not occur as a result of non-impulse sounds associated with testing activities under Alternative 1.

Pursuant to the ESA, the use of sonar and other non-impulse acoustic sources during testing activities under Alternative 1 may affect, but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.

3.9.3.1.2.5 Alternative 2 – Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Chapter 3 (Affected Environment and Environmental Consequences), the number of annual training activities that produce noise from vessels and aircraft, and the use of sonar and other active acoustic sources under Alternative 2 would increase; however, the locations, types, and severity of impacts would not be discernable from those described above in Section 3.9.3.1.2.1 (No Action Alternative – Training). Based on the lack of low-frequency sonar for training and the majority of sonar and other active acoustic sources that are outside the hearing range of scalloped hammerhead sharks, long-term consequences are not expected.

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.5 (Vessel Noise), training activities, under Alternative 2 include an increase in the numbers of activities that involve vessels compared to the No Action Alternative; however, the locations and predicted impacts would not differ. Proposed training activities under Alternative 2 that involve vessel movement differ in number from training activities proposed under the No Action Alternative; however, the locations, types, and severity of impacts would not be discernable from those described above in Section 3.9.3.1.2.1 (No Action Alternative – Training).

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.3.1.6 (Aircraft Overflight Noise), training activities under Alternative 2 include an increase in the number of activities that involve aircraft as compared to the No Action Alternative; however, the training locations, types of aircraft, and types of activities would not differ. The number of individual predicted impacts associated with Alternative 2 aircraft overflight noise may increase; however, the locations, types, and severity of impacts would not be discernable from those described above in Section 3.9.3.1.2.1 (No Action Alternative – Training). The primary exposure to vessel and aircraft noise may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

Despite the increase in activity, the potential effects of training activities involving sonar and other active acoustic sources under Alternative 2 on fish species would be similar to those described above for training activities under the No Action Alternative, and are expected to be limited to short-term, minor behavioral reactions. Effects to fish populations would not occur as a result of non-impulse sounds associated with training activities under Alternative 2.

Pursuant to the ESA, the use of sonar and other non-impulse acoustic sources during training activities under Alternative 2 may affect, but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.

3.9.3.1.2.6 Alternative 2 – Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Tables 2.8-2 to 2.8-4, and Section 3.0.5.2.1 (Acoustic Stressors), the number of annual testing activities that produce in-water sound from the use of sonar and other active acoustic sources analyzed under Alternative 2 would increase over what was analyzed for the No Action Alternative. These activities would happen in the same general locations under Alternative 2 as described under Alternative 2 in Section 3.9.3.1.2.5 (Alternative 2 – Training). The use of low-frequency sonar for testing activities may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

The primary exposure to vessel and aircraft noise would occur around ports and air bases. Vessel and aircraft overflight noise have the potential to expose fish to sound and general disturbance, potentially resulting in short-term behavioral responses. However, as discussed above, any short-term behavioral reactions, physiological stress, or auditory masking is unlikely to lead to long-term consequences for individuals. Therefore, long-term consequences for populations are not expected. The primary exposure to vessel and aircraft noise may have the potential to expose scalloped hammerhead sharks to sound or general disturbance. However, any potential impacts would result in short-term behavioral or physiological responses; long-term impacts would be unlikely.

Despite the increase in activity, the potential effects of testing activities involving sonar and other active acoustic sources under Alternative 2 on fish species would be similar to those described above for training activities under Alternative 1, and are expected to be limited to short-term, minor behavioral reactions. No population level effects on fish are expected as a result of non-impulse sounds associated with testing activities under Alternative 2.

Pursuant to the ESA, the use of sonar and other non-impulse acoustic sources during testing activities under Alternative 2 may affect, but is not likely to adversely affect ESA-listed scalloped hammerhead sharks.

3.9.3.1.3 Impacts from Explosives and Other Impulse Sound Sources

Explosions and other impulse sound sources include explosions from underwater detonations and explosive ordnance, swimmer defense airguns, and noise from weapons firing, launch, and impact with the water's surface. Potential acoustic effects to fish from impulse sound sources may be considered in four categories, as detailed above in Section 3.9.3.1 (Acoustic Stressors): (1) direct injury, (2) hearing loss, (3) auditory masking, and (4) physiological stress and behavioral reactions.

Potential impacts on fish from explosions and impulse sound sources can range from brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997).

Animals that experience hearing loss (permanent or temporary threshold shift) as a result of exposure to explosions and impulse sound sources may have a reduced ability to detect relevant sounds such as predators, prey, or social vocalizations. It is uncertain whether some permanent hearing loss over a part of a fish's hearing range would have long-term consequences for that individual. If this did affect the fitness (reproductive success) of a few individuals, it is unlikely to have long-term consequences for the population.

Occasional behavioral reactions to intermittent explosions and impulse sound sources are unlikely to cause long-term consequences for individual fish or populations.

Explosives

Concern about potential fish mortality associated with the use of at-sea explosives led military researchers to develop mathematical and computer models that predict safe ranges for fish and other animals from explosions of various sizes (e.g., Yelverton et al. 1975, Goertner 1982, Goertner et al. 1994). Young (1991) provides equations that allow estimation of the potential effect of underwater explosions on fish possessing swim bladders using a damage prediction method developed by Goertner (1982). Young's parameters include the size of the fish and its location relative to the explosive source, but are independent of environmental conditions (e.g., depth of fish and explosive shot frequency). An example of such model predictions is shown in Table 3.9-4, which lists estimated explosive-effects ranges using Young's (1991) method for fish possessing swim bladders exposed to explosions that would typically occur during training exercises. The 10 percent mortality range is the distance beyond which 90 percent of the fish present would be expected to survive. It is difficult to predict the range of more subtle effects causing injury but not mortality (Continental Shelf Associates 2004).

Table 3.9-4: Estimated Explosive Effects Ranges for Fish with Swim Bladders

Training Operation and Type of Ordnance	Net Explosive Weight (lb.)	Depth of Explosion (ft.)	10% Mortality Range (ft.)		
			1 oz. Fish	1 lb. Fish	30 lb. Fish
Mine Neutralization					
MK 103 Charge	0.002	10	40	28	18
AMNS Charge	3.24	20	366	255	164
20 lb. NEW UNDET Charge	20	30	666	464	299
Missile Exercise					
Hellfire	8	3.3	317	221	142
Maverick	100	3.3	643	449	288
Firing Exercise with IMPASS					
Explosive Naval Gun Shell, 5-inch	8	1	244	170	109
Bombing Exercise					
MK 20	109.7	3.3	660	460	296
MK 82	192.2	3.3	772	539	346
MK 83	415.8	3.3	959	668	430
MK 84	945	3.3	1,206	841	541

Notes: ft. = foot/feet, lb. = pound, NEW = Net Explosive Weight, oz. = ounce

Fish not killed or driven from a location by an explosion might change their behavior, feeding pattern, or distribution. Changes in behavior of fish have been observed as a result of sound produced by explosives, with effect intensified in areas of hard substrate (Wright 1982). Stunning from pressure waves could also temporarily immobilize fish, making them more susceptible to predation.

The number of fish killed by an underwater explosion would depend on the population density in the vicinity of the blast, as well as factors discussed above such as net explosive weight, depth of the explosion, and fish size. For example, if an explosion occurred in the middle of a dense school of fish, a large number of fish could be killed. Furthermore, the probability of this occurring is low based on the patchy distribution of dense schooling fish.

Sounds from explosions could cause hearing loss in nearby fish (dependent upon charge size). Permanent hearing loss has not been demonstrated in fish, as lost sensory hair cells can be replaced unlike in mammals. Fish that experience hearing loss could miss opportunities to detect predators or prey, or reduce interspecific communication. If an individual fish were repeatedly exposed to sounds from underwater explosions that caused alterations in natural behavioral patterns or physiological stress, these impacts could lead to long-term consequences for the individual such as reduced survival, growth, or reproductive capacity. However, the time scale of individual explosions is very limited, and training exercises involving explosions are dispersed in space and time. Consequently, repeated exposure of individual fish to sounds from underwater explosions is not likely and most acoustic effects are expected to be short-term and localized. Long-term consequences for populations would not be expected.

Weapons Firing, Launch, and Impact Noise

As described in Chapter 2 (Description of Proposed Action and Alternatives) and Table 2.8-1, training activities under the No Action Alternative include activities that produce in water noise from weapons firing, launch, and non-explosive ordnance impact with the water's surface. Activities are spread throughout the Study Area, and could take place within coastal or open ocean areas. Most activities involving large-caliber naval gunfire or the launching of targets, missiles, bombs, or other ordnance are conducted greater than 12 nm from shore.

A detailed description of weapons firing, launch, and impact noise is provided in Section 3.0.5.2.1.4 (Weapons Firing, Launch, and Impact Noise). Noise under the muzzle blast of a 5 in. (12.7 cm) gun and directly under the flight path of the shell (assuming the shell is a few meters above the water's surface) would produce a peak sound pressure level of approximately 200 dB re 1 µPa near the surface of the water (1 to 2 m [3.3 to 6.6 ft.] depth). Sound due to missile and target launches is typically at a maximum during initiation of the booster rocket and rapidly fades as the missile or target travels downrange. Many missiles and targets are launched from aircraft, which would produce minimal noise in the water due to the altitude of the aircraft at launch. Mines, non-explosive bombs, and intact missiles and targets could impact the water with great force and produce a large impulse and loud noise of up to approximately 270 dB re 1 µPa at 1 m (3.3 ft.), but with very short pulse durations, depending on the size, weight, and speed of the object at impact (McLennan 1997). This corresponds to sound exposure levels of around 200 dB re 1 μPa^2-s at 1 m (3.3 ft.). These sounds from weapons firing launch, and impact noise would be transient and of short duration, lasting no more than a few seconds at any given location.

Fish that are exposed to noise from weapons firing, launch, and non-explosive ordnance impact with the water's surface may exhibit brief behavioral reactions; however, due to the short term, transient nature of weapons firing, launch, and non-explosive impact noise, animals are unlikely to be exposed multiple times within a short period. Behavioral reactions would likely be short term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected.

3.9.3.1.3.1 No Action Alternative – Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.2 (Explosives), training activities under the No Action Alternative would use underwater detonations and explosive ordnance. With the exception of those used at FDM and the nearshore underwater detonation sites, the vast majority of explosives used under the No Action Alternative occur in areas greater than 3 nm from shore. There is a potential (albeit small) for aberrant ordnance at FDM to miss land-based targets and strike the beaches and nearshore habitats of FDM.

Under the No Action Alternative, explosive bombs (32), missiles/rockets (58), explosive sonobuoys (8), and large-caliber projectiles (1,240) are proposed to be expended during training activities in the Study Area (see Table 3.0-19). As described above, impacts from weapons firing, launch, and impact noise would likely be short term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected. Additionally, individuals are unlikely to be exposed multiple times within a short period.

Scalloped hammerhead sharks have the potential to be exposed to explosive energy and sound associated with training activities under the No Action Alternative. Training activities involving impulse acoustic sources have the potential to affect the ESA-listed species present, potentially resulting in short-term behavioral or physiological responses, hearing loss, injury, or mortality. However, given the infrequent nature of training activities involving impulse acoustic sources, the likelihood of these species encountering an explosive activity is remote.

Pursuant to the ESA, the use of explosives and other impulse sound sources during training activities under the No Action Alternative may affect, and is likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.1.3.2 No Action Alternative – Testing Activities

Testing activities under the No Action Alternative do not involve the use of impulse sources.

3.9.3.1.3.3 Alternative 1 – Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.2 (Explosives), the number of annual training activities that use explosions under Alternative 1 would increase. Under Alternative 1, explosive bombs (212), missiles/rockets (239), large- and medium-caliber projectiles (9,450), and explosive sonobuoys (11) are proposed to be expended during training activities in the Study Area (see Table 3.0-19 for details), which would be a 640 percent increase over the No Action Alternative. As described above, impacts from weapons firing, launch, and impact noise would likely be short term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected. Additionally, individuals are unlikely to be exposed multiple times within a short period. These activities would happen in the same general locations as described by the No Action Alternative.

As discussed for the No Action Alternative, potential impacts on fish from explosions and impulse sound sources can range from no effect, brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997). Occasional behavioral reactions to intermittent explosions and impulse sound sources are unlikely to cause long-term consequences for individual fish or populations. While serious injury and/or mortality to individual fish would be expected if they were present in the immediate vicinity of explosive ordnance use, despite the increase in activities under Alternative 1, the activities are infrequent and widely dispersed throughout the Study Area, and the distribution of potentially affected fishes also varies, impacts from at-sea explosion from training activities would be temporary and localized, and are not expected to result in population level impacts.

Scalloped hammerhead sharks have the potential to be exposed to explosive energy and sound associated with training activities under Alternative 1. Training activities involving impulse acoustic sources have the potential to affect the ESA-listed species present, potentially resulting in short-term behavioral or physiological responses, hearing loss, injury, or mortality. However, given the infrequent nature of training activities involving impulse acoustic sources, the likelihood of these species encountering an explosive activity is remote.

Pursuant to the ESA, the use of explosives and other impulse sound sources during training activities under Alternative 1 may affect, and is likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.1.3.4 Alternative 1 –Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Tables 2.8-2 to 2.8-4, and Section 3.0.5.2.1.2 (Explosives), the number of annual testing activities that use explosives under Alternative 1 would increase over the No Action Alternative (see Table 3.0-9 for details). Testing activities involving explosions could be conducted throughout the Study Area, although activities do not normally occur within 3 nm of shore except at designated underwater detonation areas. As described above, impacts from weapons firing, launch, and impact noise would likely be short term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected. Additionally, individuals are unlikely to be exposed multiple times within a short period. These testing activities are spread throughout the Study Area, and described in Tables 2.8-2 to 2.8-4.

Swimmer Defense Airguns

Testing activities under Alternative 1 would include the use of swimmer defense airguns up in Inner Apra Harbor as described in Section 3.0.5.2.1.3 (Swimmer Defense Airguns). Source levels are estimated to be 185 to 195 dB re 1 μPa^2-s at 1 m. For 100 shots, the cumulative sound exposure level would be approximately 215 to 225 dB re 1 μPa^2-s at 1 m.

Single, small airguns (60 cubic inches) are unlikely to cause direct trauma to marine fish. Impulses from airguns lack the strong shock wave and rapid pressure increase, as would be expected from explosive sources that can cause primary blast injury or barotrauma. As discussed in Section 3.9.3.1.1.1 (Direct Injury), there is little evidence that airguns can cause direct injury to adult fish, with the possible exception of injuring small juvenile or larval fish nearby (approximately 16 ft. [4.9 m]). Therefore, larval and small juvenile fish within a few meters of the airgun may be injured or killed. Considering the small footprint of this hypothesized injury zone, and the isolated and infrequent use of the swimmer defense airgun, population consequences would not be expected.

As discussed in Section 3.9.3.1.1.2 (Hearing Loss), temporary hearing loss in fish could occur if fish were exposed to impulses from swimmer defense airguns, although some studies have shown no hearing loss from exposure to airguns within 16 ft. (4.9 m). Therefore, fish within a few meters of the airgun may receive temporary hearing loss. However, due to the relatively small size of the airgun, and their limited use in pierside areas, impacts would be minor, and may only impact a few individual fish. Population consequences would not be expected.

Airguns do produce broadband sounds; however, the duration of an individual impulse is about one-tenth of a second. Airguns could be fired up to 100 times per activity, but would generally be used less based on the actual testing requirements. The pierside areas where these activities are proposed are inshore, with high levels of use, and therefore have high levels of ambient noise, see Appendix I (Acoustic and Explosives Primer). Auditory masking is discussed in Section 3.9.3.1.1.3 (Auditory

Masking), and only occurs when the interfering signal is present. Due to the limited duration of individual shots and the limited number of shots proposed for the swimmer defense airgun, only brief, isolated auditory masking to marine fish would be expected. Population consequences would not be expected.

In addition, fish that are able to detect the airgun impulses may exhibit alterations in natural behavior. As discussed in Section 3.9.3.1.1.4 (Physiological Stress and Behavioral Reactions), some fish species with site fidelity such as reef fish may show initial startle reactions, returning to normal behavioral patterns within a matter of a few minutes. Pelagic and schooling fish that typically show less site fidelity may avoid the immediate area for the duration of the activities. Due to the limited use and relatively small footprint of swimmer defense airguns, impacts to fish are expected to be minor. Population consequences would not be expected.

Conclusion

As discussed for training activities, potential impacts on fish from explosions and impulse acoustic sources can range from no impact, brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997). Occasional behavioral reactions to intermittent explosives and impulse acoustic sources are unlikely to cause long-term consequences for individual fish or populations.

Animals that experience hearing loss (permanent or temporary threshold shift) as a result of exposure to explosions and impulse acoustic sources may have a reduced ability to detect relevant sounds such as predators, prey, or social vocalizations. It is uncertain whether some permanent hearing loss over a part of a fish's hearing range would have long-term consequences for that individual. If this did affect the fitness of a few individuals, it is unlikely to have long-term consequences for the population.

It is possible for fish to be injured or killed by an explosion; however, the loss of a few individuals is unlikely to have measureable impacts on overall stocks or populations present in the Study Area. Therefore, long-term consequences to fish populations or stocks would not be expected.

Scalloped hammerhead sharks have the potential to be exposed to explosive energy and sound associated with testing activities under Alternative 1. Testing activities involving impulse acoustic sources have the potential to affect the ESA-listed species present, potentially resulting in short-term behavioral or physiological responses, hearing loss, injury, or mortality. However, given the infrequent nature of testing activities involving impulse acoustic sources, the likelihood of these species encountering an explosive activity is remote.

Pursuant to the ESA, the use of explosives and other impulse sound sources during testing activities under Alternative 1 may affect, and is likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.1.3.5 Alternative 2 – Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.8-1, and Section 3.0.5.2.1.2 (Explosives), the number of annual training activities that use explosions under Alternative 2 would increase. Under Alternative 2, explosive torpedoes (2), explosive bombs (212), missiles/rockets (517), large- and medium-caliber projectiles (9,450), and explosive sonobuoys (11) are proposed to be expended during training activities in the Study Area (see Table 3.0-19), which would be a 662 percent increase over the No Action Alternative. As described above, impacts from weapons firing, launch, and impact noise would likely be short term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected. Additionally, individuals are unlikely to be exposed multiple times within a short period. These activities would happen in the same general locations as described by the No Action Alternative.

As discussed for Alternative 1, potential impacts on fish from explosions and impulse sound sources can range from no effect, brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997). Occasional behavioral reactions to intermittent explosions and impulse sound sources are unlikely to cause long-term consequences for individual fish or populations. While serious injury and/or mortality to individual fish would be expected if they were present in the immediate vicinity of explosive ordnance use, the activities are infrequent and widely dispersed throughout the Study Area, and the distribution of potentially affected fishes also varies, impacts from at-sea explosion from training activities would be temporary and localized, and are not expected to result in population level impacts.

Scalloped hammerhead sharks have the potential to be exposed to explosive energy and sound associated with training activities under Alternative 2. Training activities involving impulse acoustic sources have the potential to affect the ESA-listed species present, potentially resulting in short-term behavioral or physiological responses, hearing loss, injury, or mortality. However, given the infrequent nature of training activities involving impulse acoustic sources, the likelihood of these species encountering an explosive activity is remote.

Pursuant to the ESA, the use of explosives and other impulse sound sources during training activities under Alternative 2 may affect, and is likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.1.3.6 Alternative 2 – Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Tables 2.8-2 to 2.8-4, and Section 3.0.5.2.1.2 (Explosives), the number of annual testing activities that use explosives under Alternative 2 would increase over the No Action Alternative (see Table 3.0-9). Testing activities involving explosions could be conducted throughout the Study Area, although activities do not normally occur within 3 nm of shore except at designated underwater detonation areas. As described above, impacts from weapons firing, launch, and impact noise would likely be short term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected. Additionally, individuals are unlikely to be exposed multiple times within a short period. These activities are spread throughout the Study Area and described in Tables 2.8-2 to 2.8-4.

Swimmer Defense Airguns

Testing activities under Alternative 2 would include the use of swimmer defense airguns up in Inner Apra Harbor as described in Section 3.0.5.2.1.3 (Swimmer Defense Airguns). Source levels are estimated to be 185 to 195 dB re 1 μPa^2-s at 1 m. For 100 shots, the cumulative sound exposure level would be approximately 215 to 225 dB re 1 μPa^2-s at 1 m.

Single, small airguns (60 cubic inches) are unlikely to cause direct trauma to marine fish. Impulses from airguns lack the strong shock wave and rapid pressure increase, as would be expected from explosive sources that can cause primary blast injury or barotrauma. As discussed in Section 3.9.3.1.1.1 (Direct Injury), there is little evidence that airguns can cause direct injury to adult fish, with the possible exception of injuring small juvenile or larval fish nearby (approximately 16 ft. [4.9 m]). Therefore, larval and small juvenile fish within a few meters of the airgun may be injured or killed. Considering the small footprint of this hypothesized injury zone, and the isolated and infrequent use of the swimmer defense airgun, population consequences would not be expected.

As discussed in Section 3.9.3.1.1.2 (Hearing Loss), temporary hearing loss in fish could occur if fish were exposed to impulses from swimmer defense airguns, although some studies have shown no hearing loss from exposure to airguns within 16 ft. (4.9 m). Therefore, fish within a few meters of the airgun may receive temporary hearing loss. However, due to the relatively small size of the airgun, and their limited use in pierside areas, impacts would be minor, and may only impact a few individual fish. Population consequences would not be expected.

Airguns do produce broadband sounds; however, the duration of an individual impulse is about one-tenth of a second. Airguns could be fired up to 100 times per activity, but would generally be used less based on the actual testing requirements. The pierside areas where these activities are proposed are inshore, with high levels of use, and therefore have high levels of ambient noise, see Appendix I (Acoustic and Explosives Primer). Auditory masking is discussed in Section 3.9.3.1.1.3 (Auditory Masking), and only occurs when the interfering signal is present. Due to the limited duration of individual shots and the limited number of shots proposed for the swimmer defense airgun, only brief, isolated auditory masking to marine fish would be expected. Population consequences would not be expected.

In addition, fish that are able to detect the airgun impulses may exhibit alterations in natural behavior. As discussed in Section 3.9.3.1.1.4 (Physiological Stress and Behavioral Reactions), some fish species with site fidelity such as reef fish may show initial startle reactions, returning to normal behavioral patterns within a matter of a few minutes. Pelagic and schooling fish that typically show less site fidelity may avoid the immediate area for the duration of the activities. Due to the limited use and relatively small footprint of swimmer defense airguns, impacts to fish are expected to be minor. Population consequences would not be expected.

Conclusion

As discussed for training activities, potential impacts on fish from explosions and impulse acoustic sources can range from no impact, brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997). Occasional behavioral reactions to intermittent explosives and impulse acoustic sources are unlikely to cause long-term consequences for individual fish or populations.

Animals that experience hearing loss (permanent or temporary threshold shift) as a result of exposure to explosions and impulse acoustic sources may have a reduced ability to detect relevant sounds such as predators, prey, or social vocalizations. It is uncertain whether some permanent hearing loss over a part of a fish's hearing range would have long-term consequences for that individual. If this did affect the fitness of a few individuals, it is unlikely to have long-term consequences for the population.

It is possible for fish to be injured or killed by an explosion; however, long-term consequences for a loss of a few individuals are unlikely to have measureable impacts on overall stocks or populations. Therefore, long-term consequences to fish populations would not be expected.

Scalloped hammerhead sharks have the potential to be exposed to explosive energy and sound associated with testing activities under Alternative 2. Testing activities involving impulse acoustic sources have the potential to affect the ESA-listed species present, potentially resulting in short-term behavioral or physiological responses, hearing loss, injury, or mortality. However, given the infrequent nature of testing activities involving impulse acoustic sources, the likelihood of these species encountering an explosive activity is remote.

Pursuant to the ESA, the use of explosives and other impulse sound sources during testing activities under Alternative 2 may affect, and is likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.1.3.7 Summary of Effects to Marine Fish from Acoustic Stressors

Under the No Action Alternative, Alternative 1, or Alternative 2, potential impacts on fish from acoustic stressors can range from no impact, brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997). Occasional behavioral reactions to intermittent explosions and impulse sound sources are unlikely to cause long-term consequences for individual fish or populations. While serious injury or mortality to individual fish would be expected if they were present in the immediate vicinity of explosive ordnance use; however, population level impacts are not expected.

Pursuant to the ESA, the use of acoustic stressors under the No Action Alternative, Alternative 1, or Alternative 2 may affect, and is likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.2 Energy Stressors

This section evaluates the potential for fishes to be impacted by electromagnetic devices used during training and testing activities in the Study Area. No high-energy lasers are used in the MITT Study Area, so the discussion of energy stressors will be restricted to electromagnetic stressors.

3.9.3.2.1 Impacts from Electromagnetic Devices

Several different electromagnetic devices are used during training and testing activities. A discussion of the type, number, and location of activities using these devices under each alternative is presented in Section 3.0.5.2.2.1 (Electromagnetic Devices).

A comprehensive review of information regarding the sensitivity of marine organisms to electric and magnetic fields, including fishes comprising the subclass elasmobranchii (sharks, skates, and rays), as well as other bony fishes, is presented in Normandeau (2011). The synthesis of available data and information contained in this report suggests that while many fish species (particularly elasmobranchs) are sensitive to electromagnetic fields, further investigation is necessary to understand the physiological response and magnitude of the potential effects. This study also highlights investigations into which electric and magnetic field strengths initiate biological and physiological responses on specific fish species (Normandeau et al. 2011). Most examinations of electromagnetic fields on marine fishes have focused on buried undersea cables associated with offshore wind farms in European waters (Boehlert and Gill 2010; Gill 2005; Ohman et al. 2007). By comparison, in the Study Area, electromagnetic devices simply mimic the electromagnetic signature of a vessel passing through the water, and none of these devices include any type of electromagnetic "pulse."

Many fish groups including lamprey, elasmobranchs, eels, salmonids, stargazers, and others, have an acute sensitivity to electrical fields, known as electroreception (Bullock et al. 1983; Helfman et al. 2009). Electroreceptors are thought to aid in navigation, orientation, and migration of sharks and rays (Kalmijn 2000). In elasmobranchs, behavioral and physiological response to electromagnetic stimulus varies by species and age, and appears to be related to foraging behavior (Rigg et al. 2009). Many elasmobranchs respond physiologically to electric fields of 10 nanovolts (nV) per cm and behaviorally at 5 nV per cm (Collin and Whitehead 2004). Electroreceptive marine fishes with ampullary (pouch) organs can detect considerably higher frequencies of 50 Hz to more than 2 kHz (Helfman et al. 2009). The distribution of electroreceptors on the head of these fishes, especially around the mouth suggests that these sensory organs may be used in foraging. Additionally, some researchers hypothesize that the electroreceptors aid in social communication (Collin and Whitehead 2004). The ampullae of some fishes are sensitive to low frequencies (< 0.1 to 25 Hz) of electrical energy (Helfman et al. 2009), which may be of physical or biological origin, such as muscle contractions. For example, the ampullae of the shovelnose sturgeon (*Scaphirhynchus platorynchus*), were shown to respond to electromagnetic stimuli in a way comparable to the well-studied elasmobranchs, which are sensitive to electric fields as low as 1 microvolt (µV) per cm with a magnetic field of 100 gauss (Bleckmann and Zelick 2009).

While elasmobranchs and other fishes can sense the level of the earth's electromagnetic field, the potential effects on fish resulting from changes in the strength or orientation of the background field are not well understood. When the electromagnetic field is enhanced or altered, sensitive fishes may experience an interruption or disturbance in normal sensory perception. Research on the electrosensitivity of sharks indicates that some species respond to electrical impulses with an apparent avoidance reaction (Helfman et al. 2009; Kalmijn 2000). This avoidance response has been exploited as a shark deterrent, to repel sharks from areas of overlap with human activity (Marcotte and Lowe 2008).

Experiments with electromagnetic pulses can provide indirect evidence of the range of sensitivity of fishes to similar stimuli. Two studies reported that exposure to electromagnetic pulses do not have any effect on fishes (Hartwell et al. 1991; Nemeth and Hocutt 1990). The observed 48-hour mortality of small estuarine fishes (sheepshead minnow, mummichog, Atlantic menhaden, striped bass, Atlantic silverside, fourspine stickleback, and rainwater killifish) exposed to electromagnetic pulses of 100 to 200 kilovolts (kV) per m (10 nanoseconds per pulse) from distances greater than 164 ft. (50 m) was not statistically different than the control group (Hartwell et al. 1991; Nemeth and Hocutt 1990). During a study of Atlantic menhaden, there were no statistical differences in swimming speed and direction (toward or away from the electromagnetic pulse source) between a group of individuals exposed to electromagnetic pulses and the control group (Hartwell et al. 1991; Nemeth and Hocutt 1990).

Both laboratory and field studies confirm that elasmobranchs (and some teleost [bony] fishes) are sensitive to electromagnetic fields, but the long-term impacts are not well known. Electromagnetic sensitivity in some marine fishes (e.g., salmonids) is already well-developed at early life stages (Ohman et al. 2007), with sensitivities reported as low as 0.6 millivolt per centimeter (mV/cm) in Atlantic salmon (Formicki et al. 2004); however, most of the limited research that has occurred focuses on adults. Some species appear to be attracted to undersea cables, while others show avoidance (Ohman et al. 2007). Under controlled laboratory conditions, the scalloped hammerhead (*Sphyrna lewini*) and sandbar shark (*Carcharhinus plumbeus*) exhibited altered swimming and feeding behaviors in response to very weak electric fields (less than 1 nV per cm) (Kajiura and Holland 2002). In a test of sensitivity to fixed magnets, five Pacific sharks were shown to react to magnetic field strengths of 25 to 234 gauss at distances ranging between 0.85 and 1.90 ft. (0.26 and 0.58 m) and avoid the area (Rigg et al. 2009). A field trial in the Florida Keys demonstrated that southern stingray (*Dasyatis americana*) and nurse shark (*Ginglymostoma cirratum*) detected and avoided a fixed magnetic field producing a flux of 950 gauss (O'Connell et al. 2010). Scalloped hammerhead sharks may also experience temporary disturbance of normal sensory perception or could experience avoidance reactions (Kalmijn 2000).

Potential impacts of electromagnetic activity on adult fishes may not be relevant to early life stages (eggs, larvae, juveniles) due to ontogenic (lifestage-based) shifts in habitat utilization (Botsford et al. 2009; Sabates et al. 2007). Some skates and rays produce egg cases that occur on the bottom, while many neonate and adult sharks occur in the water column or near the water surface. Other species may have an opposite life history, with egg and larval stages occurring near the water surface, while adults may be demersal.

Based on current literature, only the fish groups identified above as capable of detecting electromagnetic fields (primarily elasmobranchs, tuna, and eels) will be carried forward in this analysis and the remaining groups (from Table 3.9-2) will not be discussed further.

3.9.3.2.1.1 No Action Alternative

Training Activities

There are no training activities under the No Action Alternative that would involve electromagnetic activities.

Testing Activities

There are no testing activities under the No Action Alternative that would involve electromagnetic activities.

3.9.3.2.1.2 Alternative 1

Training Activities

As indicated in Section 3.0.5.2.2.1 (Electromagnetic Devices), training activities involving electromagnetic devices under Alternative 1 occur up to five times annually as part of mine countermeasure (MCM) (towed mine detection) and Civilian Port Defense activities. Table 2.8-1 lists the number and location of training activities that use electromagnetic devices. Exposure of fishes to electromagnetic stressors is limited to those fish (primarily elasmobranchs, tuna, and eels) that are able to detect the electromagnetic properties in the water column (Bullock et al. 1983; Helfman et al. 2009).

Electromagnetic devices are used primarily during mine detection/neutralization activities, and in most cases, the devices simply mimic the electromagnetic signature of a vessel passing through the water. None of the devices include any type of electromagnetic “pulse.” The towed body used for mine sweeping is designed to simulate a ship’s electromagnetic signal in the water, and so would not be experienced by fishes as anything unusual. The static magnetic field generated by the electromagnetic systems is of relatively minute strength, typically 23 gauss at the cable surface and 0.002 gauss at a radius of 656 ft. (199.9 m). The strength of the electromagnetic field decreases quickly away from the cable down to the level of earth’s magnetic field (0.5 gauss) at less than 13 ft. (3.9 m) from the source. In addition, training activities generally occur offshore in the water column, where fishes with high mobility predominate and fish densities are relatively low, compared with nearshore benthic habitat. Because the towed body is continuously moving, most fishes are expected to move away from it or follow behind it, in ways similar to responses to a vessel.

For any electromagnetically sensitive fishes in close proximity to the source, the generation of electromagnetic fields during training activities has the potential to interfere with prey detection and navigation. They may also experience temporary disturbance of normal sensory perception or could experience avoidance reactions (Kalmijn 2000), resulting in alterations of behavior and avoidance of normal foraging areas or migration routes. Mortality from electromagnetic devices is not expected.

Therefore, the electromagnetic devices used would not cause any potential risk to fishes because (1) the range of impact (i.e., greater than earth's magnetic field) is small (i.e., 13 ft. [3.9 m] from the source), (2) the electromagnetic components of these activities are limited to simulating the electromagnetic signature of a vessel as it passes through the water, and (3) the electromagnetic signal is temporally variable and would cover only a small spatial range during each activity in the Study Area. Some fishes could have a detectable response to electromagnetic exposure, but any impacts would be temporary with no anticipated impact on an individual's growth, survival, annual reproductive success, or lifetime reproductive success (i.e., fitness). Fitness refers to changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success. Electromagnetic exposure of eggs and larvae of sensitive bony fishes would be low relative to their total ichthyoplankton biomass (Able and Fahay 1998) and; therefore, potential impacts on recruitment would not be expected.

The ESA-listed scalloped hammerhead shark is capable of detecting electromagnetic energy. Therefore, electromagnetic stressors could affect scalloped hammerhead sharks. The electromagnetic signal is temporally variable and would cover only a small spatial range during each activity in the Study Area, therefore any disturbance to scalloped hammerhead sharks would be limited in range. If located in the immediate area where electromagnetic devices are being used, scalloped hammerhead sharks could experience temporary disturbance in normal sensory perception during migratory or foraging movements, or avoidance reactions (Kalmijn 2000).

Pursuant to the ESA, the use of electromagnetic devices during training activities under, Alternative 1 may affect, but is not likely to adversely affect, ESA-listed scalloped hammerhead sharks.

Testing Activities

As described in Section 2.7 (Alternative 1 [Preferred Alternative]: Expansion of Study Area Plus Adjustments to the Baseline and Additional Weapons, Platforms, and Systems), Alternative 1 consists of the No Action Alternative and adjustments to location, type, and tempo of training and testing activities, which includes the addition of platforms and systems.

Mine Countermeasure Mission package testing for new ship systems includes the use of electromagnetic devices (magnetic fields generated underwater to detect mines). Under Alternative 1, the Naval Sea Systems Command will engage in up to 32 MCM mission package testing activities annually. Exposure of fishes to electromagnetic stressors is limited to those fish groups identified in Sections 3.9.2.3 to 3.9.2.21 (Marine Fish Groups) that are able to detect the electromagnetic properties in the water column (Bullock et al. 1983; Helfman et al. 2009). Fish species that do not occur within these specified areas would not be exposed to the electromagnetic fields. The electromagnetic devices used in testing activities would not cause any potential risk to fishes for the same reasons stated for training activities above.

The ESA-listed scalloped hammerhead shark is capable of detecting electromagnetic energy. Therefore, electromagnetic stressors could affect scalloped hammerhead sharks. The electromagnetic signal is temporally variable and would cover only a small spatial range during each activity in the Study Area, therefore any disturbance to scalloped hammerhead sharks would be limited in range. If located in the immediate area where electromagnetic devices are being used, scalloped hammerhead sharks could experience temporary disturbance in normal sensory perception during migratory or foraging movements, or avoidance reactions (Kalmijn 2000).

Pursuant to the ESA, the use of electromagnetic devices during testing activities under, Alternative 1 may affect, but is not likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.2.1.3 Alternative 2

Training Activities

The number and location of training activities under Alternative 2 are identical to training activities under Alternative 1. Therefore, the impacts from electromagnetic training events under Alternative 2 would be the same as those described under Alternative 1.

The ESA-listed scalloped hammerhead shark is capable of detecting electromagnetic energy. Therefore, electromagnetic stressors could affect scalloped hammerhead sharks. The electromagnetic signal is temporally variable and would cover only a small spatial range during each activity in the Study Area, therefore any disturbance to scalloped hammerhead sharks would be limited in range. If located in the immediate area where electromagnetic devices are being used, scalloped hammerhead sharks could experience temporary disturbance in normal sensory perception during migratory or foraging movements, or avoidance reactions (Kalmijn 2000).

Pursuant to the ESA, the use of electromagnetic devices during training activities under, Alternative 2 may affect, but is not likely to adversely affect, ESA-listed scalloped hammerhead sharks.

Testing Activities

Mine Countermeasure Mission package testing for new ship systems includes the use of electromagnetic devices (magnetic fields generated underwater to detect mines). Under Alternative 2, the Naval Sea Systems Command will engage in up to 36 Mine Counter Measure mission package testing activities annually. Exposure of fishes to electromagnetic stressors is limited to those fish groups identified in Sections 3.9.2.3 to 3.9.2.21 (Marine Fish Groups) that are able to detect the electromagnetic properties in the water column (Bullock et al. 1983; Helfman et al. 2009). Fish species that do not occur within these specified areas would not be exposed to the electromagnetic fields. The electromagnetic devices used in testing activities would not cause any potential risk to fishes for the same reasons stated for training activities above.

The ESA-listed scalloped hammerhead shark is capable of detecting electromagnetic energy. Therefore, electromagnetic stressors could affect scalloped hammerhead sharks. The electromagnetic signal is temporally variable and would cover only a small spatial range during each activity in the Study Area, therefore any disturbance to scalloped hammerhead sharks would be limited in range. If located in the immediate area where electromagnetic devices are being used, scalloped hammerhead sharks could experience temporary disturbance in normal sensory perception during migratory or foraging movements, or avoidance reactions (Kalmijn 2000).

Pursuant to the ESA, the use of electromagnetic devices during testing activities under, Alternative 2 may affect, but is not likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.2.2 Summary and Conclusions of Energy Impacts

Under the No Action Alternative, Alternative 1, or Alternative 2, disturbance from activities using electromagnetic energy could be expected to elicit brief behavioral or physiological responses only in those exposed fishes with sensitivities/detection abilities (primarily sharks and rays) within the corresponding portion of the electromagnetic spectrum that these activities use. For electromagnetic devices, the typical reaction would be for the fish to avoid (move away from) the signal upon detection. The impact of electromagnetic signals are expected to be inconsequential on fishes or fish populations because signals are similar to regular vessel traffic, and the electromagnetic signal would be continuously moving and cover only a small spatial area during use.

Pursuant to the ESA, energy stressors under the No Action Alternative, Alternative 1, or Alternative 2 may affect, but are not likely to adversely affect, ESA-listed scalloped hammerhead sharks.

3.9.3.3 Physical Disturbance and Strike Stressors

This section evaluates the potential effects of various types of physical disturbance and strike stressors associated with military training and testing activities within the Study Area. Section 3.0.5.2.3 (Physical Disturbance and Strike Stressors) discusses the activities that may produce physical disturbance and strike stressors.

Physical disturbance and strike risks have the potential to impact all taxonomic groups found within the Study Area (Table 3.9-2), because strikes could occur anywhere in the water column or on the seafloor. Potential impacts of physical strike include behavioral responses such as avoidance response behavior, change in swimming speed/direction, physiological stress response, temporary disorientation, injury, or mortality. These disturbances could result in abnormal behavioral, growth, or reproductive impacts. Although fishes can detect approaching vessels using a combination of sensory abilities (sight, hearing, lateral line), the slow-moving fishes (e.g., ocean sunfish, basking sharks) are unable to avoid all collisions, with some vessel strikes resulting in mortality.

The way a physical strike impacts a fish would depend in part on the relative size of the object and the location of the fish in the water column. Before being struck by an object, the fish would sense a pressure wave through the water (Hawkins and Johnstone 1978). Small fishes in the open water, such as anchovies or sardines, would simply be displaced by the movement generated by a large object moving through the water. Some fish might have time to detect the approaching object and swim away; others could be struck before it becomes aware of the object. An open-ocean fish displaced a small distance by movements from an object falling into the water nearby would likely continue on as if nothing had happened. However, a bottom-dwelling fish in the vicinity of a falling object would likely be disturbed and may exhibit a generalized stress response. If the object actually hit the fish, direct injury in addition to stress may result. As in all vertebrates, the function of the stress response in fishes is to rapidly raise the blood sugar level to prepare the fish to flee or fight (Helfman et al. 2009). This generally adaptive physiological response can become a liability to the fish if the stressor persists and the fish is not able to return to its baseline physiological state. When stressors are chronic, the fish may experience reduced growth, health, or survival (Wedemeyer et al. 1990).

Most fishes respond to sudden physical approach or contact by darting quickly away from the stimulus. Other species may respond by freezing in place and adopting cryptic coloration. In either case, the individual must stop its current activity and divert its physiological and cognitive attention to responding to the stressor (Helfman et al. 2009). The energy costs of reacting to a stressor depend on the specific situation, but in all cases the caloric requirements of stress reactions reduce the amount of energy available to the fish for other functions, such as predator avoidance, reproduction, growth, and maintenance (Wedemeyer et al. 1990).

The ability of a fish to return to its previous activity following a physical strike (or near-miss resulting in a stress response) is a function of both genetic and environmental factors. Some fish species are more tolerant of stressors than others and become acclimated more easily. Experiments with species for use in aquaculture have revealed the immense variability among species in their tolerance to crowding, handling, and other physical stressors, as well as to chemical stressors. Within a species, the rate at which an individual recovers from a physical strike may be influenced by its age, sex, reproductive state, and general condition. A fish that has reacted to a sudden disturbance by swimming at burst speed would tire after only a few minutes; its blood hormone and sugar levels (cortisol and glucose) may not return to normal for 24 hours. During the recovery period, the fish would not be able to attain burst speeds and would be more vulnerable to predators (Wardle 1986). If the individual were not able to regain a steady state following exposure to a physical stressor, it may suffer reduced immune function and even death (Wedemeyer et al. 1990).

Potential impacts of physical disturbance or strike to adults may be different than for other lifestages (eggs, larvae, juveniles) because these lifestages do not necessarily occur together in the same location (Botsford et al. 2009; Sabates et al. 2007), and many egg and larval stages occur near the water surface. Early lifestages of most fishes could be displaced by vessels, but not struck in the same manner as adults of larger species. Early lifestages could also become entrained by the propeller movement, or propeller wash, of vessels. However, no measurable impacts on fish recruitment would occur because the number of eggs and larvae exposed to vessel movements would be low relative to total ichthyoplankton biomass.

3.9.3.3.1 Impacts from Vessel and In-Water Devices

The majority of the activities under all alternatives involve vessels, and a few of the activities involve the use of in-water devices. For a discussion of the types of activities that use vessels and in-water devices, where they are used, and how many activities would occur under each Alternative, see Chapter 2 and Section 3.0.5.2.3 (Physical Disturbance and Strike Stressors).

Vessels and in-water devices do not normally collide with adult fish, most of which can detect and avoid them. One study on fishes' behavioral responses to vessels showed that most adults exhibit avoidance responses to engine noise, sonar, depth finders, and fish finders (Jørgensen et al. 2004), reducing the potential for vessel strikes. Misund (1997) found that fishes ahead of a ship that showed avoidance reactions did so at ranges of 160 to 490 ft. (48.8 to 149.4 m). When the vessel passed over them, some fishes responded with sudden escape responses that included lateral avoidance or downward compression of the school. Conversely, Rostad et al. (2006) observed that some fishes are attracted to different types of vessels (e.g., research vessels, commercial vessels) of varying sizes, noise levels, and habitat locations. Fish behavior in the vicinity of a vessel is therefore quite variable, depending on the type of fish, its life history stage, behavior, time of day, and the sound propagation characteristics of the water (Schwarz 1985). Early life stages of most fishes could be displaced by vessels and not struck in the same manner as adults of larger species. However, a vessel's propeller movement or propeller wash could entrain early life stages. The low-frequency sounds of large vessels or accelerating small vessels caused avoidance responses among herring (Chapman and Hawkins 1973), but avoidance ended within 10 seconds after the vessel departed. Because a towed in-water device is continuously moving, most fishes are expected to move away from it or to follow behind it, in a manner similar to their responses to a vessel. When the device is removed, most fishes would simply move to another area.

There are a few notable exceptions to this assessment of potential vessel strike impacts on marine fish groups. Large slow-moving fish such as ocean sunfish, whale sharks, basking sharks, and manta rays occur near the surface in open-ocean and coastal areas, and are more susceptible to ship strikes, causing blunt trauma, lacerations, fin damage, or mortality. Speed et al. (2008) evaluated this specifically for whale sharks, but these other large slow-moving fishes are also likely to be susceptible because of their similar behavior and location in the water column. Increases in the numbers and sizes of shipping vessels in the modern cargo fleets make it difficult to gather mortality data because personnel on large ships are often unaware of whale shark collisions (Stevens 2007), therefore, the occurrence of whale shark strikes is likely much higher than has been documented by the few studies that have been conducted. The results of a whale shark study outside of the Study Area in the Gulf of Tadjoura, Djibouti, revealed that of the 23 whale sharks observed during a 5-day period, 65 percent had scarring from boat and propeller strikes (Rowat et al. 2007). Based on the typical physiological responses described in Section 3.9.3.3 (Physical Disturbance and Strike Stressors), vessel movements are not expected to compromise the general health or condition of individual fishes, except for whale sharks, basking sharks, manta rays, and ocean sunfish.

3.9.3.3.1.1 No Action Alternative, Alternative 1 and Alternative 2

Training Activities

As indicated in Sections 3.0.5.2.3 (Physical Disturbance and Strike Stressors) and 3.0.5.2.3.3 (In-Water Devices), training activities involving in-water devices can occur anywhere in the Study Area. Navy vessel activity primarily occurs within the U.S. Exclusive Economic Zone, and certain portions of the Study Area, such as areas near ports or naval installations and training ranges are used more heavily by vessels than other portions of the Study Area. These activities do not differ seasonally and could be widely dispersed throughout the Study Area. The differences in the number of in-water device activities between alternatives increases under Alternative 1 and Alternative 2 compared to the No Action Alternative; however, this increase is not expected to increase impacts. Species that do not occur near the surface within the Study Area would not be exposed to in-water device strike potential.

Exposure of fishes to vessel strike stressors is limited to those fish groups identified in Sections 3.9.2.3 to 3.9.2.21 (Marine Fish Groups) that are large, slow-moving, and may occur near the surface, such as ocean sunfish, whale sharks, and manta rays. These species are most likely distributed widely in offshore and nearshore portions of the Study Area. Any isolated cases of a military vessel striking an individual could injure that individual, impacting the fitness of an individual fish, but not to the extent that the viability of populations would be impacted. Vessel strikes would not pose a risk to most of the other marine fish groups, because many fish can detect and avoid vessel movements, making strikes rare and allowing the fish to return to their normal behavior after the ship or device passes. As a vessel approaches a fish, they could have a detectable behavioral or physiological response (e.g., swimming away and increased heart rate) as the passing vessel displaces them. However, such reactions are not expected to have lasting effects on the survival, growth, recruitment, or reproduction of these marine fish groups at the population level.

Operational features of in-water devices and their use substantially limit the exposure of fish to potential strikes. First, in-water devices would not pose any strike risk to benthic fishes because the towed equipment is designed to stay off the bottom. Prior to deploying a towed in-water device, there is a standard operating procedure to search the intended path of the device for any floating debris (i.e., driftwood) or other potential obstructions, since they have the potential to cause damage to the device.

The likelihood of strikes by towed mine warfare devices on adult fish, which could result in injury or mortality, would be extremely low because these life stages are highly mobile. The use of in-water devices may result in short-term and local displacement of fishes in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness, or species recruitment, and are not expected to result in population-level impacts. Ichthyoplankton (fish eggs and larvae) in the water column could be displaced, injured, or killed by towed mine warfare devices. The numbers of eggs and larvae exposed to vessels or in-water devices would be extremely low relative to total ichthyoplankton biomass (Able and Fahay 1998); therefore, measurable changes on fish recruitment would not occur.

The risk of a strike from vessels and in-water devices used in training activities would be extremely low because: (1) most fish can detect and avoid vessel and in-water device movements, and (2) the types of fish that are likely to be exposed to vessel and in-water device strike are limited and occur in low concentrations where vessels and in-water devices are used. Potential impacts of exposure to vessels and in-water devices are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts. Since impacts from strikes would be rare, and although any increase in vessel and in-water device use proposed under Alternatives 1 and 2 could potentially increase the probability of a strike, for the reasons stated above for the No Action Alternative, impacts on fish or fish populations would be negligible. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to escape collision with vessels and in-water devices. Therefore, vessel and in-water device use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of vessels and in-water devices during training activities under the No Action Alternative, Alternative 1, and Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

As indicated in Sections 3.0.5.2.3 (Physical Disturbance and Strike Stressors) and 3.0.5.2.3.3 (In-Water Devices), testing activities involving in-water devices can occur anywhere in the Study Area.

As discussed for training activities, the risk of a strike from vessels and in-water devices used in testing activities would be extremely low because: (1) most fish can detect and avoid vessel and in-water device movements, and (2) the types of fish that are likely to be exposed to vessel and in-water device strike are limited and occur in low concentrations where vessels and in-water devices are used. Potential impacts of exposure to vessels and in-water devices are not expected to result in substantial changes to an individual's behavior, fitness, or species recruitment, and are not expected to result in population-level impacts. Since impacts from strikes would be rare, and although any increase in vessel and in-water device use proposed under Alternatives 1 and 2 could potentially increase the probability of a strike, for the reasons stated above for the No Action Alternative, Alternative 1, and Alternative 2, impacts on fish or fish populations would be negligible. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to escape collision with vessels and in-water devices. Therefore, vessel and in-water device use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of vessels and in-water devices during testing activities under the No Action Alternative, Alternative 1, and Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.3.2 Impacts from Military Expended Materials

Navy training and testing activities in the Study Area include firing a variety of weapons and employing a variety of explosive and non-explosive rounds including bombs, and small-, medium-, and large-caliber projectiles, or even entire ship hulks during a sinking exercise. During these training and testing activities, various items may be introduced and expended into the marine environment and are referred to as military expended materials.

This section analyzes the strike potential to marine fish of the following categories of military expended materials: (1) non-explosive practice munitions; (2) fragments from explosive munitions; and (3) expended materials other than ordnance, such as sonobuoys, vessel hulks, and expendable targets. For a discussion of the types of activities that use military expended materials, where they are used, and how many activities would occur under each alternative, see Section 3.0.5.2.3.4 (Military Expended Materials).

While disturbance or strike from any of these objects as they sink through the water column is possible, it is not very likely for most expended materials because the objects generally sink through the water slowly and can be avoided by most fishes. Although some objects may sink faster, it is unlikely even at these faster rates that fish in the middle of the water column would be struck. Therefore, with the exception of sinking exercises, the discussion of military expended materials strikes focuses on strikes at the surface or in the upper water column from fragments (of explosives) and projectiles because those items have a greater potential for a fish strike as they hit the water, before slowing down as they move through the water column.

Vessel Hulk. During a sinking exercise, aircraft, ship, and submarine crews deliver ordnance on a seaborne target, usually a clean deactivated ship (Section 3.1, Sediments and Water Quality), which is deliberately sunk using multiple weapon systems. Sinking exercises occur in specific open ocean areas, outside of the coastal area, in waters exceeding 3,000 m (9,842.5 ft.) in depth, as shown in Figure 3.0-2. Direct ordnance strikes from the various weapons used in these exercises are a source of potential impact. However, these impacts are discussed for each of those weapons categories in this section and are not repeated here. Therefore, the analysis of sinking exercises as a strike potential for benthic fishes is discussed in terms of the ship hulk landing on the seafloor.

Small-, Medium-, and Large-Caliber Projectiles. Various types of projectiles could cause a temporary (seconds), localized impact when they strike the surface of the water. Current Navy training and testing in the Study Area, such as gunnery exercises, include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including small-, medium-, and large-caliber projectiles. The larger-caliber projectiles are primarily used in the open ocean beyond 12 nm. Direct ordnance strikes from firing weapons are potential stressors to fishes. There is a remote possibility that an individual fish at or near the surface may be struck directly if it is at the point of impact at the time of non-explosive ordnance delivery. Expended rounds may strike the water surface with sufficient force to cause injury or mortality. There are 77 epipelagic species (including flying fish, jacks, and tuna) in the Study Area swim right at, or near, the surface of the water (Myers and Donaldson 2003).

Various projectiles will fall on soft or hard bottom habitats, where they could either become buried immediately in the sediments, or sit on the bottom for an extended time period (see Figures 3.3-1 through 3.3-5). Except for the 5 in. (12.7 cm) and the 30 mm rounds, which are fired from a helicopter, all projectiles will be aimed at surface targets. These targets will absorb most of the projectiles' energy before they strike the surface of the water and sink. This factor will limit the possibility of high-velocity impacts with fish from the rounds entering the water. Furthermore, fish can quickly and easily leave an area temporarily when vessels or helicopters approach. It is reasonable to assume, therefore, that fish will leave an area prior to, or just after the onset of, projectile firing and will return once tests are completed.

Most ordnance would sink through the water column and come to rest on the seafloor, stirring up sediment and possibly inducing a startle response, displacing, or injuring nearby fishes in extremely rare cases. Particular impacts on a given fish species would depend on the size and speed of the ordnance, the water depth, the number of rounds delivered, the frequency of training and testing, and the sensitivity of the fish.

Bombs, Missiles, and Rockets. Direct ordnance strikes from bombs, missiles, and rockets are potential stressors to fishes. Some individual fish at or near the surface may be struck directly if they are at the point of impact at the time of non-explosive ordnance delivery. However, most missiles hit their target or are disabled before hitting the water. Thus, most of these missiles and aerial targets hit the water as fragments, which quickly dissipates their kinetic energy within a short distance of the surface. A limited number of fishes swim right at, or near, the surface of the water, as described for small-, medium-, and large-caliber projectiles.

Statistical modeling could not be conducted to estimate the probability of military expended material strikes on fish, because fish density data are not available at the scale of an Operating Area or testing range. In lieu of strike probability modeling, the number, size, and area of potential impact (or "footprints") of each type of military expended material is presented in Tables 3.3-4 through 3.3-6. The application of this type of footprint analysis to fish follows the notion that a fish occupying the impact area could be susceptible to potential impacts, either at the water surface (e.g., pelagic sharks, flying fishes, jacks, tuna, mackerels, billfishes, and molas [Table 3.9-2]) or as military expended material falls through the water column and settles to the bottom (e.g., flounders, skates, and other benthic fishes listed in Table 3.9-2). Furthermore, most of the projectiles fired during training and testing activities are fired at targets, and most projectiles hit those targets, so only a very small portion of those would hit the water with their maximum velocity and force. Of that small portion, a small number of fish at or near the surface (pelagic fishes) or near the bottom (benthic fishes) may be directly impacted if they are in the target area and near the expended item that hits the water surface (or bottom), but population-level effects would not occur.

Propelled fragments are produced by an exploding bomb. Close to the explosion, fishes could potentially sustain injury or death from propelled fragments (Stuhmiller et al. 1990). However, studies of underwater bomb blasts have shown that fragments are larger than those produced during air blasts and decelerate much more rapidly (O'Keefe and Young 1984; Swisdak Jr. and Montaro 1992), reducing the risk to marine organisms.

Fish disturbance or strike could result from bomb fragments (after explosion) falling through the water column in very small areas compared to the vast expanse of the testing ranges, operating areas, range complexes, or the Study Area. The expected reaction of fishes exposed to this stressor would be to immediately leave the area where bombing is occurring, thereby reducing the probability of a fish strike after the initial expended materials hit the water surface. When a disturbance of this type concludes, the area would be repopulated and the fish stock would rebound with inconsequential impacts on the resource (Lundquist et al. 2010).

3.9.3.3.2.1 No Action Alternative

Training Activities

Marine fish groups identified in Sections 3.9.2.3 to 3.9.2.21 (Marine Fish Groups) that are particularly susceptible to military expended material strikes are those occurring at the surface, within the offshore and coastal portions of the range complexes (where the strike would occur). Those groups include pelagic sharks, flying fishes, jacks, tuna, mackerels, billfishes, molas, and other similar species (see Table 3.9-2). Additionally, certain deep-sea fishes would be exposed to strike risk as a ship hulk, expended during a sinking exercise, settles to the seafloor. These groups include hagfishes, lanternfishes, and anglerfishes.

An estimated 116,271 military expended materials would be used annually during training activities within the MITT Study Area (Tables 3.0-18 through 3.0-20 and 3.0-25 through 3.0-27). Projectiles, bombs, missiles, rockets, torpedoes and associated fragments have the potential to directly strike fish as they hit the water surface and below the surface to the point where the projectile loses its forward momentum. Fish at and just below the surface would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as the materials travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching munitions or fragments as they fall through the water column. The probability of strike based on the “footprint” analysis included in Table 3.3-4 indicates that even for an extreme case of expending all small-caliber projectiles within a single gunnery box, the probability of any of these items striking a fish (even as large as bluefin tuna or whale sharks) is extremely low. Therefore, since most fishes are smaller than bluefin tuna or whale sharks, and most military expended materials are less abundant than small-caliber projectiles, the risk of strike by these items is exceedingly low for fish overall. A possibility exists that a small number of fish at or near the surface may be directly impacted if they are in the target area and near the point of physical impact at the time of military expended material strike, but population-level impacts would not occur.

Sinking exercises occur in open-ocean areas, outside of the coastal waters. While serious injury or mortality to individual fish would be expected if they were present in the immediate vicinity of the high intensity of explosive stressors (analyzed in Section 3.9.3.1, Acoustic Stressors), sinking exercises under the No Action Alternative would not result in impacts on pelagic fish populations at the surface based on the low number of fish in the immediate area and the placement of these activities in deep, ocean areas where fish abundance is low or widely dispersed. Disturbances to benthic fishes from sinking exercises would be highly localized. Any deep sea fishes located on the bottom where a ship hulk would settle could experience displacement, injury, or death. However, population level impacts on the deep sea fish community would not occur because of the limited spatial extent of the impact.

The impact of military expended material strikes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and (3) the ability of most fish to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would be short-term (seconds) and localized disturbances of the water surface (and seafloor areas within sinking exercise boxes), and are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Additionally, scalloped hammerhead sharks are more likely to be located near the seafloor and not on the surface, where there would be a greater potential for a strike. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of military expended materials during training activities under the No Action Alternative will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

No military expended materials will be used during testing activities under the No Action Alternative (Tables 3.0-18 through 3.0-20 and 3.0-25 through 3.0-27).

3.9.3.3.2.2 Alternative 1

Training Activities

An estimated 261,482 military expended materials would be used annually during training activities (Tables 3.0-18 through 3.0-20 and 3.0-25 through 3.0-27), which is a 120 percent increase over the No Action Alternative. Compared to the No Action Alternative, the overall increase in military expended materials used under Alternative 1 is due primarily to a large increase in medium-caliber projectiles, and a relatively smaller increase in the number of small-caliber projectiles. These changes would result in increased exposure of fish to military expended materials; however, for reasons stated in the No Action Alternative, the overall increase of military expended material under Alternative 1 would not result in an increased strike risk. The impact of military expended material strikes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and (3) the ability of most fish to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would be short-term (seconds) and localized disturbances of the water surface and seafloor areas, and are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Additionally, scalloped hammerhead sharks are more likely to be located near the seafloor and not on the surface, where there would be a greater potential for a strike. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of military expended materials during training activities under Alternative 1 will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

An estimated 23,713 military expended materials would be used annually during testing activities under Alternative 1 (Tables 3.0-18 through 3.0-20 and 3.0-25 through 3.0-27). These expended materials would result in increased exposure of fish to potential strikes; however, for reasons stated in the No Action Alternative for training, the overall increase of military expended material under Alternative 1 would result in an increased strike risk; however, this increase would be negligible. The impact of military expended material strikes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and (3) the ability of most fish to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would be short-term (seconds) and localized disturbances of the water surface and seafloor areas, and are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Additionally, scalloped hammerhead sharks are more likely to be located near the seafloor and not on the surface, where there would be a greater potential for a strike. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of military expended materials during testing activities under Alternative 1 will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.3.2.3 Alternative 2

Training Activities

An estimated 269,375 military expended materials would be used annually during training activities under Alternative 2 (Tables 3.0-18 through 3.0-20 and 3.0-25 through 3.0-27), which is a 130 percent increase over the No Action Alternative. Compared to the No Action Alternative, the overall increase in military expended materials used under Alternative 2 is due primarily to a large increase in medium-caliber projectiles, and a relatively smaller increase in the number of small-caliber projectiles. These changes would result in increased exposure of fish to military expended materials; however, for reasons stated in the No Action Alternative and Alternative 1, the overall increase of military expended material under Alternative 2 would not result in an increased strike risk. The impact of military expended material strikes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and (3) the ability of most fish to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would be short-term (seconds) and localized disturbances of the water surface (and seafloor areas, and are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Additionally, scalloped hammerhead sharks are more likely to be located near the seafloor and not on the surface, where there would be a greater potential for a strike. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of military expended materials during training activities under Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

An estimated 27,415 military expended materials would be used annually during testing activities under Alternative 2 (Tables 3.0-18 through 3.0-20 and 3.0-25 through 3.0-27). These expended materials would result in increased exposure of fish to potential strikes; however, for reasons stated in Alternative 1, the overall increase of military expended material under Alternative 2 would result in an increased strike risk, although this risk would be minimal. The impact of military expended material strikes would be inconsequential due to (1) the limited number of species found directly at the surface where military expended material strikes could occur, (2) the rare chance that a fish might be directly struck at the surface by military expended materials, and (3) the ability of most fish to detect and avoid an object falling through the water below the surface. The potential impacts of military expended material strikes would be short-term (seconds) and localized disturbances of the water surface and seafloor areas, and are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Additionally, scalloped hammerhead sharks are more likely to be located near the seafloor and not on the surface where there would be a greater potential for a strike. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of military expended materials during testing activities under Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.3.3 Impacts from Seafloor Devices

For a discussion of the types of activities that use seafloor devices, where they are used, and how many activities would occur under each alternative, see Section 3.0.5.2.3.5 (Seafloor Devices). Seafloor devices include items that are placed on, dropped on, or moved along the seafloor such as mine shapes, anchor blocks, anchors, bottom-placed instruments, bottom-crawling unmanned undersea vehicles, and bottom-placed targets that are not expended. As discussed in the military expended materials strike section, objects falling through the water column will slow in velocity as they sink toward the bottom and could be avoided by most fish.

Seafloor devices with a strike potential for fish include those items temporarily deployed on the seafloor. The potential strike impacts of unmanned underwater vehicles, including bottom crawling types, are also included here. Some fishes are attracted to virtually any tethered object in the water column (Dempster and Taquet 2004) and could be attracted to an inert mine assembly. However, while a fish might be attracted to the object, their sensory abilities allow them to avoid colliding with fixed tethered objects in the water column (Bleckmann and Zelick 2009), so the likelihood of a fish striking one of these objects is implausible. Therefore, strike hazards associated with collision into other seafloor devices such as deployed mine shapes or anchored devices are highly unlikely to pose any strike hazard to fishes and are not discussed further.

3.9.3.3.3.1 No Action Alternative

Training Activities

Under the No Action Alternative, 480 mine shapes would be used during mine-laying training activities. Seafloor devices have the potential to directly strike fish as they hit the water surface and below the surface to the point where the device strikes the bottom. Fish at and just below the surface, as well as those on the bottom, would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as the materials travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching devices as they fall through the water column. A possibility exists that a small number of fish at or near the surface or resting on the bottom may be directly impacted if they are in the target area and near the point of physical impact at the time of seafloor device strike. However, the likelihood of one of these objects striking a fish is implausible, and in the rare event that a strike occurred, population-level impacts would not occur. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of seafloor devices during training activities under the No Action Alternative will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

Under the No Action Alternative, seafloor devices are only utilized during testing activities at the North Pacific Acoustic Lab's Deep Water site. The deep water experimental site consists of an acoustic tomography array, a distributed vertical line array, and moorings in the deep-water environment (depths greater than 3,280 ft. [1,000 m]) of the northwestern Philippine Sea. A possibility exists that a small number of fish at or near the surface may be directly impacted if they are in the target area and near the point of physical impact at the time of seafloor device strike, but the likelihood of one of these objects striking a fish is implausible and in the rare event that a strike occurred, population-level impacts would not occur. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of seafloor devices during testing activities under the No Action Alternative will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.3.3.2 Alternative 1

Training Activities

Under Alternative 1, 480 mine shapes would be used during mine-laying training activities. Mine shapes would be used throughout Warning Area (W-)517. Additionally there would be 18 precision anchoring activities which would occur within predetermined shallow water anchorage locations near ports. Seafloor devices have the potential to directly strike fish as they hit the water surface and below the surface to the point where the device strikes the bottom. Fish at and just below the surface, as well as those on the bottom, would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as the materials travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching devices as they fall through the water column. A possibility exists that a small number of fish at or near the surface or resting on the bottom may be directly impacted if they are in the target area and near the point of physical impact at the time of seafloor device strike. However, the likelihood of one of these objects striking a fish is implausible, and in the rare event that a strike occurred, population-level impacts would not occur. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of seafloor devices during training activities under Alternative 1 will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

Under Alternative 1, seafloor devices are utilized during pierside integrated swimmer defense activities, testing activities at the North Pacific Acoustic Lab's Deep Water site, and during the MCM mission package testing. The deep water experimental site consists of an acoustic tomography array, a distributed vertical line array, and moorings in the deep-water environment (depths greater than 3,280 ft. [1,000 m]) of the northwestern Philippine Sea.

Seafloor devices have the potential to directly strike fish as they hit the water surface and below the surface to the point where the device strikes the bottom. Fish at and just below the surface, as well as those on the bottom, would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as it the materials travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching devices as they fall through the water column. A possibility exists that a small number of fish at or near the surface or resting on the bottom may be directly impacted if they are in the target area and near the point of physical impact at the time of seafloor device strike. During the pierside integrated swimmer defense activities, seafloor devices are placed by hand on the seafloor and removed after the activity; therefore, there would be no impact to fish from these items. However, the likelihood of objects used during MCM mission package testing striking a fish is implausible, and in the rare event that a strike occurred, population-level impacts would not occur. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of seafloor devices during testing activities under Alternative 1 will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.3.3.3 Alternative 2

Training Activities

Under Alternative 2, 480 mine shapes would be used during mine laying training activities. Mine shapes would be deployed throughout W-517. Additionally there would be 18 precision anchoring activities which would occur within predetermined shallow water anchorage locations near ports. Seafloor devices have the potential to directly strike fish as they hit the water surface and below the surface to the point where the device strikes the bottom. Fish at and just below the surface, as well as those on the bottom, would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as it the materials travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching devices as they fall through the water column. A possibility exists that a small number of fish at or near the surface or resting on the bottom may be directly impacted if they are in the target area and near the point of physical impact at the time of seafloor device strike. However, the likelihood of one of these objects striking a fish is implausible, and in the rare event that a strike occurred, population-level impacts would not occur. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of seafloor devices during training activities under Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

Testing Activities

Under Alternative 2, seafloor devices are utilized during pierside integrated swimmer defense activities, testing activities at the North Pacific Acoustic Lab's Deep Water site, and during the MCM mission package testing. The deep water experimental site consists of an acoustic tomography array, a distributed vertical line array, and moorings in the deep-water environment (depths greater than 3,280 ft. [1,000 m]) of the northwestern Philippine Sea.

Seafloor devices have the potential to directly strike fish as they hit the water surface and below the surface to the point where the device strikes the bottom. Fish at and just below the surface, as well as those on the bottom, would be most susceptible to injury from strikes because velocity of these materials would rapidly decrease upon contact with the water and as it the materials travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching devices as they fall through the water column. A possibility exists that a small number of fish at or near the surface or resting on the bottom may be directly impacted if they are in the target area and near the point of physical impact at the time of seafloor device strike During the pierside integrated swimmer defense activities, seafloor devices are placed by hand on the seafloor and removed after the activity; therefore, there would be no impact to fish from these items. However, the likelihood of objects used during MCM mission package testing striking a fish is implausible, and in the rare event that a strike occurred, population-level impacts would not occur. The ESA-listed scalloped hammerhead sharks can sense pressure changes in the water column and swim quickly, and are likely to avoid an object falling through the water. Therefore, military expended materials use would not affect scalloped hammerhead sharks.

Pursuant to the ESA, the use of seafloor devices during testing activities under Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.3.4 Summary and Conclusions of Physical Disturbance and Strike Impacts

The greatest potential for combined impacts of physical disturbance and strike stressors under the Proposed Action would occur for sinking exercises because of multiple opportunities for potential strike by vessel, ordnance, or other military expended material. Under the Proposed Action, no more than two sinking exercises would occur per year. Sinking exercises were specifically chosen to evaluate impacts on military expended material strike because sinking exercises represent the activity with the greatest amount of military expended materials by weight. During each sinking exercise, approximately 725 objects would be expended, including large bombs, missiles, large projectiles, torpedoes, and one target vessel. Therefore, during each sinking exercise, approximately 105 objects per square kilometer would sink to the ocean floor. These items, combined with the mass and size of the ship hulk itself, are representative of an extreme case for military expended materials of all types striking benthic fishes. However, the overlap of these activities would only occur during a limited number of activities and only within the open ocean areas where the sinking exercises areas are located.

A less intensive example of potential impacts of combined strike stressors would be for cases where a fish could be displaced by a vessel in the water column during any number of activities utilizing bombs, missiles, rockets, or projectiles. As the vessel maneuvers during the exercise, any fishes displaced by that vessel movement could potentially be struck by munitions expended by that vessel during that same exercise. This would be more likely to occur in concentrated areas of this type of activity (e.g., a gunnery exercise inside a gunnery box). However, the likelihood of this occurring is probably quite low anywhere else, because most activities do not expend their munitions towards, or in proximity to, a training or testing vessel for safety reasons. While small-caliber projectiles are expended away from but often close to the vessel from which the projectiles are fired, this does not necessarily increase the risk of strike. During the initial displacement of the fish from vessel activity, or after the first several projectiles are fired, most fishes would disperse widely and the probability of strike may actually be reduced in most cases. Also, the combination of these stressors would cease immediately when the activity ends; therefore, combination is possible but not reasonably foreseeable.

Research suggests that only a limited number of marine fish species are susceptible to being struck by a vessel. Most fishes would not respond to vessel disturbance beyond a temporary displacement from their normal activity, which would be inconsequential and not detectable. The Navy identified and analyzed three physical disturbance or strike substressors that have potential to impact fishes: vessel and in-water device strikes, military expended material strikes, and seafloor device strikes. While the potential for vessel strikes on fish can occur anywhere vessels are operated, most fishes are highly mobile and capable of avoiding vessels, expended materials, or objects in the water column. For the larger slower-moving species (e.g., whale shark, manta ray, and molas) the potential for a vessel or military expended material strike increases, as discussed in the analysis. The potential for a seafloor device striking a fish is very low because the sensory capabilities of most fishes allow them to detect and avoid underwater objects.

Pursuant to the ESA, physical disturbance and strikes under the No Action Alternative, Alternative 1, or Alternative 2 will have no effect on ESA-listed scalloped hammerhead sharks.

3.9.3.4 Entanglement Stressors

This section evaluates potential entanglement impacts of various types of expended materials used by the military during training and testing activities within the Study Area. The likelihood of fish being affected by an entanglement stressor is a function of the physical properties, location, and buoyancy of the object and the behavior of the fish as described in Appendix H.5 (Conceptual Framework for Assessing Effects from Entanglement). Two types of military expended materials are considered here: (1) fiber optic cables and guidance wires, and (2) decelerators/parachutes.

Most entanglement observations involve abandoned or discarded nets, lines, and other materials that form loops or incorporate rings (Laist 1987; Derraik 2002; Macfadyen et al. 2009; Keller et al. 2010). A 25-year dataset assembled by the Ocean Conservancy reported that fishing line, rope, and fishing nets accounted for approximately 68 percent of fish entanglements, with the remainder due to encounters with various items such as bottles, cans, and plastic bags (Ocean Conservancy 2010). No occurrences involving military expended materials were documented.

Fish entanglement occurs most frequently at or just below the surface or in the water column where objects are suspended. A smaller number involve objects on the seafloor, particularly abandoned fishing gear designed to catch bottom fish or invertebrates (Ocean Conservancy 2010). More fish species are entangled in coastal waters and the continental shelf than elsewhere in the marine environment because of higher concentrations of human activity (e.g., fishing, sources of entangling debris), higher fish abundances, and greater species diversity (Helfman et al. 2009; Macfadyen et al. 2009). The consequences of entanglement range from temporary and inconsequential to major physiological stress or mortality.

The military uses some types of materials that could become entanglement stressors during training and testing activities in the Study Area. Possible expended materials from MITT activities that pose a risk of entanglement include sonobuoy components, torpedo guidance wires, torpedo flex hoses, cables, and decelerators/parachutes. Cables are used to moor vessels, mine shapes, and other objects to the bottom, and to connect to seafloor devices. Cables used in these scenarios are held taut, have insufficient slack to form loops, and are recovered after use; therefore, no potential for entanglement exists and activities using cables in this way are not discussed further. A flex hose is released when a torpedo is deployed to protect the guidance wire while near the launch vessel. Flex hoses are stiff, heavy, and would rapidly sink to the bottom on release. The flex hose is designed to remain free of loops, so no potential for entanglement exists and is not discussed further.

Oceanic fishes may encounter guidance wires and decelerators/parachutes, but nearshore fishes are extremely unlikely to encounter these materials because of where activities occur. Training and testing using heavyweight torpedoes do not take place in nearshore waters, so guidance wires would not be expended there, although decelerators/parachutes could be expended indirectly by drifting in from offshore areas. The discussion in this section focuses on the likelihood of overlap of these expended items with those fishes in the water column and benthic habitats that might be susceptible to becoming entangled in these items. This evaluation is based on the size, location, and buoyancy of the object and the behavior of the fishes.

3.9.3.4.1 Impacts from Fiber Optic Cables and Guidance Wires

Fiber optic cables and guidance wires are used during training and testing activities. A discussion of the types of activities, physical characteristics, location of use, and the number of items expended under each alternative is presented in Section 3.0.5.2.4.1 (Fiber Optic Cables and Guidance Wires).

Marine fish groups identified in Sections 3.9.2 (Affected Environment), that could be susceptible to entanglement in expended cables and wires are those with elongated snouts lined with tooth-like structures that easily snag on other similar marine debris, such as derelict fishing gear (Macfadyen et al. 2009). Some elasmobranchs (hammerhead sharks) and billfish occurring within the offshore and continental shelf portions of the range complexes (where the potential for entanglement would occur) could be susceptible to entanglement in cables and wires. Species occurring outside the specified areas within these range complexes would not be exposed to fiber optic cables or guidance wires.

Once a guidance wire is released, it is likely to sink immediately and remain on the seafloor. In some cases, the wire may snag on a hard structure near the bottom and remain partially or completely suspended. The types of fish that encounter any given wire would depend, in part, on its geographic location and vertical location in the water column. In any situation, the most likely mechanism for entanglement would involve fish swimming through loops in the wire that tighten around it; however, loops are unlikely to form in guidance wire (Environmental Sciences Group 2005).

Because of their physical characteristics, guidance wires and fiber optic cables pose a potential, though unlikely, entanglement risk to susceptible fish. Potential entanglement scenarios are based on fish behavior in abandoned monofilament, nylon, and polypropylene lines used in commercial nets. Such derelict fishing gear is abundant in the ocean (Macfadyen et al. 2009) and pose a greater hazard to fish than the very thin wire expended by the military. Fishing gear materials often have breaking strengths that can be up to orders of magnitude greater than that of guidance wire and fiber optic cables (Environmental Sciences Group 2005), and are far more prone to tangling, as discussed in Section 3.0.5.2.4.1 (Fiber Optic Cables and Guidance Wires). Fiber optic cables do not easily form loops, are brittle, and break easily if bent, so they pose a negligible entanglement risk. Additionally, the encounter rate and probability of impact from guidance wires and fiber optic cables are low, as few are expended.

3.9.3.4.1.1 No Action Alternative

Training Activities

As indicated in Table 2.8-1, under the No Action Alternative, torpedoes expending guidance wire would occur in throughout the Study Area during tracking exercises, all greater than 3 nm from the shore. Under the No Action Alternative there would be a total of 40 events that would expend wires per year during training activities (Table 2.8-1). Billfishes and other open ocean species susceptible to entanglement that occur where the torpedoes are used may encounter the expended guidance wires. However, given the low numbers used, the likelihood of encountering the expended guidance wires would be extremely low in those isolated areas. Some individual fish could be injured or killed if entangled by guidance wire, but most would simply be temporarily disturbed and would recover completely soon after exposure.

Scalloped hammerhead sharks that occur in areas where torpedoes are used may encounter an expended guidance wire. However, given that few are expended annually, in mostly offshore areas; and given that guidance wires would sink to the seafloor and would not remain suspended in the water column, the likelihood of a scalloped hammerhead shark encountering expended guidance wires would be extremely low.

Pursuant to the ESA, the use of fiber optic cables and guidance wires during training activities under the No Action Alternative may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Under the No Action Alternative, no activities that could generate entanglement stressors are conducted in the Study Area (see Tables 2.8-2 to 2.8-4).

3.9.3.4.1.2 Alternative 1

Training Activities

Under Alternative 1, the number of fiber optic cables and guidance wires used for training activities would increase by approximately 40 percent compared to the No Action Alternative (Tables 3.0-23 and 3.0-24). Billfishes and other open ocean species susceptible to entanglement that occur where the torpedoes are used may encounter the expended guidance wires and fiber optic cables. However, given the low numbers used, the likelihood of encountering the expended guidance wires and fiber optic cables would be extremely low in those isolated areas. Some individual fish could be injured or killed if entangled by guidance wire or fiber optic cable, but most would simply be temporarily disturbed and would recover completely soon after exposure. Scalloped hammerhead sharks that occur in areas where torpedoes are used may encounter an expended guidance wire. However, given that few are expended annually, in mostly offshore areas; and given that guidance wires would sink to the seafloor and would not remain suspended in the water column, the likelihood of a scalloped hammerhead shark encountering expended guidance wires would be extremely low.

Pursuant to the ESA, the use of fiber optic cables and guidance wires during training activities under Alternative 1 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

As indicated in Tables 2.8-2 through 2.8-4 and Table 3.0-24, under Alternative 1, the number of torpedo activities that expended guidance wire increases from that of the No Action Alternative from 0 to 20.

Under Alternative 1, MCM Mission Package testing (Table 2.8-3) expends up to 48 fiber optic cables. Billfishes and other open ocean species susceptible to entanglement may encounter expended fiber optic cables and guidance wires, if these species are in the same location. However, given the low numbers used, the likelihood of encountering the expended fiber optic cables and guidance wires would be extremely low in those isolated areas. Some individual fish could be injured or killed if entangled by fiber optic cables and guidance wire, but most would simply be temporarily disturbed and would recover completely soon after exposure.

Scalloped hammerheads that occur in areas where torpedoes are used and mine countermeasure mission package testing activities occur may encounter an expended guidance wire or fiber optic cable. However, given that few are expended annually, most would sink to the seafloor and would not remain suspended in the water column, and most are expended in offshore areas, the likelihood of a scalloped hammerhead encountering an expended guidance wire or fiber optic cable would be extremely low.

Pursuant to the ESA, the use of fiber optic cables and guidance wires during testing activities under Alternative1 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.4.1.3 Alternative 2

Training Activities

Under Alternative 2, the number of fiber optic cables and guidance wires used for training activities would increase by approximately 40 percent compared to the No Action Alternative (Tables 3.0-23 and 3.0-24). Billfishes and other open ocean species susceptible to entanglement that occur where the torpedoes are used may encounter the expended guidance wires and fiber optic cables. However, given the low numbers used, the likelihood of encountering the expended guidance wires and fiber optic cables would be extremely low in those isolated areas. Some individual fish could be injured or killed if entangled by guidance wire or fiber optic cable, but most would simply be temporarily disturbed and would recover completely soon after exposure.

Scalloped hammerhead sharks that occur in areas where torpedoes are used may encounter an expended guidance wire. However, given that few are expended annually, in mostly offshore areas; and given that guidance wires would sink to the seafloor and would not remain suspended in the water column, the likelihood of a scalloped hammerhead shark encountering expended guidance wires would be extremely low.

Pursuant to the ESA, the use of fiber optic cables and guidance wires during training activities under Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

As indicated in Tables 2.8-2 through 2.8-4 and Table 3.0-24, under Alternative 2, the number of torpedo activities that expended guidance wire increases from that of the No Action Alternative from 0 to 20. Under Alternative 1, MCM Mission Package testing (Table 2.8-3) expends up to 56 fiber optic cables. Risk of entanglement resulting from proposed testing activities would be low as described in training activities above.

Scalloped hammerheads that occur in areas where torpedoes are used and mine countermeasure mission package testing activities occur may encounter an expended guidance wire or fiber optic cable. However, given that few are expended annually, most would sink to the seafloor and would not remain suspended in the water column, and most are expended in offshore areas, the likelihood of a scalloped hammerhead encountering an expended guidance wire or fiber optic cable would be extremely low.

Pursuant to the ESA, the use of fiber optic cables and guidance wires during testing activities under Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.4.2 Impacts from Decelerators/Parachutes

Decelerators/parachutes of varying sizes are used during training and testing activities. The types of activities that use decelerators/parachutes, physical characteristics and size of decelerators/parachutes, locations where decelerators/parachutes are used, and the number of parachute activities proposed under each alternative are presented in Section 3.0.5.2.4.2 (Decelerators/Parachutes).

Fish face many potential entanglement scenarios in abandoned monofilament, nylon, polypropylene line, and other derelict fishing gear in the nearshore and offshore marine habitats of the Study Area (Macfadyen et al. 2009; Ocean Conservancy 2010). Abandoned fishing gear is dangerous to fish because it is abundant, essentially invisible, strong, and easily tangled. In contrast, decelerators/parachutes are rare, highly visible, and not designed to capture fish.

Once a parachute has been released to the water, it poses a potential entanglement risk to fish. The Naval Ocean Systems Center identified the potential impacts of torpedo air launch accessories, including decelerators/parachutes, on fish (U.S. Department of the Navy 1996). Unlike other materials in which fish become entangled (such as gill nets and nylon fishing line), the parachute is relatively large and visible, reducing the chance that visually oriented fish would accidentally become entangled in it. No cases of fish entanglement have been reported for decelerators/parachutes (U.S. Department of the Navy 2001a; Ocean Conservancy 2010). Entanglement in a newly-expended decelerator/parachute while it is in the water column is unlikely because fish generally react to sound and motion at the surface with a behavioral reaction by swimming away from the source (see Section 3.9.3.3.2, Impacts from Military Expended Materials) and would detect the oncoming decelerator/parachute in time to avoid contact. While the decelerator/parachute is sinking, fish would have ample opportunity to swim away from the large moving object. Even if the decelerator/parachute landed directly on a fish, it would likely be able to swim away faster than the decelerator/parachute would sink because the resistance of the water would slow the parachute's downward motion.

Once the decelerator/parachute is on the bottom, however, it is feasible that a fish could become entangled in the decelerator/parachute or its suspension lines while diving and feeding, especially in deeper waters where it is dark. If the decelerator/parachute dropped in an area of strong bottom currents, it could billow open and pose a short-term entanglement threat to large fish feeding on the bottom. Benthic fish with elongated spines could become caught on the decelerator/parachute or lines. Most sharks and other smooth-bodied fish are not expected to become entangled because their soft, streamlined bodies can more easily slip through potential snares. A fish with spines or protrusions (e.g., some sharks, billfish, or sawfish) on its body that swam into the decelerator/parachute or a loop in the lines, and then struggled, could become bound tightly enough to prevent escape. Although this scenario is possible based on the structure of the materials and the shape and behavior of fish, it is not considered a likely event.

Aerial-launched sonobuoys are deployed with a decelerator/parachute. The sonobuoy itself is not considered an entanglement hazard for upon deployment (Environmental Sciences Group 2005), but their components may pose an entanglement hazard once released into the ocean. Sonobuoys contain cords, electronic components, and plastic mesh that may entangle fish (Environmental Sciences Group 2005). Open-ocean filter feeding species, such as whale sharks, and manta rays could become entangled in these items, whereas smaller species such as flying fish could become entangled in the plastic mesh in the same manner as a small gillnet. Since most sonobuoys are expended in offshore areas, many coastal fish would not encounter or have any opportunity to become entangled in materials associated with sonobuoys, apart from the risk of entanglement in decelerators/parachutes described above.

3.9.3.4.2.1 No Action Alternative

Training Activities

Under the No Action Alternative, approximately 8,032 decelerators/parachutes would be expended during training activities (see Table 3.0-25). Decelerators/parachutes would be expended in locations greater than 3 nm from shore throughout the Study Area.

Given the size of the range complex and the resulting widely scattered decelerators/parachutes, it would be very unlikely that fishes would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a few individual fish were to encounter and become entangled in any of these items, the growth, survival, annual reproductive success, or lifetime reproductive success of the population as a whole would not be impacted directly or indirectly.

Once a decelerator/parachute is released into the water, it could pose an entanglement risk to the scalloped hammerhead shark in offshore waters, although the risk is unlikely. Entanglement at the water's surface in a newly expended decelerator/parachute is unlikely, because scalloped hammerhead sharks would generally react to sound and motion at the surface by swimming away from the source (see Section 3.9.3.3.2, Impacts from Military Expended Materials) and would detect the decelerator/parachute in time to avoid contact. The probability of a decelerator/parachute landing directly on a scalloped hammerhead shark is remote.

Once the decelerator/parachute is on the bottom, however, it is feasible that a scalloped hammerhead shark, which is known to feed near the bottom, could become entangled in a decelerator/parachute or its suspension lines, especially in waters where visibility is poor and male scalloped hammerheads are known to feed. If the decelerator/parachute dropped in an area of strong bottom currents, it could billow open and pose a short-term entanglement threat. A fish with spines or protrusions (such as the scalloped hammerhead shark) on its body that swam into the decelerator/parachute or a loop in the lines, and then struggled, could become bound tightly enough to prevent escape and cause injury. Although this scenario is possible based on the structure of the materials and the shape and behavior of the scalloped hammerhead shark, it is not considered a likely event because the encounter rate and occurrence of this scenario is expected to be very low, given the seafloor depth in the majority of the Study Area is deeper than 500 m (1,640 ft.), which is deeper than the diving depth of a scalloped hammerhead shark.

Given the size of the Study Area and the widely scattered expended decelerators/parachutes, it would be very unlikely that the scalloped hammerhead shark would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a shark were to encounter and become entangled in any of these items it could be injured or killed, but the most likely scenario would be a temporary disturbance or behavioral response.

Pursuant to the ESA, the use of decelerators/parachutes during training activities under the No Action Alternative may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Under the No Action Alternative, no activities that would create entanglement hazards from decelerators/parachutes are conducted in the Study Area (see Table 3.0-25).

3.9.3.4.2.2 Alternative 1

As described in Section 2.7 (Alternative 1 [Preferred Alternative]: Expansion of Study Area Plus Adjustments to the Baseline and Additional Weapons, Platforms, and Systems), Alternative 1 consists of the No Action Alternative and adjustments to location, type, and tempo of training and testing activities, which includes the addition of platforms and systems.

Training Activities

Under Alternative 1, there would be 10,845 decelerators/parachutes expended during training activities, an increase by 35 percent from the number expended under the No Action Alternative (see Table 3.0-25).

Given the size of the range complexes and the resulting widely scattered decelerators/parachutes, it would be very unlikely that fishes would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a few individual fish were to encounter and become entangled in any of these items, the growth, survival, annual reproductive success, or lifetime reproductive success of the population as a whole would not be impacted directly or indirectly.

Once a decelerator/parachute is released into the water, it could pose an entanglement risk to the scalloped hammerhead shark in offshore waters, although the risk is unlikely. Entanglement at the water's surface in a newly expended decelerator/parachute is unlikely, because scalloped hammerhead sharks would generally react to sound and motion at the surface by swimming away from the source (see Section 3.9.3.3.2, Impacts from Military Expended Materials) and would detect the decelerator/parachute in time to avoid contact. The probability of a decelerator/parachute landing directly on a scalloped hammerhead shark is remote.

Once the decelerator/parachute is on the bottom, however, it is feasible that a scalloped hammerhead shark, which is known to feed near the bottom, could become entangled in a decelerator/parachute or its suspension lines, especially in waters where visibility is poor and male scalloped hammerheads are known to feed. If the decelerator/parachute dropped in an area of strong bottom currents, it could billow open and pose a short-term entanglement threat. A fish with spines or protrusions (such as the scalloped hammerhead shark) on its body that swam into the decelerator/parachute or a loop in the lines, and then struggled, could become bound tightly enough to prevent escape and cause injury. Although this scenario is possible based on the structure of the materials and the shape and behavior of the scalloped hammerhead shark, it is not considered a likely event because the encounter rate and occurrence of this scenario is expected to be very low, given the seafloor depth in the majority of the Study Area is deeper than 500 m (1,640 ft.), which is deeper than the diving depth of a scalloped hammerhead shark.

Given the size of the Study Area and the widely scattered expended decelerators/parachutes, it would be very unlikely that the scalloped hammerhead shark would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a shark were to encounter and become entangled in any of these items it could be injured or killed, but the most likely scenario would be a temporary disturbance or behavioral response.

Pursuant to the ESA, the use of decelerators/parachutes during training activities under Alternative 1 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Under Alternative 1, there would be 1,727 decelerators/parachutes expended during testing activities, an increase from the No Action Alternative (see Table 3.0-25).

Given the size of the MITT Study Area and the resulting widely scattered decelerators/parachutes, it would be very unlikely that fishes would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a fish were to encounter and become entangled in any of these items, the growth, survival, annual reproductive success, or lifetime reproductive success of populations would not be impacted directly or indirectly.

Once a decelerator/parachute is released into the water, it could pose an entanglement risk to the scalloped hammerhead shark in offshore waters, although the risk is unlikely. Entanglement at the water's surface in a newly expended decelerator/parachute is unlikely, because scalloped hammerhead sharks would generally react to sound and motion at the surface with a behavioral reaction by swimming away from the source (see Section 3.9.3.3.2, Impacts from Military Expended Materials) and would detect the decelerator/parachute in time to avoid contact. The probability of a decelerator/parachute landing directly on a scalloped hammerhead shark is remote.

Once the decelerator/parachute is on the bottom, however, it is feasible that a scalloped hammerhead shark, which is known to feed near the bottom, could become entangled in a decelerator/parachute or its suspension lines, especially in waters where visibility is poor and male scalloped hammerheads are known to feed. If the decelerator/parachute dropped in an area of strong bottom currents, it could billow open and pose a short-term entanglement threat. A fish with spines or protrusions (such as the scalloped hammerhead shark) on its body that swam into the decelerator/parachute or a loop in the lines, and then struggled, could become bound tightly enough to prevent escape and cause injury. Although this scenario is possible based on the structure of the materials and the shape and behavior of the scalloped hammerhead shark, it is not considered a likely event because the encounter rate and occurrence of this scenario is expected to be very low, given the seafloor depth in the majority of the Study Area is deeper than 500 m (1,640 ft.), which is deeper than the diving depth of a scalloped hammerhead shark.

Given the size of the Study Area and the widely scattered expended decelerators/parachutes, it would be very unlikely that the scalloped hammerhead shark would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a shark were to encounter and become entangled in any of these items it could be injured or killed, but the most likely scenario would be a temporary disturbance or behavioral response.

Pursuant to the ESA, the use of decelerators/parachutes during testing activities under Alternative 1 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.4.2.3 Alternative 2

Training Activities

The number and location of training activities under Alternative 2 are identical to training activities under Alternative 1 (see Table 3.0-25). Therefore, impacts and comparisons to the No Action Alternative will also be identical.

Given the size of the Study Area and the widely scattered expended decelerators/parachutes, it would be very unlikely that the scalloped hammerhead shark would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a shark were to encounter and become entangled in any of these items it could be injured or killed, but the most likely scenario would be a temporary disturbance or behavioral response.

Pursuant to the ESA, the use of decelerators/parachutes during training activities under Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Under Alternative 2, there would be 1,912 decelerators/parachutes expended during testing activities, an increase from the No Action Alternative (see Table 3.0-25).

Given the size of the MITT Study Area and the resulting widely scattered decelerators/parachutes, it would be very unlikely that fishes would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a few individual fish were to encounter and become entangled in any of these items, the growth, survival, annual reproductive success, or lifetime reproductive success of the populations as a whole would not be impacted directly or indirectly.

Given the size of the Study Area and the widely scattered expended decelerators/parachutes, it would be very unlikely that the scalloped hammerhead shark would encounter and become entangled in any decelerators/parachutes or sonobuoy accessories. If a shark were to encounter and become entangled in any of these items it could be injured or killed, but the most likely scenario would be a temporary disturbance or behavioral response.

Pursuant to the ESA, the use of decelerators/parachutes during testing activities under Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.4.3 Combined Entanglement Stressors

An individual fish could experience the following consequences of entanglement stressors: displacement, stress, avoidance response, behavioral changes, entanglement causing injury, and entanglement causing mortality. If entanglement results in mortality, it cannot act in combination because mortal injuries occur with the first instance. Therefore, there is no possibility for the occurrence of this consequence to increase if sub-stressors are combined.

Sub-lethal consequences may result in delayed mortality because they cause irrecoverable injury or alter the individual's ability to feed or detect and avoid predation. Sub-lethal effects resulting in mortality could be more likely if the events occurred in essentially the same location and occurred within the individual's recovery time from the first disturbance. This circumstance is only likely to arise during training activities that cause frequent and recurring entanglement stressors to essentially the same location (e.g., torpedoes expended at the same location as sonobuoys). In these specific circumstances the potential consequences to fishes from combinations of entanglement stressors may be greater than the sum of their individual consequences.

These specific circumstances that could multiply the consequences of entanglement stressors are highly unlikely to occur for two reasons. First, it is highly unlikely that torpedo guidance wires and sonobuoy decelerators/parachutes would impact essentially the same space because most of these sub-stressors are widely dispersed in time and space. Second, the risk of injury or mortality is extremely low for each sub-stressor independently; therefore, the combined impact of these sub-stressors does not increase the risk in a meaningful way. Furthermore, while it is conceivable that interaction between sub-stressors could magnify their combined risks, the necessary circumstances are highly unlikely to overlap.

Interaction between entanglement sub-stressors is likely to have neutral consequences for fishes. There is no potential for these entangling objects to combine in a way that would multiply their impact, as is the case with derelict (abandoned or discarded) fishing nets that commonly occur in the Study Area (Macfadyen et al. 2009) and entangle fish by design. Fish entangled in derelict nets attract scavengers and predators that may themselves become entangled in an ongoing cycle (Morgan and Chuenpagdee 2003). Guidance wires and decelerators/parachutes are used relatively infrequently over a wide area, and are mobile for only a short time. Therefore, unlike discarded fishing gear, it is extremely unlikely that guidance wires and decelerators/parachutes could interact.

3.9.3.4.4 Summary of Entanglement Stressors

While most fish species are susceptible to entanglement in fishing gear that is designed to entangle a fish by trapping it by its gills or spines (e.g., gill nets), only a limited number of fish species that possess certain features such as an irregular shaped or rigid rostrum (snout) (e.g., billfish) are susceptible to entanglement by military expended materials. A survey of marine debris entanglements found no fish entanglements in military expended materials in a 25-year dataset (Ocean Conservancy 2010).

The Navy identified and analyzed three military expended materials types that have potential to entangle fishes: guidance wires, fiber optic cables, and decelerators/parachutes. Other military expended material types, such as bomb or missile fragments, do not have the physical characteristics to entangle fishes in the marine environment and were not analyzed. Even for fishes that might encounter and become entangled in an expended guidance wire, the breaking strength of that wire is low enough that the impact would be only temporary and not likely to cause harm to the individual.

Pursuant to the ESA, entanglement stressors used under the No Action Alternative, Alternative 1, and Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.5 Ingestion Stressors

This section evaluates the potential ingestion impacts of the various types of expended materials used by the military during training and testing activities within the Study Area. Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Appendix H.6 (Conceptual Framework for Assessing Effects from Ingestion). Ingestion of expended materials by fish could occur in all large marine ecosystems and open ocean areas and can occur at or just below the surface, in the water column, or at the seafloor, depending on the size and buoyancy of the expended object and the feeding behavior of the fish. Floating material is more likely to be eaten by fish of all sizes that feed at or near the water surface (e.g., molas, whale sharks, manta rays, herring, or flying fish), while materials that sink to the seafloor present a higher risk to bottom-feeding fish (e.g., hammerhead sharks, skates, rays, and flounders).

It is reasonable to assume that any item of a size that can be swallowed by a fish could be eaten at some time; this analysis focuses on ingestion of materials in two locations: (1) at the surface or water column, and (2) at the seafloor. Open-ocean predators and open-ocean planktivores are most likely to ingest materials in the water column. Coastal bottom-dwelling predators and estuarine bottom-dwelling predators could ingest materials from the seafloor.

The military expends the following types of materials during training and testing in the Study Area that could become ingestion stressors: non-explosive practice munitions (small- and medium-caliber), fragments from explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), and small decelerators/parachutes. The activities that expend these items and their general distribution are detailed in Section 3.0.5.2.5 (Ingestion Stressors). Metal items eaten by marine fish are generally small (such as fishhooks, bottle caps, and metal springs), suggesting that small- and medium-caliber projectiles, pistons, or end caps (from chaff canisters or flares) are more likely to be ingested. Both physical and toxicological impacts could occur as a result of consuming metal or plastic materials. Items of concern are those of ingestible size that either drift at or just below the surface (or in the water column) for a time or sink immediately to the seafloor. The likelihood that expended items would cause a potential impact on a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item. In this analysis only small- and medium-caliber munitions (or small fragments from larger munitions), chaff, small decelerators/parachutes, and end caps and pistons from flares and chaff cartridges are considered to be of ingestible size for a fish.

The analysis of ingestion impacts on fish is structured around the following feeding strategies:

Feeding at or Just Below the Surface or Within the Water Column

- **Open-Ocean Predators.** Large, migratory, open-ocean fish, such as tuna, sharks, and billfish, feed on fast-swimming prey in the water column of the Study Area. These fish range widely in search of unevenly distributed food patches. Smaller military expended materials could be mistaken for prey items and ingested purposefully or incidentally as the fish is swimming (Table 3.9-5). Prey fish sometimes dive deeper to avoid an approaching predator (Pitcher 1986). A few of these predatory fish (e.g., tiger sharks) are known to ingest any type of marine debris that they can swallow, even automobile tires. Some marine fish, such as the dolphinfish (*Coryphaena hippurus*) (South Atlantic Fishery Management Council 2011) and tuna (Hoss and Settle 1990), have been known to eat plastic fragments, strings, nylon lines, ropes, or even small light bulbs.
- **Open-Ocean Planktivores.** Plankton-eating fish in the open-ocean portion of the Study Area include flyingfish, whale sharks, and manta rays. These fish feed by either filtering plankton from the water column or by selectively ingesting larger zooplankton. These planktivores could encounter and incidentally feed on smaller types of military expended materials (e.g., chaff, end caps, and pistons) at or just below the surface or in the water column (Table 3.9-5). While not a plankton eater, molas may also be capable of ingesting items at or just below the surface in the open ocean.

Military expended materials that could potentially impact these types of fish at or just below the surface or in the water column include those items that float or are suspended in the water column for some period of time (e.g., decelerators/parachutes and end caps and pistons from chaff cartridges or flares).

Fish Feeding at the Seafloor

- **Coastal Bottom-Dwelling Predators/Scavengers.** Large predatory fishes near the seafloor are represented by scorpion fishes, groupers, and jacks, which are typical seafloor predators in coastal and oceanic waters of the Study Area (Table 3.9-5). These species feed opportunistically on or near the bottom, taking fish and invertebrates from the water column and from the bottom. Bottom-dwelling fishes in the coastal waters (Table 3.9-5) may feed by seeking prey and by scavenging on dead fishes and invertebrates (e.g., skates, rays, flatfish).

Military expended materials that could be ingested by fish at the seafloor include items that sink (e.g., small-caliber projectiles and casings, fragments from explosive munitions).

Table 3.9-5: Summary of Ingestion Stressors on Fish Based on Location

Feeding Guild	Representative Species	Overall Potential for Impact
Open-ocean predators	Tuna, most shark species	These fish may eat floating or sinking expended materials, but the encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.
Open-ocean plankton eaters (planktivores)	Sardines, whale shark	These fish may ingest floating expended materials incidentally as they feed in the water column, but the encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.
Coastal bottom-dwelling predators	Skates, and rays	These fish may eat expended materials on the seafloor, but the encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.
Coastal bottom-dwelling scavengers	Skates and rays, flounders	These fish could incidentally eat some expended materials while foraging, especially in muddy waters with limited visibility. However, encounter rate would be extremely low. May result in individual injury or death but is not anticipated to have population-level effects.

Potential impacts of ingestion on adults are different than for other life stages (larvae and juveniles) because early life stages are too small to ingest any military expended materials except for chaff, which has been shown to have no impact on fish (U.S. Air Force 1997; Spargo 1999; Arfsten et al. 2002). Therefore, no ingestion potential impacts on early life stages would occur, with the exception of later stage juveniles that are large enough to ingest military expended materials.

Within the context of fish location in the water column and feeding strategies, the analysis is divided into (1) munitions (small- and medium-caliber projectiles, and small fragments from larger munitions); and (2) military expended material other than munitions (chaff, chaff end caps, pistons, decelerators/parachutes, flares, and target fragments).

3.9.3.5.1 Impacts from Munitions and Military Expended Materials Other than Munitions

The potential impacts of ingesting foreign objects on a given fish depend on the species and size of the fish. Fish that normally eat spiny, hard-bodied invertebrates could be expected to have tougher mouths and digestive systems than fish that normally feed on softer prey. Materials that are similar to the normal diet of a fish would be more likely to be ingested and more easily handled once ingested—for example, by fish that feed on invertebrates with sharp appendages. These items could include fragments from explosives that a fish could encounter on the seafloor. Relatively small or smooth objects, such as small-caliber projectiles or their casings, might pass through the digestive tract without causing harm. A small sharp-edged item could cause a fish immediate physical distress by tearing or cutting the mouth, throat, or stomach. If the object is rigid and large (relative to the fish's mouth and throat), it may block the throat or obstruct the flow of waste through the digestive system. An object may be enclosed by a cyst in the gut lining (Hoss and Settle 1990; Danner et al. 2009). Ingestion of large foreign objects could lead to disruption of a fish's normal feeding behavior, which could be sublethal or lethal.

Munitions are heavy and would sink immediately to the seafloor, so exposure would be limited to those fish identified as bottom-dwelling predators and scavengers. It is possible that expended small-caliber projectiles on the seafloor could be colonized by seafloor organisms and mistaken for prey or that expended small-caliber projectiles could be accidentally or intentionally eaten during foraging. Over time, the metal may corrode or become covered by sediment in some habitats, reducing the likelihood of a fish encountering the small-caliber, non-explosive practice munitions.

Fish feeding on the seafloor in the offshore locations where these items are expended would be more likely to encounter and ingest them than fish in other locations. A particularly large item (relative to the fish ingesting it) could become permanently encapsulated by the stomach lining, with the rare chance that this could impede the fish's ability to feed or take in nutrients. However, in most cases, a fish would pass a round, smooth item through its digestive tract and expel it, with no long-term measurable reduction in the individual's fitness.

If explosive ordnance does not explode, it would sink to the bottom. In the unlikely event that explosive material, high-melting-point explosive (known as HMX) or royal demolition explosive (known as RDX), is exposed on the ocean floor it would break down in a few hours (U.S. Department of the Navy 2001a). HMX or RDX would not accumulate in the tissues of fish (Price et al. 1998; Lotufo et al. 2010). Fish may take up trinitrotoluene (TNT) from the water when it is present at high concentrations but not from sediments (Lotufo et al. 2010). The rapid dispersal and dilution of TNT expected in the marine water column reduces the likelihood of a fish encountering high concentrations of TNT to near zero. A study of discarded military munitions in Hawaii, at depths of 1,300–2,000 ft. (400–600 m), recorded no confirmed detections of chemical agents or explosives in the sediments or biota that could be attributed to the munitions (University of Hawaii at Manoa 2010).

3.9.3.5.1.1 No Action Alternative

Training Activities

Projectiles

Under the No Action Alternative, a total of 60,000 small-caliber projectiles would be expended during training activities). Under the No Action Alternative, a total of 61,786 munitions (other projectiles, bombs, and missiles of all sizes) would be expended during training activities.

These items are heavy and would sink immediately to the seafloor, so exposure to fishes would be limited to those groups identified as bottom-dwelling predators and scavengers. It is possible that expended small-caliber projectiles on the seafloor could be colonized by seafloor organisms and mistaken for prey or that expended small-caliber projectiles could be accidentally or intentionally eaten during foraging. Over time, the metal corrodes slowly or may become covered by sediment in some habitats, reducing the likelihood of a fish encountering the small-caliber non-explosive practice munitions. Explosive munitions are typically fused to detonate within 5 ft. (1.5 m) of the water surface, with steel fragments breaking off in all directions and rapidly decelerating in the water and settling to the seafloor. The analysis generally assumes that most explosive expended materials sink to the seafloor and become incorporated into the seafloor, with no substantial accumulations in any particular area (see Section 3.1, Sediments and Water Quality).

Encounter rates in locations with concentrated small-caliber projectiles would be assumed to be greater than in less concentrated areas. Fishes feeding on the seafloor in the offshore locations where these items are expended (e.g., focused in gunnery boxes) would be more likely to encounter these items and at risk for potential ingestion impacts than in other locations. If ingested, and swallowed, these items could potentially disrupt an individual's feeding behavior or digestive processes. If the item is particularly large for the fish ingesting it, the projectile could become permanently encapsulated by the stomach lining, with the rare chance that this could impede the fish's ability to feed or take in nutrients. However, in most cases a fish would pass the round and smooth item through their digestive tract and expel the item with full recovery expected without impacting the individual's growth, survival, annual reproductive success, or lifetime reproductive success.

Unexploded explosive munitions would sink to the bottom. The residual explosive material would not be exposed to the marine environment, as it is encased in a non-buoyant cylindrical package. Should the High Melting point Explosive or Royal Demolition Explosive be exposed on the ocean floor, they would break down within a few hours (U.S. Department of the Navy 2001b) and would not accumulate in the tissues of fishes (Lotufo et al. 2010; Price et al. 1998). TNT would bioaccumulate in fish tissues if present at high concentrations in the water, but not from fish exposure to TNT in sediments (Lotufo et al. 2010). Given the rapid dispersal and dilution expected in the marine water column, the likelihood of a fish encountering high concentrations of TNT is very low. Over time, Royal Demolition Explosive residue would be covered by ocean sediments in most habitats or diluted by ocean water.

It is not possible to predict the size or shape of fragments resulting from explosives. Explosives used in the Study Area range in size from medium-caliber projectiles to large bombs, and missiles. When these items explode, they partially break apart or remain largely intact with irregular shaped pieces—some of which may be small enough for a fish to ingest. Fishes would not be expected to ingest most fragments from explosives because most pieces would be too large to ingest. Also, since fragment size cannot be quantified, it is assumed that fragments from larger munitions are similarly sized as larger munitions, but more fragments would result from larger munitions than smaller munitions. Small-caliber projectiles far outnumber the larger-caliber explosive projectiles/bombs/missiles/rockets expended as fragments in the Study Area. Although it is possible that the number of fragments resulting from an explosive could exceed this number, this cannot be quantified. Therefore, small-caliber projectiles would be more prevalent throughout the Study Area, and more likely to be encountered by bottom-dwelling fishes, and potentially ingested than fragments from any type of explosive munitions.

Scalloped hammerhead sharks feeding near the seafloor in offshore locations where these items are expended would be more likely to encounter and ingest them than fish in nearshore locations. If ingested, a particularly large munition (relative to the digestive tract of the hammerhead) could become permanently encapsulated by the stomach lining, with the rare chance that this could impede the fish's ability to feed or take in nutrients. However, in most cases, a fish would pass a round, smooth item through its digestive tract and expel it, with no long-term measurable reduction in the individual's fitness.

The potential effects on a scalloped hammerhead shark ingesting a munition or fragment from an explosive munition could range from no effect to injury or mortality. However, with the exception of expended materials at FDM, it is unlikely that a scalloped hammerhead shark would encounter a projectile while foraging near the seafloor. In either case, it is unlikely that a scalloped hammerhead shark would inadvertently ingest a projectile or fragment in the event one is encountered. In a 23-year study, Miller et al. (2013) reported that in South African waters, only 2 of 1,916 scalloped hammerhead sharks examined had ingested plastic objects. Even if a projectile or fragment was inadvertently ingested by a foraging scalloped hammerhead shark, if small enough, the item should pass through the shark's digestive tract with no effect on the shark (Hoss and Settle 1990). Furthermore, a scalloped hammerhead shark might recognize an ingested munition as a non-food item and expel it before swallowing (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, but then expel it. Based on these factors, the probability that a scalloped hammerhead shark would be affected by ingestion of munitions or munitions fragments would be very low.

Sonobuoys

Under the No Action Alternative, approximately 8,073 sonobuoys would be expended during training activities. Small decelerators/parachutes associated with sonobuoys could be potentially ingested by open-ocean plankton eaters. Molas are the only fish species that could be susceptible to ingestion of sonobuoy decelerators/parachutes, because they are large enough to eat a parachute that they might mistake for jellyfish while foraging. The estimated density of sonobuoys in the Study Area is 0.013 sonobuoy per square nautical mile (nm^2) and, given this low density, it is not likely that an ocean sunfish would encounter any sonobuoy decelerators/parachutes; therefore, the risk of ingestion is extremely low for these fish.

In the event a decelerator/parachute was encountered by a foraging scalloped hammerhead shark, the decelerator/parachute, which ranges in diameter from 18 to 48 in. (46 to 122 cm), could conceivably be mistaken for a ray or cephalopod. Along the seafloor, however, sub-surface currents and the likelihood that some decelerator/parachutes would be buried in soft sediments would result in a lower probability of being suspended on the seafloor and potentially mistaken as prey by a foraging scalloped hammerhead shark.

Chaff and Flares

Under the No Action Alternative, a total of 5,830 chaff cartridges would be expended from aircraft during training activities. No potential impacts would occur from the chaff itself, as previously discussed, but there is some potential for the end caps or pistons associated with the chaff cartridges to be ingested. Under the No Action Alternative, a total of 5,740 flares would be expended during training flare exercises. The flare device consists of a cylindrical cartridge approximately 1.4 in. (3.6 cm) in diameter and 5.8 in. (14.7 cm) in length. Items that could be potentially ingested from flares include plastic end caps and pistons. An extensive literature review and controlled experiments conducted by the U.S. Air Force revealed that self-protection flare use poses little risk to the environment (U.S. Air Force 1997). The light generated by flares in the air (designed to burn out completely prior to entering the water) would have no impact on fish based on short burn time, relatively high altitudes where they are used, and the wide-spread and infrequent use. The potential exists for large, open-ocean predators (e.g., tunas, billfishes, pelagic sharks) to ingest self-protection flare end caps or pistons as they float on the water column for some time. A variety of plastic and other solid materials have been recovered from the stomachs of billfishes, dorado (South Atlantic Fishery Management Council 2011) and tuna (Hoss and Settle 1990).

End caps and pistons sink in saltwater (Spargo 2007), which reduces the likelihood of ingestion by surface-feeding fishes. However, some of the material could remain at or near the surface, and predatory fishes may incidentally ingest these items. Assuming that all end-caps and pistons would be evenly dispersed, the annual relative end-cap and piston concentration would be very low (0.02 nm^2).

Based on the low environmental concentration, it is unlikely that a larger number of fish would ingest an end cap or piston, much less a harmful quantity. Furthermore, a fish might expel the item before swallowing it. The number of fish potentially impacted by ingestion of end caps or pistons would be low based on the low environmental concentration and population-level impacts would not occur.

Based on the small size of chaff fibers compared to the size of the preferred prey of scalloped hammerhead sharks, it is unlikely that the scalloped hammerhead shark would confuse the fibers with prey or purposefully feed on chaff fibers. Furthermore, scalloped hammerhead sharks feed near the seafloor, and chaff is expected to remain near the surface for some time. Once chaff has sunk to the bottom, concentrations, which are expected to be low at the surface, would be further reduced by dispersion throughout the water column as chaff fibers sink. Although unlikely, a scalloped hammerhead shark could ingest low concentrations of chaff inadvertently from the surface, water column, or seafloor. While no studies have been conducted to evaluate the effects of chaff ingestion on sharks, the effects are expected to be negligible, based on the low concentrations that could reasonably be ingested, the small size of chaff fibers, and available data on the toxicity of silicon and aluminum. In laboratory studies conducted by the University of Delaware (Hullar et al. 1999), blue crabs and killifish were fed a food-chaff mixture daily for several weeks, and no significant mortality was observed at the highest exposure treatment. Similar results were found when chaff was added directly to exposure chambers containing filter-feeding menhaden. Histological examination indicated no damage from chaff exposures.

Plastic end caps and pistons from chaff cartridges would also be released into the marine environment, where they would persist for long periods and could be ingested by scalloped hammerhead sharks foraging near the seafloor, because the items are expected to sink in saltwater (Spargo 2007).

An extensive literature review and controlled experiments conducted by the U.S. Air Force demonstrated that self-protection flare use poses little risk to the environment or animals (U.S. Air Force 1997). Nevertheless, a scalloped hammerhead shark within the vicinity of expended flares could encounter pistons and end caps from flares.

Summary of Training Activities

Overall, the potential impacts of ingesting small-caliber projectiles, explosive fragments, decelerators/parachutes, or end caps/pistons would be limited to individual cases where a fish might suffer a negative response, for example, ingesting an item too large to be digested. While ingestion of ordnance-related materials, or the other military expended materials identified here, could result in sublethal or lethal impacts, the likelihood of ingestion is low based on the dispersed nature of the materials and the limited exposure of those items at the surface/water column or seafloor where certain fishes could be at risk of ingesting those items. Furthermore, a fish might taste an item then expel it before swallowing it (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, then spit it out. Based on these factors, the number of fish potentially impacted by ingestion of ordnance-related materials would be low and population-level impacts would not occur.

It is unlikely that a scalloped hammerhead shark would encounter target related materials, pistons and end caps from chaff and flares, or decelerator parachutes while foraging near the seafloor, and it is even more unlikely that a scalloped hammerhead shark would ingest one of these items in the event a scalloped hammerhead shark encountered the item. Even if one of these expended materials were to be inadvertently ingested by a foraging scalloped hammerhead shark, a small enough item could pass through the shark's digestive tract with no effect on the shark (Hoss and Settle 1990). Furthermore, a hammerhead might recognize an ingested material, such as a decelerator/parachute, as a non-food item and expel it before swallowing (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, but then expel it. Based on these factors, the probability that a scalloped hammerhead shark would be affected by ingestion of expended materials (i.e., target related materials, pistons and end caps from chaff and flares, or decelerator parachutes) would be very low.

Pursuant to the ESA, the use of munitions or military expended materials of ingestible size for training activities under the No Action Alternative may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Under the No Action Alternative, no military expended materials would be expended during testing activities.

3.9.3.5.1.2 Alternative 1

Training Activities

Projectiles

Under Alternative 1, a total of 86,140 small-caliber projectiles would be expended during training activities. Under Alternative 1, a total of 96,915 explosive munitions (projectiles, bombs, missiles, and rockets of all sizes) would be expended during training activities, a 57 percent increase over the No Action Alternative.

Sonobuoys

Under Alternative 1, a total of 10,980 sonobuoys would be expended during training activities, which would be a 37 percent increase over the No Action Alternative

Chaff and Flares

Under Alternative 1, a total of 25,840 chaff cartridges would be expended from aircraft during training activities, a 340 percent increase over the No Action Alternative. No potential impacts would occur from the chaff itself, as previously discussed, but there is some potential for the end caps or pistons associated with the chaff cartridges to be ingested.

Under Alternative 1, a total of 25,600 flares would be expended during training flare exercises, which would be a 340 percent increase over the No Action Alternative.

Summary of Training Activities

The increase in expended materials under Alternative 1 would increase the probability of ingestion risk; however, as discussed under the No Action Alternative, the likelihood of ingestion would still be low based on the dispersed nature of the materials and the limited exposure of those items at the surface/water column or seafloor where certain fishes could be at risk of ingesting those items. Therefore, the number of fish potentially impacted by ingestion of expended materials would be low and population-level impacts would not occur.

It is unlikely that a scalloped hammerhead would encounter target related materials, pistons and end caps from chaff and flares, or decelerator parachutes while foraging near the seafloor, and it is even more unlikely that a scalloped hammerhead shark would ingest one of these items in the event a scalloped hammerhead shark encountered the item. Even if one of these expended materials were to be inadvertently ingested by a foraging scalloped hammerhead shark, a small enough item could pass through the shark's digestive tract with no effect on the shark (Hoss and Settle 1990). Furthermore, a hammerhead might recognize an ingested material, such as a decelerator/parachute, as a non-food item and expel it before swallowing (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, but then expel it. Based on these factors, the probability that a scalloped hammerhead shark would be affected by ingestion of expended materials (i.e., target related materials, pistons and end caps from chaff and flares, or decelerator parachutes) would be very low.

Pursuant to the ESA, the use of munitions or military expended materials of ingestible size for training activities under Alternative 1 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Projectiles

Under Alternative 1, a total of 2,000 small-caliber projectiles would be expended during testing activities. Under Alternative 1, a total of 6,805 explosive munitions (projectiles, missiles, and torpedoes) would be expended during testing activities.

Sonobuoys

Under Alternative 1, a total of 2,006 sonobuoys would be expended during testing activities.

Chaff and Flares

Under Alternative 1, 600 chaff cartridges and 300 flares would be expended during testing exercises.

Summary of Testing Activities

The increase in expended materials under Alternative 1 would increase the probability of ingestion risk; however, the likelihood of ingestion would still be low based on the dispersed nature of the materials and the limited exposure of those items at the surface/water column or seafloor where certain fishes could be at risk of ingesting those items. Therefore, the number of fish potentially impacted by ingestion of expended materials would be low and population-level impacts would not occur.

It is unlikely that a scalloped hammerhead shark would encounter target related materials, pistons and end caps from chaff and flares, or decelerator parachutes while foraging near the seafloor, and it is even more unlikely that a scalloped hammerhead shark would ingest one of these items in the event a scalloped hammerhead encountered the item. Even if one of these expended materials were to be inadvertently ingested by a foraging scalloped hammerhead shark, a small enough item could pass through the shark's digestive tract with no effect on the shark (Hoss and Settle 1990). Furthermore, a scalloped hammerhead shark might recognize an ingested material, such as a decelerator/parachute, as a non-food item and expel it before swallowing (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, but then expel it. Based on these factors, the probability that a scalloped hammerhead shark would be affected by ingestion of expended materials (i.e., target related materials, pistons and end caps from chaff and flares, or decelerator parachutes) would be very low.

Pursuant to the ESA, the use of munitions or military expended materials of ingestible size for testing activities under Alternative 1 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.5.1.3 Alternative 2

Training Activities

Projectiles

Under Alternative 2, a total of 86,140 small-caliber projectiles would be expended during training activities. Under Alternative 2, a total of 97,193 explosive munitions (projectiles, bombs, missiles, and rockets of all sizes) would be expended during training activities, a 57 percent increase over the No Action Alternative.

Sonobuoys

Under Alternative 2, a total of 10,991 sonobuoys would be expended during training, a 37 percent increase over the No Action Alternative.

Chaff and Flares

Under Alternative 2, a total of 28,512 chaff cartridges would be expended from aircraft during training activities, a 390 percent increase over the No Action Alternative. No potential impacts would occur from the chaff itself, as previously discussed, but there is some potential for the end caps or pistons associated with the chaff cartridges to be ingested.

Under Alternative 2, a total of 28,272 flares would be expended during training flare exercises, a 390 percent increase over the No Action Alternative.

Summary of Training Activities

The increase in expended materials under Alternative 2 would increase the probability of ingestion risk; however, as discussed under the No Action Alternative, the likelihood of ingestion would still be low based on the dispersed nature of the materials and the limited exposure of those items at the surface/water column or seafloor where certain fishes could be at risk of ingesting those items. Therefore, the number of fish potentially impacted by ingestion of expended materials would be low and population-level impacts would not occur.

It is unlikely that a scalloped hammerhead shark would encounter target related materials, pistons and end caps from chaff and flares, or decelerator parachutes while foraging near the seafloor, and it is even more unlikely that a scalloped hammerhead shark would ingest one of these items in the event a scalloped hammerhead shark encountered the item. Even if one of these expended materials were to be inadvertently ingested by a foraging scalloped hammerhead shark, if small enough the item could pass through the shark's digestive tract with no effect on the shark (Hoss and Settle 1990). Furthermore, a scalloped hammerhead shark might recognize an ingested material, such as a decelerator/parachute, as a non-food item and expel it before swallowing (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, but then expel it. Based on these factors, the probability that a scalloped hammerhead shark would be affected by ingestion of expended materials (i.e., target related materials, pistons and end caps from chaff and flares, or decelerator parachutes) would be very low.

Pursuant to the ESA, the use of munitions or military expended materials of ingestible size for training activities under Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

Testing Activities

Projectiles

Under Alternative 2, a total of 2,500 small-caliber projectiles would be expended during testing activities. Under Alternative 2, a total of 8,335 explosive munitions (projectiles, missiles, and torpedoes) would be expended during testing activities. These explosive items would be detonated with fragments expended in the Study Area.

Sonobuoys

Under Alternative 2, a total of 2,228 sonobuoys would be expended during testing activities.

Chaff and Flares

Under Alternative 2, 660 chaff cartridges and 330 flares would be expended during testing exercises.

Summary of Testing Activities

The increase in expended materials under Alternative 2 would increase the probability of ingestion risk; however, as discussed under Alternative 1, the likelihood of ingestion would still be low based on the dispersed nature of the materials and the limited exposure of those items at the surface/water column or seafloor where certain fishes could be at risk of ingesting those items. Therefore, the number of fish potentially impacted by ingestion of expended materials would be low and population-level impacts would not occur.

It is unlikely that a scalloped hammerhead shark would encounter target related materials, pistons and end caps from chaff and flares, or decelerator parachutes while foraging near the seafloor, and it is even more unlikely that a scalloped hammerhead shark would ingest one of these items in the event a scalloped hammerhead shark encountered the item. Even if one of these expended materials were to be inadvertently ingested by a foraging scalloped hammerhead shark, a small enough item could pass through the shark's digestive tract with no effect on the shark (Hoss and Settle 1990). Furthermore, a scalloped hammerhead shark might recognize an ingested material, such as a decelerator/parachute, as a non-food item and expel it before swallowing (Felix et al. 1995), in the same manner that fish would temporarily take a lure into its mouth, but then expel it. Based on these factors, the probability that a scalloped hammerhead shark would be affected by ingestion of expended materials (i.e., target related materials, pistons and end caps from chaff and flares, or decelerator parachutes) would be very low.

Pursuant to the ESA, the use of munitions or military expended materials of ingestible size for testing activities under Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.5.2 Combined Ingestion Stressors

An individual fish could experience the following consequences of ingestion stressors: stress, behavioral changes, ingestion causing injury, and ingestion causing mortality. Ingestion causing mortality cannot act in combination because mortal injuries occur with the first instance. Therefore, there is no possibility for the occurrence of this consequence to increase if sub-stressors are combined.

Sub-lethal consequences may result in delayed mortality because they cause irrecoverable injury or alter the individual's ability to feed or detect and avoid predation. Normally, for fish large enough to ingest it, most small-caliber projectiles would pass through a fish's digestive system without injury. However, in this scenario it is possible that a fish's digestive system could already be compromised or blocked in such a manner that the small-caliber projectiles can no longer easily pass through without harm. It is conceivable that a fish could first ingest a small bomb fragment that might damage or block its digestive tract, then ingest a small-caliber projectile, with magnified combined impacts. The frequency of sub-lethal consequences resulting in mortality could be magnified as a result of ingestion stressors acting in combination only if the combined activities occur in essentially the same location and occur within the individual's recovery time from the first disturbance. This circumstance is likely to arise only during training and testing activities that cause frequent and recurring ingestion stressors to essentially the same location (e.g., chaff cartridge end caps/flares expended at the same location as small-caliber projectiles). In these specific circumstances the potential consequences to fishes from combinations of ingestion stressors may be greater than the sum of their individual consequences.

These specific circumstances that could magnify the consequences of ingestion stressors are highly unlikely to occur because, with the exception of a sinking exercise, it is highly unlikely that chaff cartridge end caps/flares and small-caliber projectiles would impact essentially the same location because most of these sub-stressors are widely dispersed in time and space.

The combined impact of these sub-stressors does not increase the risk in a meaningful way because the risk of injury or mortality is extremely low for each sub-stressor independently. While it is conceivable that interaction between sub-stressors could magnify their combined risks, the necessary circumstances are highly unlikely to overlap. Interaction between ingestion sub-stressors is likely to have neutral consequences for fishes.

3.9.3.5.3 Summary and Conclusions of Ingestion Impacts

The Navy identified and analyzed three military expended materials types that have ingestion potential for fishes: non-explosive practice munitions, military expended materials from explosives, and military expended materials from non-ordnance items (e.g., end caps, canisters, chaff, and accessory materials). The probability of fishes ingesting military expended materials depends on factors such as the size, location, composition, and buoyancy of the expended material. These factors, combined with the location and feeding behavior of fishes, were used to analyze the likelihood the expended material would be mistaken for prey and what the potential impacts would be if ingested. Most expended materials, such as large- and medium-caliber ordnance, would be too large to be ingested by a fish, but other materials, such as small-caliber munitions or some fragments of larger items, may be small enough to be swallowed by some fishes. During normal feeding behavior, many fishes ingest nonfood items and often reject (spit out) nonfood items prior to swallowing. Other fishes may ingest and swallow both food and nonfood items indiscriminately. There are concentrated areas where bombing, missile, and gunnery activities generate materials that could be ingested. However, even within those areas, the overall impact on fishes would be inconsequential.

The potential impacts of military expended material ingestion would be limited to individual cases where a fish might suffer a negative response—for example, ingesting an item too large, sharp, or pointed to pass through the digestive tract without causing damage. Based on available information, it is not possible to accurately estimate actual ingestion rates or responses of individual fishes. Nonetheless, the number of military expended materials ingested by fishes is expected to be very low and only an extremely small percentage of the total would be potentially encountered by fishes. Certain feeding behavior such as “suction feeding” along the seafloor exhibited by sturgeon may increase the probability of ingesting military expended materials relative to other fishes; however, encounter rates would still remain low.

Pursuant to the ESA, the use of munitions or military expended materials of ingestible size for training and testing activities under the No Action Alternative, Alternative 1, or Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.3.6 Secondary Stressors

This section analyzes potential impacts on fishes exposed to stressors indirectly through effects on habitat and prey availability from impacts associated with sediments and water quality. These are also primary elements of marine fish habitat and firm distinctions between indirect impacts and habitat impacts are difficult to maintain. For the purposes of this analysis, indirect impacts on fishes via sediment or water which do not require trophic transfer (e.g., bioaccumulation) in order to be observed are considered here. It is important to note that the terms "indirect" and "secondary" do not imply reduced severity of environmental consequences, but instead describe how the impact may occur in an organism or its ecosystem.

Stressors from training and testing activities could pose secondary or indirect impacts on fishes via habitat, sediment, and water quality. These include (1) explosives and byproducts; (2) metals; (3) chemicals; (4) other materials such as targets, chaff, and plastics; and (5) impacts on fish habitat. Activities associated with these stressors are detailed in Tables 2.8-1 to 2.8-4, and analyses of their potential impacts are discussed in Section 3.1 (Sediments and Water Quality) and Section 3.3 (Marine Habitats).

3.9.3.6.1 Explosives

In addition to directly impacting fish and fish habitat, underwater explosions could impact other species in the food web including plankton and other prey species that fish feed upon. The impacts of underwater explosions would differ depending upon the type of prey species in the area of the blast. As discussed in Section 3.9.3.1 (Acoustic Stressors), fish with swim bladders are more susceptible to blast injuries than fish without swim bladders.

In addition to physical impacts of an underwater blast, prey might have behavioral reactions to underwater sound. For instance, prey species might exhibit a strong startle reaction to detonations that might include swimming to the surface or scattering away from the source. This startle and flight response is the most common secondary defense among animals. The sound from underwater explosions might induce startle reactions and temporary dispersal of schooling fishes if they are within close proximity. The abundances of fish and invertebrate prey species near the detonation point could be diminished for a short period of time before being repopulated by animals from adjacent waters. Alternatively, any prey species that would be directly injured or killed by the blast could draw in scavengers from the surrounding waters that would feed on those organisms, and in turn could be susceptible to becoming directly injured or killed by subsequent explosions. Any of these scenarios would be temporary, only occurring during activities involving explosives, and no lasting impact on prey availability or the pelagic food web would be expected. Indirect impacts of underwater detonations and explosive ordnance use under the proposed action would not result in a decrease in the quantity or quality of fish populations or fish habitats in the Study Area.

3.9.3.6.2 Explosive Byproducts and Unexploded Ordnance

Deposition of undetonated explosive materials into the marine environment can be reasonably well estimated by the known failure and low-order detonation rates of explosives. Undetonated explosives associated with ordnance disposal and mine clearance are collected after training is complete;

therefore, potential impacts are assumed to be inconsequential for these training and testing activities, but other activities could leave these items on the seafloor. Fishes may be exposed by contact with the explosive, contact with contaminants in the sediment or water, and ingestion of contaminated sediments.

Explosions consume most of the explosive material, creating typical combustion products. In the case of Royal Demolition Explosive, 98 percent of the products are common seawater constituents and the remainders are rapidly diluted below threshold impact level. Explosive byproducts associated with high order detonations present no indirect impacts to fishes through sediment or water. However, low order detonations and unexploded ordnance present elevated likelihood of impacts on fishes.

Indirect impacts of explosives and unexploded ordnance to fishes via sediment is possible in the immediate vicinity of the ordnance. Degradation of explosives proceeds via several pathways discussed in Section 3.1 (Sediments and Water Quality). Degradation products of Royal Demolition Explosive are not toxic to marine organisms at realistic exposure levels (Rosen and Lotufo 2010). TNT and its degradation products impact developmental processes in fishes and are acutely toxic to adults at concentrations similar to real-world exposures (Halpern et al. 2008; Rosen and Lotufo 2010). Relatively low solubility of most explosives and their degradation products means that concentrations of these contaminants in the water are relatively low and readily diluted. Furthermore, while explosives and their degradation products were detectable in marine sediment approximately 6 to 12 in. (15.2 to 30.5 m) away from degrading ordnance, the concentrations of these compounds were not statistically distinguishable from background beyond 3 to 6 ft. (0.9 to 1.8 m) from the degrading ordnance (see Section 3.1, Sediments and Water Quality). Taken together, it is likely that various lifestages of fishes could be impacted by the indirect impacts of degrading explosives within a very small radius of the explosive (1–6 ft. [0.3–1.8 m]).

3.9.3.6.3 Metals

Certain metals are harmful to fishes at concentrations above background levels (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) (Wang and Rainbow 2008). Metals are introduced into seawater and sediments as a result of Navy training and testing activities involving vessel hulks, targets, ordnance, munitions, and other military expended materials (Section 3.1.3.2, Metals). Some metals bioaccumulate and physiological impacts begin to occur only after several trophic transfers concentrate the toxic metals (see Section 3.3, Marine Habitats, and Chapter 4, Cumulative Impacts). Indirect impacts of metals to fishes via sediment and water involve concentrations several orders of magnitude lower than concentrations achieved via bioaccumulation. Fishes may be exposed by contact with the metal, contact with contaminants in the sediment or water, and ingestion of contaminated sediments. Concentrations of metals in sea water are orders of magnitude lower than concentrations in marine sediments. It is extremely unlikely that fishes would be indirectly impacted by toxic metals via the water.

3.9.3.6.4 Chemicals

Several military training and testing activities introduce potentially harmful chemicals into the marine environment; principally, flares and propellants for rockets, missiles, and torpedoes. Polychlorinated biphenyls (PCBs) are discussed in Section 3.1 (Sediments and Water Quality), but there is no additional risk to fishes because the Proposed Action does not introduce this chemical into the Study Area and the use of PCBs has been nearly zero since 1979. Properly functioning flares missiles, rockets, and torpedoes combust most of their propellants; leaving benign or readily diluted soluble combustion byproducts (e.g., hydrogen cyanide). Operational failures allow propellants and their degradation products to be released into the marine environment.

The greatest risk to fishes from flares, missile, and rocket propellants is perchlorate, which is highly soluble in water, persistent, and impacts metabolic processes in many plants and animals. Fishes may be exposed by contact with contaminated water or ingestion of contaminated sediments. Since perchlorate is highly soluble, it does not readily absorb to sediments. Therefore, missile and rocket fuel poses no risk of indirect impact on fishes via sediment. In contrast, the principal toxic components of torpedo fuel, propylene glycol dinitrate and nitrodiphenylamine, adsorbs to sediments, has relatively low toxicity, and is readily degraded by biological processes (Section 3.1, Sediments and Water Quality). It is conceivable that various lifestages of fishes could be indirectly impacted by propellants via sediment in the immediate vicinity of the object (e.g., within a few inches), but these potential impacts would diminish rapidly as the propellant degrades.

3.9.3.6.5 Other Materials

Some military expended materials (e.g., decelerators/parachutes) could become remobilized after their initial contact with the sea floor (e.g., by waves or currents) and could be reintroduced as an entanglement or ingestion hazard for fishes. In some bottom types (without strong currents, hard-packed sediments, and low biological productivity), items such as projectiles might remain intact for some time before becoming degraded or broken down by natural processes. While these items remain intact sitting on the bottom, they could potentially remain ingestion hazards. These potential impacts may cease only (1) when the military expended materials is too massive to be mobilized by typical oceanographic processes, (2) if the military expended materials becomes encrusted by natural processes and incorporated into the seafloor, or (3) when the military expended materials becomes permanently buried. In this scenario, a parachute could initially sink to the seafloor, but then be transported laterally through the water column or along the seafloor, increasing the opportunity for entanglement. In the unlikely event that a fish would become entangled, injury or mortality could result. The entanglement stressor would eventually cease to pose an entanglement risk as it becomes encrusted or buried, or degrades.

3.9.3.6.6 Impacts on Fish Habitat

The Proposed Action could result in localized and temporary changes to the benthic community during activities that impact fish habitat. Fish habitat could become degraded during activities that would strike the seafloor or introduce military expended materials, bombs, projectiles, missiles, rockets, or fragments to the seafloor. During, or following activities that impact benthic habitats, fish species may experience loss of available benthic prey at locations in the Study Area where these items might be expended on EFH or habitat areas of particular concern. Additionally, plankton and zooplankton that are eaten by fish may also be negatively impacted by these same expended materials.

Impacts of physical disturbance and strike by small, medium, and large projectiles would be concentrated within designated gunnery box areas, resulting in localized disturbances of hard bottom areas, but could occur anywhere in the Study Area. Hard bottom is important habitat for many different species of fish, including those fishes managed by various fishery management plans.

When a projectile hits a biogenic habitat, the substrate immediately below the projectile is not available at that habitat type on a long-term basis, until the material corrodes. The substrate surrounding the projectile would be disturbed, possibly resulting in short-term localized increased turbidity. Given the large spatial area of the range complexes, it is unlikely that most of the small, medium, and large projectiles expended in the Study Area would fall onto this habitat type. Furthermore, these activities are distributed within discrete locations within the Study Area, and the overall footprint of these areas is quite small with respect to the spatial extent of this biogenic habitat within the Study Area.

Strike warfare activities such as Bombing Exercises (Land) and Missile Exercises involve the use of live munitions by aircrews that practice on ground targets on FDM. These warfare training activities occur on the FDM land mass and are limited to the designated impact zones along the central corridor of the island. Explosives that detonate on land could loosen soils and subsequently get transported into surface drainage areas or nearshore waters. It should be noted that FDM is highly susceptible to natural causes of erosion because it is comprised of highly weathered limestone overlain by a thin layer of clay soil. Sediments entering the nearshore environment could cause temporary water quality impacts, some of which may be in foraging areas used by marine organisms. By limiting the location and extent of target areas, along with the types of ordnance allowed within specific impact areas, the Navy minimizes the potential for soil transport and, thus, water quality impacts. Additionally, as described in Section 3.1.3.1.5.3 (Farallon de Medinilla Specific Impacts), the Navy has conducted annual marine dive surveys in waters surrounding FDM from 1999 to 2010. Throughout all dive surveys, the coral fauna at FDM was observed to be healthy and robust. The nearshore physical environment and basic habitat types at FDM have remained unchanged over the 13 years of survey activity. Given the status and stability of coral fauna in waters surrounding FDM, it is unlikely that temporary water quality impacts have contributed to degradation of fish habitat and thus, impacts to local fish populations.

Sinking exercises could also provide secondary impacts on deep sea populations. These activities occur in open-ocean areas, outside of the coastal range complexes, with potential direct disturbance or strike impacts on deep sea fishes. Secondary impacts on these fishes could occur after the ship hulks sink to the seafloor. Over time, the ship hulk would be colonized by marine organisms that attach to hard surfaces. For fishes that feed on these types of organisms, or whose abundances are limited by available hard structural habitat, the ships that are sunk during sinking exercises could provide an incidental beneficial impact on the fish community (Love and York 2005; Quattrini and Ross 2006).

Secondary stressors involve impacts to habitat (sediment or water quality) or prey (i.e., impacting the availability or quality of prey) that have the potential to affect scalloped hammerhead sharks. Secondary stressors from military training and testing activities could pose impacts to scalloped hammerhead sharks via habitat degradation or an effect on prey availability. Secondary stressors that may affect scalloped hammerhead sharks include only those related to the use of explosives. Secondary effects on scalloped hammerhead shark prey and habitat from the release of metals, chemicals, and other materials into the marine environment during training and testing activities are not anticipated. In addition to directly impacting scalloped hammerhead sharks, underwater explosives could impact other species in the food web, including prey species that scalloped hammerhead sharks feed upon. The impacts of explosions would differ depending upon the type of prey species in the area of the blast. In addition to physical effects of an underwater blast, prey might have behavioral reactions to underwater sound. For instance, prey species might exhibit a strong startle reaction to explosions that might include swimming to the surface or scattering away from the source. This startle and flight response is the most common secondary defense among animals. The abundances of prey species near the detonation point could be diminished for a short period of time, affecting prey availability for scalloped hammerhead sharks feeding in the vicinity. Any effects to prey, other than prey located within the impact zone when the explosive detonates, would be temporary. The likelihood of direct impacts to fishes and mobile invertebrates is low, as described in this section. No lasting effects on prey availability or the pelagic food web would be expected.

Pursuant to the ESA, secondary stressors resulting under the No Action Alternative, Alternative 1, or Alternative 2 may affect, but is not likely to adversely affect, the scalloped hammerhead shark.

3.9.4 Summary of Potential Impacts on Fish

As described in Section 3.0.5.4 (Resource-Specific Impacts Analysis for Multiple Stressors), this section evaluates the potential for combined impacts of all the stressors from the Proposed Action. The analysis and conclusions for the potential impacts from each individual stressor are discussed in the analyses of each stressor in the sections above.

There are generally two ways that a fish could be exposed to multiple stressors. The first would be if a fish were exposed to multiple sources of stress from a single activity (e.g., a mine warfare activity may include the use of a sound source and a vessel). The potential for a combination of these impacts from a single activity would depend on the range of effects of each stressor and the response or lack of response to that stressor. Most of the activities as described in the Proposed Action involve multiple stressors; therefore, it is likely that if a fish were within the potential impact range of those activities, they may be impacted by multiple stressors simultaneously. This would be even more likely to occur during large-scale exercises or activities that span a period of days or weeks (such as a sinking exercises or composite training unit exercise).

Fish could be exposed to a combination of stressors from multiple activities over the course of its life. This is most likely to occur in areas where training and testing activities are more concentrated and in areas that individual fish frequent because it is within the animal's home range (including spawning and feeding areas) or migratory corridor. Except for in the few concentration areas mentioned above, combinations are unlikely to occur because training and testing activities are generally separated in space and time in such a way that it would be very unlikely that any individual fish would be exposed to stressors from multiple activities. However, animals with a home range intersecting an area of concentrated military activity have elevated exposure risks relative to animals that simply transit the area through a migratory corridor. The majority of the proposed training and testing activities occur over a small spatial scale relative to the entire Study Area, have few participants, and are of a short duration (the order of a few hours or less).

Multiple stressors may also have synergistic effects. For example, fish that experience temporary hearing loss or injury from acoustic stressors could be more susceptible to physical strike and disturbance stressors via a decreased ability to detect and avoid threats. Fish that experience behavioral and physiological consequences of ingestion stressors could be more susceptible to entanglement and physical strike stressors via malnourishment and disorientation. These interactions are speculative, and without data on the combination of multiple Navy stressors, the synergistic impacts from the combination of Navy stressors are difficult to predict in any meaningful way. Navy research and monitoring efforts include data collection through conducting long-term studies in areas of Navy activity, occurrence surveys over large geographic areas, biopsy of animals occurring in areas of Navy activity, and tagging studies where animals are exposed to Navy stressors. These efforts are intended to contribute to the overall understanding of what impacts may be occurring overall to animals in these areas.

Although potential impacts to certain fish species from the Proposed Action may include injury or mortality, impacts are not expected to decrease the overall fitness of any given population. Mitigation measures designed to reduce the potential impacts are discussed in Chapter 5 (Standard Operating Procedures, Mitigation, and Monitoring). The potential impacts anticipated from the Proposed Action are summarized in Section 3.9.5 (Endangered Species Act Determinations), with respect to each regulation applicable to fish.

3.9.5 ENDANGERED SPECIES ACT DETERMINATIONS

Table 3.9-6 summarizes the ESA determinations for each substressor analyzed.

Table 3.9-6: Summary of Endangered Species Act Determinations for Training and Testing Activities for the Preferred Alternative

Stressor		Scalloped Hammerhead Shark
Acoustic Stressors		
Non-Impulse Sources	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect
Explosives and other non-impulse sources	Training Activities	May affect, likely to adversely affect
	Testing Activities	May affect, likely to adversely affect
Energy Stressors		
Electromagnetic devices	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect
Physical Disturbance and Strike Stressors		
Vessels and in-water devices	Training Activities	No effect
	Testing Activities	No effect
Military expended materials	Training Activities	No effect
	Testing Activities	No effect
Seafloor devices	Training Activities	No effect
	Testing Activities	No effect
Entanglement Stressors		
Cables and wires	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect
Decelerators/Parachutes	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect
Ingestion Stressors		
Munitions	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect
Military expended materials other than munitions	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect
Secondary Stressors		
Secondary Stressors	Training Activities	May affect, not likely to adversely affect
	Testing Activities	May affect, not likely to adversely affect

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