Atlantic Fleet Training and Testing Draft Environmental Impact Statement / Overseas Environmental Impact Statement

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INVERTEBRATES SYNOPSIS

The United States Department of the Navy considered all potential stressors that invertebrates could potentially be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: Invertebrates could be exposed to noise from the proposed training and testing activities. However, available information indicates that invertebrate sound detection is primarily limited to low frequency (less than 1 kilohertz [kHz]) particle motion and water movement that diminishes rapidly with distance from a sound source. The expected impact of noise on invertebrates is correspondingly diminished and mostly limited to offshore surface layers of the water column where only zooplankton, squid, and jellyfish are prevalent mostly at night when training and testing occur less frequently. Offshore waters are considered to occur beyond areas near land where nutrients and habitat structures are typically more prevalent and often result in increased invertebrate abundance. Exceptions occur at nearshore and inland locations where occasional pierside sonar, air gun, or pile driving actions occur near relatively resilient soft bottom or artificial substrate communities. Because the number of individuals affected would be small relative to population numbers, population-level impacts are unlikely.
- Explosives: Explosives produce pressure waves that can harm invertebrates in the vicinity of where they typically occur: mostly offshore surface waters where zooplankton, squid, and jellyfish are prevalent mostly at night when training and testing do not typically occur. Offshore waters occur beyond areas near land where nutrients and habitat structures are typically more prevalent and often result in increased invertebrate abundance. Exceptions occur where explosives are used on the bottom within nearshore or inland waters on or near sensitive hard bottom communities. Soft bottom communities are resilient to occasional disturbances. Due to the relatively small number of individuals affected, population-level impacts are unlikely.
- Energy: The proposed action produces electromagnetic and high-energy laser energies that briefly affect a very limited area of water, based on the relatively weak magnetic fields and mobile nature of the stressors. Whereas some invertebrate species can detect magnetic fields, the effect has been documented at much higher field strength than what the proposed action generates. Though high-energy lasers can damage invertebrates, the effects are limited to surface waters where relatively few invertebrates species occur (e.g., zooplankton, squid, jellyfish) mostly at night when actions do not typically occur and only where the target is missed. Due to the relatively small number of individuals that may be affected, population-level impacts are unlikely.

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- Physical Disturbance and Strike: Invertebrates could experience physical disturbance and strike impacts from vessels and in-water devices, military expended materials, seafloor devices, and pile driving. Most risk occurs offshore (away from areas near land where increased nutrient availability and habitat complexity may result in increased invertebrate abundance) and near the surface where relatively few invertebrates occur, and at night when actions are not typically occurring. The majority of expended materials are used in areas far from nearshore and inland bottom areas where invertebrates are the most abundant. Exceptions occur for actions taking place within inland and nearshore waters over primarily soft bottom communities, such as related to vessel transits, inshore and nearshore vessel training, nearshore explosive ordnance disposal, operation of bottom-crawling seafloor devices, and pile driving. Invertebrate communities in affected soft bottom areas are naturally resilient to occasional disturbances. Accordingly, population-level impacts are unlikely.
- Entanglement: Invertebrates could be entangled by various expended materials (wires, cables, decelerators/parachutes, biodegradable polymer). Most entanglement risk occurs in offshore areas where invertebrates are relatively less abundant. Offshore waters occur beyond areas near land where nutrients and habitat structures are typically more prevalent and often result in increased invertebrate abundance. The risk of entangling invertebrates is minimized by the typically rigid nature of the expended structures (e.g., wires, cables), although decelerators/parachutes have mesh that could pose a risk to invertebrates large and slow enough to be entangled (e.g., jellyfish). Deep water coral could also be entangled by drifting decelerators/parachutes, but a coincidence is highly unlikely given the extremely sparse coverage of corals in the deep ocean. Accordingly, population-level impacts are unlikely.
- Ingestion: Small expended materials and material fragments pose an ingestion risk to some invertebrates. However, most military expended materials are too large to be ingested, and many invertebrate species are unlikely to consume an item that does not visually or chemically resemble its natural food. Exceptions occur for materials fragmented by explosive charges or weathering in nearshore or inland locations where filter- or deposit-feeding invertebrates are more abundant relative to offshore waters. Furthermore, the vast majority of ingestible materials in the ocean originate from non-military sources. Accordingly, population-level impacts are unlikely.
- Secondary: Secondary impacts on invertebrates are possible via changes to habitats (sediment or water) and to prey availability due to explosives, explosives byproducts, unexploded munitions, metals, and toxic expended material components. Other than bottom-placed explosives, the impacts are mostly in offshore waters where invertebrates are less abundant. The impacts of occasional bottom-placed explosives is mostly limited to nearshore soft bottom habitats that recover quickly from disturbance. Explosive byproducts are rapidly diluted by vast quantities of relatively clean seawater and further they are mostly common seawater constituents. Contamination from unexploded munitions is likely inconsequential because the material has low solubility in seawater and is slowly delivered to the water column. Heavy metals and chemicals such as unspent propellants can reach harmful levels around stationary range targets but are not likely in vast open waters where proposed action targets are typically mobile or temporarily stationary. Accordingly, overall impacts of secondary stressors on widespread invertebrate populations are not likely. Impacts due to decreased availability of prey items (fish and other invertebrates) would likely be undetectable.

3.4.1 INTRODUCTION

This chapter provides the analysis of potential impacts on invertebrates found in the Atlantic Fleet Training and Testing (AFTT) Study Area (Study Area). This section provides an introduction to the species that occur in the Study Area.

The affected environment provides the context for evaluating the effects of the Navy training and testing activities on invertebrates. Because invertebrates occur in all habitats, activities that interact with the water column or the bottom could potentially impact many species and individuals, including microscopic zooplankton (e.g., invertebrate larvae, copepods, protozoans) that drift with currents, larger invertebrates living in the water column (e.g., jellyfish, shrimp, squid), and benthic invertebrates that live on or in the seafloor (e.g., clams, corals, crabs, worms). Because many benthic animals have limited mobility compared to pelagic species, activities that contact the bottom generally have a greater potential for impact. Activities that occur in the water column generally have a lesser potential for impact due to dispersion and dilution associated with currents and water depth, as well as the greater mobility of open water invertebrates large enough to resist drifting with the current or remaining within an impact area.

The following subsections provide brief introductions to the major taxonomic groups and Endangered Species Act (ESA)-listed species of marine invertebrates that occur in the Study Area. The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) maintains a website that provides additional information on the biology, life history, species distribution (including maps), and conservation of invertebrates.

3.4.2 AFFECTED ENVIRONMENT

Three subsections are included in this section. General background information is given in Section 3.4.2.1 (General Background), which provides summaries of habitat use, movement and behavior, sound sensing and production, and threats that affect or have the potential to affect natural communities of marine invertebrates within the Study Area. Species listed under the ESA are described in Section 3.4.2.2 (Endangered Species Act-Listed Species). General types of marine invertebrates that are not listed under the ESA are reviewed in Section 3.4.2.3 (Species Not Listed Under the Endangered Species Act).

3.4.2.1 General Background

Invertebrates, which are animals without backbones, are the most abundant life form on Earth, with marine invertebrates representing a large, diverse group with approximately 367,000 species described worldwide to date (World Register of Marine Species Editorial Board, 2015). However, it is estimated that most existing species have not yet been described (Mora et al., 2011). The total number of invertebrate species that occur in the Study Area is unknown, but is likely to be many thousands. The results of a research effort to estimate the number of marine invertebrate species in various areas identified over 3,000 species in the Northeast U.S. large marine ecosystem and over 10,000 species in the Gulf of Mexico (Fautin et al., 2010). Invertebrate species vary in their use of abiotic habitats and some populations are threatened by human activities and other natural changes, especially endangered species.

Marine invertebrates are important ecologically and economically, providing an important source of food, essential ecosystem services (coastal protection, nutrient recycling, food for other animals, habitat formation), and income from tourism and commercial fisheries (Spalding et al., 2001). The health and abundance of marine invertebrates are vital to the marine ecosystem and the sustainability of the world's fisheries (Pauly et al., 2002). Economically important invertebrate groups that are fished, commercially and recreationally, for food in the United States include crustaceans (e.g., shrimps, lobsters, and crabs), bivalves (e.g., scallops, clams, and oysters), echinoderms (e.g., sea urchins and sea cucumbers), and cephalopods (e.g., squids and octopuses) (Food and Agriculture Organization of the United Nations, 2005; Morgan & Chuenpagdee, 2003; Pauly et al., 2002). Marine invertebrates or the structures they form (e.g., shells and coral colonies) are harvested for many purposes including jewelry, curios, and the aquarium trade. In addition, some marine invertebrates are sources of chemical compounds with potential medical applications. Natural products have been isolated from a variety of marine invertebrates and have shown a wide range of therapeutic properties, including anti-microbial, antioxidant, anti-hypertensive, anticoagulant, anticancer, anti-inflammatory, wound healing and immune modulation, and other medicinal effects (De Zoysa, 2012).

3.4.2.1.1 Habitat Use

Marine invertebrates live in all of the world's oceans, from warm shallow waters to cold deep waters. They inhabit the bottom and water column in all the large marine ecosystems (West Greenland, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast United States (U.S.) Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea) and open ocean areas (Labrador Current, Gulf Stream, and North Atlantic Gyre) in the Study Area (Brusca & Brusca, 2003). The Study Area extends from the bottom up to the mean high tide line (often termed mean high water in literature). The description of habitat use in this section pertains to common marine invertebrates found in the different habitats. The abiotic (nonliving) components of all habitat types are addressed in Section 3.5 (Habitats), and marine vegetation components are discussed in Section 3.3 (Vegetation). This section also identifies marine invertebrates that form persistent habitats, which are considered to be structures that do not quickly disintegrate or become incorporated into soft or intermediate substrate after the death of the organism (e.g., crab shells). The principal habitat-forming invertebrates are corals and shellfish species (e.g., oysters, mussels). In a strict sense, individual invertebrates with hard shells (e.g., molluscs), outer skeletons (e.g., crabs), tubes (e.g., annelid worms), or cavities (e.g., sponges) also may be habitat-forming, providing attachment surfaces or living spaces for other organisms.

Marine invertebrate distribution in the Study Area is influenced by habitat (e.g., abiotic substrate, topography, biogenic [formed by living organisms] features), ocean currents, and physical and water chemistry factors such as temperature, salinity, and nutrient content (Levinton, 2009). Distribution is also influenced by distance from the equator (latitude) and distance from shore. In general, the number of marine invertebrate species (species richness) increases toward the equator (Cheung et al., 2005; Macpherson, 2002). Species richness and overall abundance is typically greater in coastal water habitats compared to the open ocean due to the increased availability of food and protection that coastal habitats provide.

The diversity and abundance of Arthropoda (e.g., crabs, lobsters, and barnacles) and Mollusca (e.g., snails, clams, and squid) is highest on the bottom over the continental shelf due to high productivity and availability of complex habitats relative to typical soft bottom habitat of the deep ocean (Karleskint et al., 2006). Organisms occurring in the bathyal and abyssal zones of the ocean are generally small and have sparse populations (Nybakken, 1993). The deep ocean has a limited food supply for sedentary deposit or filter feeders. The only areas of the deep ocean known to be densely populated are hydrothermal vents and cold seeps (refer to Section 3.5, Habitats, for additional information on these features).

Sandy coastal shores are dominated by species that are adapted to living in shifting substrates, many of which are highly mobile and can burrow. Common invertebrates in these habitats include mole crabs (*Emerita talpoida*), coquina clams (*Donax variabilis*), and a variety of isopods, amphipods, snails, and worms (South Carolina Department of Natural Resources and National Oceanic and Atmospheric Administration, 1996a; Tewfik et al., 2016). Inland soft shores consist of mud flats and sand flats that occur in areas sheltered from strong currents and waves. Soft shore habitats may support a wide variety of invertebrate species including amphipods, decapods, snails, bivalves, worms, and echinoderms (Dineen, 2010; South Carolina Department of Natural Resources and National Oceanic and Atmospheric Administration, 1996b). Habitat-forming invertebrates such as eastern oyster (*Crassostrea virginica*) may occur in coastal flats.

Intermediate (e.g., cobble, gravel) and rocky shores provide habitat for a variety of marine invertebrates (e.g., sea anemones, barnacles, chitons, limpets, mussels, urchins, sea stars, sponges, tunicates, and various worms). Rocky intertidal invertebrates may be attached or free living/mobile, and use various feeding strategies (filter-feeders, herbivores, carnivores, scavengers). Many invertebrates occurring in rocky intertidal zones are preyed upon by fish, birds, and other invertebrates. This particular habitat does not coincide with any of the proposed actions and will therefore not be discussed further. However, hard artificial structures such as pier pilings and seawalls can have a similar community of invertebrates that are in close proximity to some of the proposed actions.

Vegetated habitats, such as kelp forests in nearshore subtidal habitats, seagrasses found in sheltered inland or nearshore waters, and floating *Sargassum* aggregations in nearshore and offshore locations, support a wide variety of marine invertebrate species. Kelp (primarily *Laminaria* species) occurs in the North Atlantic portion of the Study Area, with the southern limit considered to be Long Island Sound (Steimle & Zetlin, 2000). A large number of invertebrate species may be associated with this vegetated habitat. For example, kelp habitats in the Gulf of Maine support a variety of amphipods, isopods, shrimps, crabs, lobsters, sea stars, hydroids, and tunicates (Woodward, 2012). Seagrasses may support numerous worms, sea cucumbers, crabs, molluscs, and anemones, among other taxa. Seagrasses provide a rich source of food for many invertebrates, primarily in the form of epiphytes (non-parasitic plants that grow on other plants) (Florida Museum of Natural History, 2016). Approximately 145 invertebrate species representing a wide range of taxa have been identified in association with floating *Sargassum* algae (Trott et al., 2011). Ten of these species are thought to be endemic to *Sargassum* habitats (South Atlantic Fishery Management Council, 2002).

Rocky reefs and other rocky habitats may occur in subtidal zones. Invertebrate species composition associated with rocky subtidal habitats may be influenced by depth, size, and structural complexity of the habitat. Hundreds of invertebrate species may occur in rocky habitats, which provide attachment sites for sessile (attached to the bottom) species such as barnacles, bryozoans, limpets, sea anemones, sea fans, sponges, and tunicates, among others. Other invertebrates move about or shelter in crevices, including crustaceans (e.g., crabs, lobsters), echinoderms (e.g., brittle stars, sea cucumbers, sea urchins, sea stars), and molluscs (e.g., snails, nudibranchs, sea hares, octopus).

Shallow-water coral reefs are formed by individual corals with symbiotic, structure-forming algae that require both light and a mean annual water temperature greater than about 64 degrees Fahrenheit (°F) (National Ocean Service, 2016a; Nybakken, 1993). Shallow-water coral reefs are found on hard substrate in southern and southeastern portions of the Study Area. Shallow-water coral reefs occur in the southern part of the Gulf of Mexico Large Marine Ecosystem, throughout the Caribbean Sea Large Marine Ecosystem, and in the southern part of the Southeast U.S. Continental Shelf Large Marine

Ecosystem. In addition to the presence of many individual corals, coral reefs also support hundreds of other marine invertebrate species, including representatives of most taxa. Researchers compiled historic and recent information on the amount of hard reef structure covered by living corals at 90 reef locations in the wider Caribbean Sea (primarily shallow reefs in water depths of 1 to 20 meters [m]) (Jackson et al., 2014). Average coral coverage on the hard reef structure is estimated to be approximately 14 to 17 percent, down from approximately 35 percent during the period of 1970 to 1983. Coverage declined in 75 percent of surveyed locations, including the Upper Florida Keys and Dry Tortugas areas. Shallow-water coral reefs may contain ESA-listed coral species, and changes in overall coral coverage provides a context for subsequent discussion of these species Section 3.4.2.2 (Endangered Species Act-Listed Species).

Deep-water corals occur in water depths where there is low or no light penetration and therefore typically lack symbiotic algae. As such, deep-water corals do not form biogenic reefs, but rather form mounds of intermediate (cobble-sized) substrate termed “lithoherms” over hard bottom areas (Lumsden et al., 2007). Differences in water clarity and the resulting light penetration at various locations affect the specific depth at which deep-water corals are found. However, in general, deep-water species are considered to occur at depths below 50 m (National Oceanic and Atmospheric Administration & National Centers for Coastal Ocean Science (NCCOS), 2016; National Oceanic and Atmospheric Administration Fisheries Service, 2008). Stony corals require calcium carbonate in the form of aragonite or calcite to build their supporting structures, which they obtain from seawater where carbonate is in solution. Combinations of temperature and pressure result in a boundary, often called the saturation depth, below which aragonite and calcite tend to dissolve. Therefore, corals (and other invertebrates) occurring below this boundary have difficulty forming persistent structures that contain calcium carbonate, and the aragonite saturation boundary imposes a depth limit for coral occurrence. The depth of the saturation boundary varies in different locations, ranging from about 200 to 3,000 m. Accordingly, deep-water corals are found in the depth range of about 50 to 3,000 m (Bryan & Metaxas, 2007; Lumsden et al., 2007; Quattrini et al., 2015; Tittensor et al., 2009), which confines them to the Coastal Large Marine Ecosystems and seamounts. Four taxa of deep-water corals are known in the Study Area, including stony corals, black coral, gorgonians, and hydrocorals. The two dominant species are ivory tree coral (*Oculina varicosa*) and *Lophelia pertusa*. Deep-water corals generally attach to hard or intermediate substrates exposed to strong currents that provide a steady supply of plankton (algae and small animals that drift in the water) to feed on, and that reduce sedimentation that would inhibit colonization and growth of these slow-growing species (Bryan & Metaxas, 2007; Tsao & Morgan, 2005).

Chemosynthetic communities may support a relatively high biomass of marine invertebrates. Instead of using photosynthesis driven by sunlight, chemosynthetic organisms derive energy from chemicals originating from the earth’s crust. The primary types of habitats supporting chemosynthetic communities are hydrothermal vents and cold seeps. Hydrothermal vents form when seawater permeates downward through the earth’s crust and upper mantle, becomes superheated, and removes minerals and chemicals from the crust. The heated fluid may then rise through fissures in the crust and reach cold ocean water at the seafloor, where metals and other minerals precipitate out to form mounds or chimneys. Communities of microbes, such as bacteria, may colonize these structures and use chemicals occurring in the fluid (primarily hydrogen sulfide or methane) to make energy. The microbes may then become the base of a food web that contains invertebrates such as crabs, clams, mussels, worms, snails, and shrimp (Ross et al., 2012; Woods Hole Oceanographic Institution, 2015). Cold seeps are similar to hydrothermal vents, but the fluid exiting the crust is cooler, typically moves at a slower rate, and may spread over a larger area. Methane hydrates (ice-like structures that contain methane) are associated with some chemosynthetic communities. Cold seeps are generally associated with hard substrate on offshore shelf breaks, submarine canyons, seamounts, and along the Mid-Atlantic Ridge; refer to Section 3.5 (Habitats) for spatial information on the habitats typically occupied by chemosynthetic communities.

Only seamounts and the Mid-Atlantic Ridge reside outside of the Coastal Large Marine Ecosystems, in the abyssal zone. Although chemosynthetic communities have not been well studied off the U.S. Atlantic coast in the past, the number of known and potential sites has increased substantially due to recent investigations. Whereas hydrothermal vents are primarily located in geologically active areas (e.g., seamounts, Mid-Atlantic Ridge), cold seeps have been documented off Massachusetts, Maryland, Virginia, and South Carolina (National Oceanic and Atmospheric Administration, 2013; National Oceanic and Atmospheric Administration Ocean Explorer, 2010, 2012, 2013). Over 500 seeps have been identified at upper portions of the continental slope between Cape Hatteras, North Carolina and Georges Bank, Maine, many of which are associated with submarine canyons (Skarke et al., 2014). Multiple areas containing chemosynthetic communities and methane hydrates have been documented within the Exclusive Economic Zone off the northeastern United States (Quattrini et al., 2015). Hydrocarbon seeps are widespread in the Atlantic Ocean basin, including the Gulf of Mexico (Fisher et al., 2007). Seep communities in the Gulf are typically dominated by mussels, polychaete tube worms, and clams (Ross et al., 2012), although numerous other taxa may be present. Communities located in water depths of less than 1,000 m off Louisiana are considered the most intensively studied and well understood seep communities in the world (Bureau of Ocean Energy Management, 2014). There are relatively few bioherms in the northern Gulf of Mexico; most deep-sea corals are found on existing hard substrata. Hundreds of mounds and ridges have been identified along the continental slope off western Florida (Ross et al., 2017). Many of these features that occur in water depths above 525 m appear to be colonized by deep-water corals (primarily *L. pertusa*) and sponges. A rocky scarp running north-to-south along the slope for at least 229 kilometers (km) also supports corals, although at a lower abundance than on the mounds and ridges.

3.4.2.1.2 Movement and Behavior

Marine benthic and epibenthic (animals that live on the surface of the substrate) invertebrates may be sessile, sedentary (limited mobility), or highly mobile (but typically slower than large vertebrate animals). Several beach invertebrates (e.g., sand crabs, polychaete worms) recruit to beaches during spring and summer and seasonally move to shallow nearshore waters during late fall and winter. Some subtidal epibenthic invertebrates undergo seasonal onshore-offshore migrations associated with reproduction.

Pelagic marine invertebrates include plankton (organisms that do not swim or generally cannot swim faster than water currents) and nekton (active swimmers that can generally swim faster than water currents). Plankton animals commonly undergo daily migrations to surface waters at dusk and return to deeper waters at dawn. This includes small, microscopic zooplankton and larvae, larger crustaceans (e.g., small shrimp), and jellyfish. Planktonic organisms vary in their swimming abilities, ranging from weak (e.g., larvae) to substantial (e.g., box jellyfish). Nekton such as prawns, shrimps, and squid have relatively strong swimming ability, although they are typically slower than most vertebrate animals.

3.4.2.1.3 Sound Sensing and Production

In general, organisms may detect sound by sensing either the particle motion or pressure component of sound, or both (refer to Appendix D, Acoustic Primer, for an explanation of these sound components).

Aquatic invertebrates probably do not detect pressure since many are generally the same density as water and few, if any, have air cavities that would respond to pressure (Budelmann, 1992a; Popper et al., 2001). Marine invertebrates are generally thought to perceive sound via either external sensory hairs or internal statocycts. Many aquatic invertebrates have ciliated "hair" cells that may be sensitive to water movements, such as those caused by currents or water particle motion very close to a sound source (Budelmann, 1992a, 1992b; Mackie & Singla, 2003). This may allow sensing of nearby prey or predators, or help with local navigation. Detection of particle motion is thought to occur in mechanical receptors found on various body parts (Roberts et al., 2016). Aquatic invertebrates that are able to sense local water movements with ciliated cells include cnidarians, flatworms, segmented worms, urochordates (tunicates), molluscs, and arthropods (Budelmann, 1992a, 1992b; Popper et al., 2001). Crustaceans in particular seem to have extensive occurrence of these structures. The sensory capabilities of adult corals are largely limited to detecting water movement using receptors on their tentacles (Gochfeld, 2004), and the exterior cilia of coral larvae likely help them detect nearby water movements (Vermeij et al., 2010).

Some aquatic invertebrates have specialized organs called statocysts that enable an animal to determine orientation, balance, and, in some cases, linear or angular acceleration. Statocysts allow the animal to sense movement and may enable some species, such as cephalopods and crustaceans, to be sensitive to water particle movements associated with sound or vibration (Hu et al., 2009; Kaifu et al., 2008; Montgomery et al., 2006; Normandeau Associates, 2012; Popper et al., 2001). Because any acoustic sensory capabilities, if present, are apparently limited to detecting the local particle motion component of sound (Edmonds et al., 2016), and because water particle motion near a sound source falls off rapidly with distance, aquatic invertebrates are probably limited to detecting nearby sound sources rather than sound caused by pressure waves from distant sources.

In addition to hair cells and statocysts that allow some marine invertebrates to detect water particle motion, some species also have sensory organs called chordotonal organs that can detect substrate vibrations. Chordotonal organs are typically attached to connective tissue of flexible appendages such as antennae and legs (Edmonds et al., 2016). The structures are connected to the central nervous system and can detect some movements or vibrations that are transmitted through substrate.

Available information indicates that aquatic invertebrates are primarily sensitive to low-frequency sounds. Both behavioral and auditory brainstem response studies suggest that crustaceans may sense sounds up to 3 kilohertz (kHz), but greatest sensitivity is likely below 200 hertz (Hz) (Goodall et al., 1990; Lovell et al., 2005; Lovell et al., 2006). Most cephalopods (e.g., octopus and squid) likely sense low-frequency sound below 1 kHz, with best sensitivities at lower frequencies (Budelmann, 1992a; Mooney et al., 2010; Packard et al., 1990). A few cephalopods may sense frequencies up to 1.5 kHz (Hu et al., 2009). Squid did not respond to playbacks of odontocete ultrasonic echolocation clicks, likely because these clicks were outside of squid hearing range (Wilson et al., 2007). Although information on the frequency range of the clicks was not provided, ultrasonic sound typically refers to high frequency sounds above the limit of human hearing (greater than about 20 kHz). Similarly, squid did not respond to killer whale echolocation clicks ranging from 199 to 226 decibels referenced to 1 micropascal (dB re 1 µPa) (Wilson et al., 2007) (refer to Appendix D, Acoustic Primer, for an explanation of this and other acoustic terms). The frequency of the clicks was not provided. However, killer whale echolocation clicks have been reported to be mostly between 45 and 80 kHz (Au et al., 2004). Some researchers have suggested sensitivity to sounds of higher frequencies in some species, although study results are inconclusive. European spiny lobsters (*Palinurus elephas*), some of which were exposed to predators, were found to produce ultrasound signals up to about 75 kHz (Buscaino et al., 2011). The investigators speculated that the signals might have an anti-predator function or might be used in intraspecific communication, although these functions (particularly communication) were considered hypothetical. The results of another study suggest that European spiny lobsters likely use acoustic signals to aggregate (frequency was not specified, although lobsters in the study produced sounds of up to 30 kHz) (Filiciotto et al., 2014). However, information currently available indicates that invertebrates are likely sensitive only to local water movement and to low frequency particle accelerations generated in their close vicinity (Normandeau Associates, 2012).

Although many types of aquatic invertebrates produce sound and at least some species have the ability to detect low-frequency particle motion, little is known about the use of sound or whether all sound production is purposeful or merely incidental in some cases (Hawkins et al., 2015; Normandeau Associates, 2012). Some invertebrates have structures that appear to be designed specifically for sound production, and the results of various studies (summarized in the following paragraphs) indicate that sound is used for communication or other behaviors in some species. For example, it has been suggested by numerous researchers that the larvae of some marine species (e.g., crustaceans, molluscs, and corals) use sound cues for directional orientation (Budelmann, 1992a, 1992b; Montgomery et al., 2006; Popper et al., 2001).

Aquatic invertebrates may produce and use sound in territorial behavior, to detect or deter predators, and in reproduction (Popper et al., 2001). Some crustaceans produce sound by rubbing or closing hard body parts together (Au & Banks, 1998; Heberholz & Schmitz, 2001; Latha et al., 2005; Patek & Caldwell, 2006). The snapping shrimp chorus makes up a significant portion of the ambient noise in many locations (Au & Banks, 1998; Cato & Bell, 1992; Heberholz & Schmitz, 2001). Each snapping shrimp click is up to 215 dB re 1 µPa at 1 m (root mean square [rms] is implied, but the authors did not explicitly state sound pressure level [SPL] or peak SPL), with a peak around 2 to 5 kHz. Some crustaceans, such as the American lobster (*Homarus americanus*) and California mantis shrimp (*Hemisquilla californiensis*), may also produce sound by muscle contraction near the antennae or carapace (Henninger & Watson, 2005; Patek & Caldwell, 2006). Spiny lobsters typically produce low-frequency rasps by moving a structure at the base of the antennae over a rigid file (Buscaino et al., 2011). Other crustaceans make low-frequency rasping or rumbling noises, perhaps used in defense or territorial display (Patek & Caldwell, 2006; Patek et al., 2009), or perhaps used incidental to a visual display. The aquatic isopod *Cymodoce japonica* produces sound by rubbing body parts together (Nakamachi et al., 2015).

Reef noises, such as fish pops and grunts, sea urchin grazing (around 1 kHz), parrotfish grazing, and snapping shrimp noises (around 5 kHz) (Radford et al., 2010), may be used as a cue by some aquatic invertebrates. Nearby reef noises were observed to affect movements and settlement behavior of coral and crab larvae (Jeffs et al., 2003; Radford et al., 2007; Stanley et al., 2010; Vermeij et al., 2010), although chemical cues and substrate color are also used by some species (Foster & Gilmour, 2016). Larvae of other crustacean species, including pelagic and nocturnally emergent species that benefit from avoiding coral reef predators, appear to avoid reef noises (Simpson et al., 2011). Detection of reef noises is likely limited to short distances. Low-frequency sound pressure and particle motion have been measured near a coral reef off Maui, Hawaii (Kaplan & Mooney, 2016). Results indicate that adult cephalopod species would not be able to detect the low level of particle acceleration at the measurement point nearest the reef (50 m). The specific particle acceleration levels detected by marine invertebrate larvae are unknown, but the authors suggest that invertebrate larvae would be unlikely to detect particle acceleration at distances beyond 150 m at this reef. Playback of reef sounds increased the settlement rate of eastern oyster (*Crassostrea virginica*) larvae (Lillis et al., 2013). Green-lipped mussel (*Perna canaliculus*) larvae settlement rate increased when exposed to underwater noise produced by a ferry (Wilkens et al., 2012).

3.4.2.1.4 General Threats

General threats to marine invertebrates include overexploitation and destructive fishing practices (Halpern et al., 2008; Jackson et al., 2001; Kaiser et al., 2002; Miloslavich et al., 2011; Pandolfi et al., 2003), habitat degradation resulting from pollution and coastal development (Cortes N. & Risk, 1985; Downs et al., 2009; Mearns et al., 2011), disease (Porter et al., 2001), invasive species (Bryant et al., 1998; Galloway et al., 2009; Wilkinson, 2002), oil spills (National Oceanic and Atmospheric Administration, 2010b), global climate change and ocean acidification (Hughes et al., 2003), and possibly human-generated noise (Brainard et al., 2011; Vermeij et al., 2010). A relatively new threat to marine invertebrates is bioprospecting, which is the collection of organisms in pursuit of new compounds for development of pharmaceutical products (Radjasa et al., 2011). Coastal waters of the entire Study Area are subject to intense bioprospecting, although the overall impacts may be minimal (Hunt & Vincent, 2006).

Compared to many other invertebrate taxa, the threats to corals and oysters are well-studied. Numerous natural and human-caused stressors may affect corals, including thermal stress, disease, tropical storms, coastal development and pollution, erosion and sedimentation, tourism/recreation, fishing, trade in coral and live reef species, vessel anchoring or groundings, marine debris, predation, invasive species, military and other security-related activities, and hydrocarbon exploration (National Oceanic and Atmospheric Administration, 2008a, 2008b; Sakashita & Wolf, 2009). Coral bleaching, which occurs when corals expel the symbiotic algae living in their tissues, is a stress response to changes in environmental parameters such as temperature or light. A widespread bleaching event occurred throughout the Caribbean Sea, extending to Florida and the Gulf of Mexico, in 2005 (Wilkinson & Souter, 2008). More recently, bleaching occurred in portions of the Caribbean Sea and off the coast of Florida in 2015 (National Oceanic and Atmospheric Administration, 2016c). In 2016, a mass die-off of corals and other invertebrates (e.g., sponges, urchins, brittle stars, and clams) was documented in the Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico (National Oceanic and Atmospheric Administration, 2016a, 2016b). The cause of the die-off is currently unknown. A large disease outbreak was documented in numerous coral species off southeastern Florida in 2014 (Precht et al., 2016). Primary threats to deep-water or cold-water corals include bottom fishing, hydrocarbon exploration, cable and pipeline placement, and waste disposal (e.g., discarded or lost rope and fishing equipment, dredged sediments) (Freiwald et al., 2004). Threats to oysters include habitat degradation (due to fishing practices, terrestrial runoff, coastal development, dredging, and vessel strikes), predation, and disease (Eastern Oyster Biological Review Team, 2007). Overharvesting is currently considered only a minor threat.

Threats related to water quality, marine debris, and climate change are further described in the subsections below.

3.4.2.1.4.1 Water Quality

Invertebrates may be affected by changes in water quality resulting from pollution, sedimentation, and waste discharge. Stormwater runoff and point source discharges associated with coastal development may introduce pollutants into bays and other nearshore coastal areas. The pollutants may degrade sediment and water quality, which in turn can impact marine invertebrate communities. Sedimentation may result from activities such as dredging, which can affect sensitive species such as some corals (Erftemeijer et al., 2012). In addition to dredging, erosion due to storm runoff may cause changes in the frequency or magnitude of sedimentation in areas in proximity to ocean outfalls, estuarine inlets, and major river discharges.

Ship discharges may affect water quality and invertebrates associated with the impacted water. Discharged materials include sewage, bilge water, graywater, ballast water, and solid waste (e.g., food and garbage). Discharges may originate from military, commercial, and recreational vessels. Under provisions of the Clean Water Act, the U.S. Environmental Protection Agency and the U.S. Department of Defense (DoD) have developed Uniform National Discharge Standards to address discharges from U.S. military vessels. Refer to Section 3.2.1.2.2 (Federal Standards and Guidelines) for more information on water quality, including Uniform National Discharge Standards.

Marine invertebrates can be impacted by exposure to oil due to runoff from land, natural seepage, or accidental spills from offshore drilling or tankers (White et al., 2012). Reproductive and early life stages are especially sensitive to oil exposure. Factors such as oil type, quantity, exposure time, and season can affect the toxicity level. Experiments using corals indicate that oil exposure can result in death, decreased reproductive success, altered development and growth, and altered behavior (National Oceanic and Atmospheric Administration, 2010b; White et al., 2012). For example, investigations conducted between 2011 and 2014 near the site of the Deepwater Horizon oil spill in the Gulf of Mexico found continuing evidence of injury to gorgonian octocoral colonies (Etnoyer et al., 2016).

3.4.2.1.4.2 Climate Change

The primary concerns of climate change in the context of impacts to marine invertebrates include increased water temperature, ocean acidification, increased frequency or intensity of cyclonic storm events, and sea level rise.

Increases in ocean temperature can lead to coral stress, bleaching, and mortality (Lunden et al., 2014). Bleaching of corals and other invertebrates that contain symbiotic algae in their tissues (e.g., some anemones and clams) is often tied to atypically high sea temperatures (Lough & van Oppen, 2009; National Ocean Service, 2016b). Bleaching events have increased in frequency in recent decades. Coral bleaching on a global scale has occurred during the summers of 2014, 2015, and 2016 (Eakin et al., 2016). In addition to elevated sea temperatures, atypically low sea temperatures may also cause mortality to corals and most other reef organisms (Colella et al., 2012; Lirman et al., 2011; National Ocean Service, 2016b), suggesting that widening climate extremes could cause more coral bleaching. Response to thermal stress may differ across species or within different environmental contexts, with some species or taxa being more tolerant than others (Bahr et al., 2016; Guest et al., 2016; Hoadley et al., 2015). For example, in the Caribbean Sea, while numerous stony corals may be negatively affected by increased water temperature, some gorgonian corals have been found to persist or increase in abundance under similar conditions (Goulet et al., 2017).

Ocean acidification has the potential to reduce calcification and growth rates in species with calcium carbonate skeletons, including shellfish (e.g., clams, oysters), corals, and sponges (Cohen et al., 2009), and crustose coralline algae that contain calcite in their cell walls (Roleda et al., 2015). Many species within these taxa are important structure-building organisms. In addition to corals and shellfish, acidification may also affect weakly calcified taxa such as lobsters and sea cucumbers (Small et al., 2016; Verkaik et al., 2016). Some climate change models predict that the depth below which corals are unable to form calcium carbonate skeletons will become shallower as the oceans acidify and temperatures increase, potentially decreasing the occurrence and habitat-forming function of corals and other invertebrates. Deep-sea scleractinian stony corals could be particularly vulnerable due to habitat loss and decreased larvae dispersal (Miller et al., 2011). However, a recent study of successive generations of shallow-water reef-building corals exposed to increased water temperature and acidification suggests some corals may be able to tolerate rapidly changing environmental conditions better than previously thought (Putnam & Gates, 2015). In addition to physical effects, increased acidity may result in behavioral changes in some species. For example, acidification of porewater was found to affect burrowing behavior and juvenile dispersal patterns of the soft-shell clam (*Mya arenaria*) (Clements et al., 2016), and increased acidity caused a reduction in the loudness and number of snaps in the snapping shrimp *Alpheus novaezelandiae* (Rossi et al., 2016). As discussed for thermal stress, some coral species may be more tolerant of changing acidity levels than others (Bahr et al., 2016).

Although the potential effects that climate change could have on future storm activity is uncertain, numerous researchers suggest that rising temperatures could result in little change to the overall number of storms, but that storm intensity could increase (Voiland, 2013). Increased storm intensity could result in increased physical damage to individual corals and reefs constructed by the corals (which support numerous other invertebrate taxa), overturning of coral colonies, and a decrease in structural complexity (due to disproportionate breakage of branching species) (Heron et al., 2008; The Nature Conservancy, 2015). However, large storms such as hurricanes may also have positive impacts on corals, such as lowering the water temperature and removing less resilient macroalgae from reef structures, which can overgrow corals.

Sea level rise could affect invertebrates by modifying or eliminating habitat, particularly estuarine and intertidal habitats bordering steep and artificially hardened shorelines (Fujii, 2012). It is possible that intertidal invertebrates would colonize newly submerged areas over time if suitable habitat is present. Coral reef growth may be able to keep pace with sea level rise because accretion rates of individual corals are generally greater than projected potential rates of sea level rise (The Nature Conservancy, 2016). Corals are currently subjected to tidal fluctuations of up to several meters (The Nature Conservancy, 2015; U.S. Geological Survey, 2016). However, the overall net accretion rate of coral reefs may be much slower than the rate of individual corals, decreasing the overall ability of reefs to keep pace with rising water levels. In addition, the compounding effect of other stressors (e.g., ocean acidification) is unknown. In an evaluation of threats to corals previously petitioned for listing under the ESA, sea level rise was considered a low to medium influence on extinction risk (Brainard et al., 2011).

Additional concerns include the potential for changes in ocean circulation patterns that affect the planktonic food supply of filter- and suspension-feeding invertebrates (e.g., corals) (Etnoyer, 2010). An increase in the future incidence of diseases in marine organisms is also theorized (Harvell et al., 2002). In addition, there is concern that cumulative effects of threats from fishing, pollution, and other human disturbance may reduce the tolerance of corals to global climate change (Ateweberhan & McClanahan, 2010; Ateweberhan et al., 2013).

3.4.2.1.4.3 Marine Debris

Marine debris (especially plastics) is a threat to many marine ecosystems, particularly in coastal waters adjacent to urban development. Microplastics (generally considered to be particles less than 5 millimeters [mm] in size), which may consist of degraded fragments of larger plastic items or intentionally manufactured items (e.g., abrasive plastic beads found in some personal care products or used in blast-cleaning), are of concern because of their durability and potential to enter marine food webs (Setala et al., 2016). Field and laboratory investigations have documented ingestion of microplastics by marine invertebrates including bivalve molluscs; crustacean arthropods such as lobsters, shore crabs, and amphipods; annelid lugworms; and zooplankton (Browne et al., 2013; Setala et al., 2014; Von Moos et al., 2012; Watts et al., 2014). While animals with different feeding modes have been found to ingest microplastics, laboratory studies suggest that filter-feeding and deposit feeding benthic invertebrates are at highest risk (Setala et al., 2016). Refer to Section 3.2 (Sediments and Water Quality) for a more detailed discussion of marine debris and the associated effects on water quality.

3.4.2.2 Endangered Species Act-Listed Species

As shown in Table 3.4-1, there are eight species of invertebrates listed as Threatened or Species of Concern under the ESA in the Study Area. Seven coral species listed as threatened are discussed in Sections 3.4.2.2.1 (Elkhorn Coral [*Acropora palmata*]) through Section 3.4.2.2.7 (Rough Cactus Coral [*Mycetophyllia ferox*]). Ivory tree coral (*Oculina varicosa*) is a species of concern. Species of concern are those for which the National Marine Fisheries Service has some concern regarding status and threats, but for which insufficient information is available to indicate a need to list them under the ESA. The species of concern designation does not impose any procedural or substantive requirements under the ESA. Until recently, the queen conch (*Lobatus gigas*, formerly *Strombus gigas*) was also listed as a species of concern. However, in 2014, NMFS announced that listing the queen conch under the ESA is not warranted (Endangered and Threatened Wildlife and Plants: Notice of 12-Month Finding on a Petition To List the Queen Conch as Threatened or Endangered Under the Endangered Species Act (ESA), 79 *Federal Register* 65628–65643 [November 5, 2014]).

In this section, corals are discussed in terms of individual coral polyps or early life stages, where "coral" is defined as follows: Species of the phylum Cnidaria, including all species of the orders Antipatharia (black corals), Scleractinia (stony corals), Gorgonacea (horny corals), Stolonifera (organ pipe corals and others), Alcyonacea (soft corals), and Helioporacea (blue coral) of the class Anthozoa; and all species of the families Milleporidea (fire corals) and Stylastreridae (stylasterid hydrocorals) of the class Hydrozoa.

NMFS has identified the overall primary factors contributing to decline of coral species listed under the ESA (National Oceanic and Atmospheric Administration Fisheries, 2015). The factors are disease outbreaks; habitat degradation and modification due to sedimentation; increased predation; hurricanes; pollution; alien species; invasive green algae; limited distribution; damage from mechanical fishing gear, anchors, fish pots, divers, and swimmers; and coral bleaching.

Table 3.4-1: Status and Presence of Endangered Species Act-Listed and Species of Concern Invertebrate Species in the Study Area

Species Name and Regulatory Status			*Location in Study Area[1]*		
Common Name	***Scientific Name***	***Endangered Species Act Listing***	***Open Ocean***	***Large Marine Ecosystem***	***Inland Waters***
Elkhorn coral	*Acropora palmata*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Florida Bay and Biscayne Bay
Staghorn coral	*Acropora cervicornis*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Florida Bay and Biscayne Bay

Table 3.4-1: Status and Presence of Endangered Species Act-Listed and Species of Concern Invertebrate Species in the Study Area (continued)

Species Name and Regulatory Status			*Location in Study Area[1]*		
Common Name	***Scientific Name***	***Endangered Species Act Listing***	***Open Ocean***	***Large Marine Ecosystem***	***Inland Waters***
Lobed star coral	*Orbicella annularis*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Florida Bay and Biscayne Bay
Boulder star coral	*Orbicella franksi*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Florida Bay and Biscayne Bay
Mountainous star coral	*Orbicella faveolata*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Florida Bay and Biscayne Bay
Pillar coral	*Dendrogyra cylindrus*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Florida Bay and Biscayne Bay
Rough cactus coral	*Mycetophyllia ferox*	Threatened	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	Biscayne Bay
Ivory tree coral	*Oculina varicosa*	Species of Concern	None	Gulf of Mexico, Southeast U.S. Continental Shelf, Caribbean Sea	None

[1] Presence in the Study Area is characterized by biogeographic units: open-ocean oceanographic features (Labrador Current, Gulf Stream, and North Atlantic Gyre) or by coastal waters of large marine ecosystems (Caribbean Sea, Gulf of Mexico, Southeast U.S. Continental Shelf, Northeast U.S. Continental Shelf, Scotian Shelf, Newfoundland-Labrador Shelf, and West Greenland Shelf) in the Study Area.

3.4.2.2.1 Elkhorn Coral (*Acropora palmata*)

3.4.2.2.1.1 Status and Management

Elkhorn coral is listed as a threatened species under the ESA, and critical habitat has been designated. The critical habitat designation identifies the physical or biological features essential to the species' conservation as "substrate of suitable quality and availability to support larval settlement and recruitment, and reattachment and recruitment of asexual fragments." For purposes of this definition, "substrate of suitable quality and availability" means natural consolidated hard substrate or dead coral skeleton that is free from fleshy or turf macroalgae cover and sediment cover (Endangered and Threatened Species; Critical Habitat for Threatened Elkhorn and Staghorn Corals, 73 *Federal Register* 72210–72241 [November 26, 2008]). This definition applies to depths from mean low water to 30 m. No other essential features were sufficiently definable. The critical habitat designation for elkhorn coral applies to staghorn coral as well (see Section 3.4.2.2.2, Staghorn Coral [*Acropora cervicornis*]). While most shallow-water coral habitat in the Study Area falls within the definition of critical habitat for elkhorn and staghorn coral, the United States contains only about 10 percent of all potential critical habitat in the Caribbean (Bryant et al., 1998). Exemptions from critical habitat designations include a small zone around Naval Air Station Key West and a small area within the South Florida Ocean Measurement Facility Testing Range. The exemption for Naval Air Station Key West was granted in accordance with a provision of the National Defense Authorization Act that allows such exemptions for installations with approved Integrated Natural Resources Management Plans. The exemption for the South Florida Ocean Measurement Facility was granted for national security reasons [73 *Federal Register* 229: 72210–72241, November 26, 2008]. However, ESA protection is not limited to critical habitat designations; the species and where it might occur are also protected via regulatory consultation requirements.

The species' four areas of critical habitat are the Florida area (1,329 square miles [mi^2]), the Puerto Rico area (1,383 mi^2), the St. John/St. Thomas area (121 mi^2), and the St. Croix area (126 mi^2) (see Figure 3.4-1). Areas adjacent to the Naval Air Station Key West and within the footprint of the South Florida Ocean Measurement Facility Testing Range include areas that meet the definition of elkhorn critical habitat. However, areas within 50 yards of the shore of Naval Air Station Key West and a small portion of the nearshore footprint of the South Florida Ocean Measurement Facility Testing Range (combined total of 5.5 mi^2) have been exempted from the critical habitat designation (Endangered and Threatened Species; Critical Habitat for Threatened Elkhorn and Staghorn Corals, 73 *Federal Register* 72210–72241 [November 26, 2008]).

3.4.2.2.1.2 Habitat and Geographic Range

Elkhorn coral is typically found on outer reef crests and slopes with exposure to wave action at depths of 1 to 20 m (3 to 66 feet [ft.]), although it has been reported as deep as 30 m (98 ft.) (Aronson et al., 2008a; Boulon et al., 2005). The optimal water temperature range for elkhorn coral is 77 to 84 °F, and it requires a salinity range of 34 to 37 parts per thousand (Aronson et al., 2008a; Boulon et al., 2005; Goreau & Wells, 1967). Elkhorn coral inhabits shallow waters with high oxygen content and low nutrient levels (Spalding et al., 2001). Clear, shallow water allows the coral sufficient sunlight exposure to support zooxanthellae (symbiotic photosynthetic organisms; analogous to plants living inside the animals). Elkhorn coral primarily inhabits the seaward margins of reefs where appropriate conditions are more likely to occur (Ginsburg & Shinn, 1964).

Elkhorn corals are typically found in the southeastern part of the Gulf of Mexico Large Marine Ecosystem, the northern part of the Caribbean Sea Large Marine Ecosystem, and the southern part of the Southeast U.S. Continental Shelf Large Marine Ecosystem. Elkhorn coral distribution in the Study Area extends from southeastern Florida through the Florida Keys, and surrounds Puerto Rico and the U.S. Virgin Islands (Aronson et al., 2008a). Elkhorn coral is known to occur in portions of the South Florida Ocean Measurement Facility Testing Range (Gilliam & Walker, 2011) and the Key West Range Complex. Two colonies of elkhorn coral occur in the Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico, but this area is not included in designated elkhorn critical habitat (Endangered and Threatened Species; Critical Habitat for Threatened Elkhorn and Staghorn Corals, 73 *Federal Register* 72210–72241 [November 26, 2008]). Although the Flower Garden Banks National Marine Sanctuary is located in the Gulf of Mexico, it does not intersect a training or testing range and would not likely be directly impacted. Therefore, this area is excluded from further analysis.

3.4.2.2.1.3 Population Trends

Elkhorn coral is in the Acroporidae family of corals. A review of quantitative data of Acroporidae in the wider Caribbean area, including the Florida Keys and Dry Tortugas, indicates a greater than 97 percent reduction of Acroporidae coverage since the 1970s with peak declines in the 1980s (Boulon et al., 2005; National Marine Fisheries Service, 2015). Multiple stressors, including disease, increased water temperature, decreased breeding population, loss of recruitment habitat, and sedimentation, may be affecting the recovery of this species. The current range of Acroporidae is considered to be the same as the historical range, despite the more than 97 percent reduction of individual (Bruckner, 2003; Rothenberger et al., 2008).

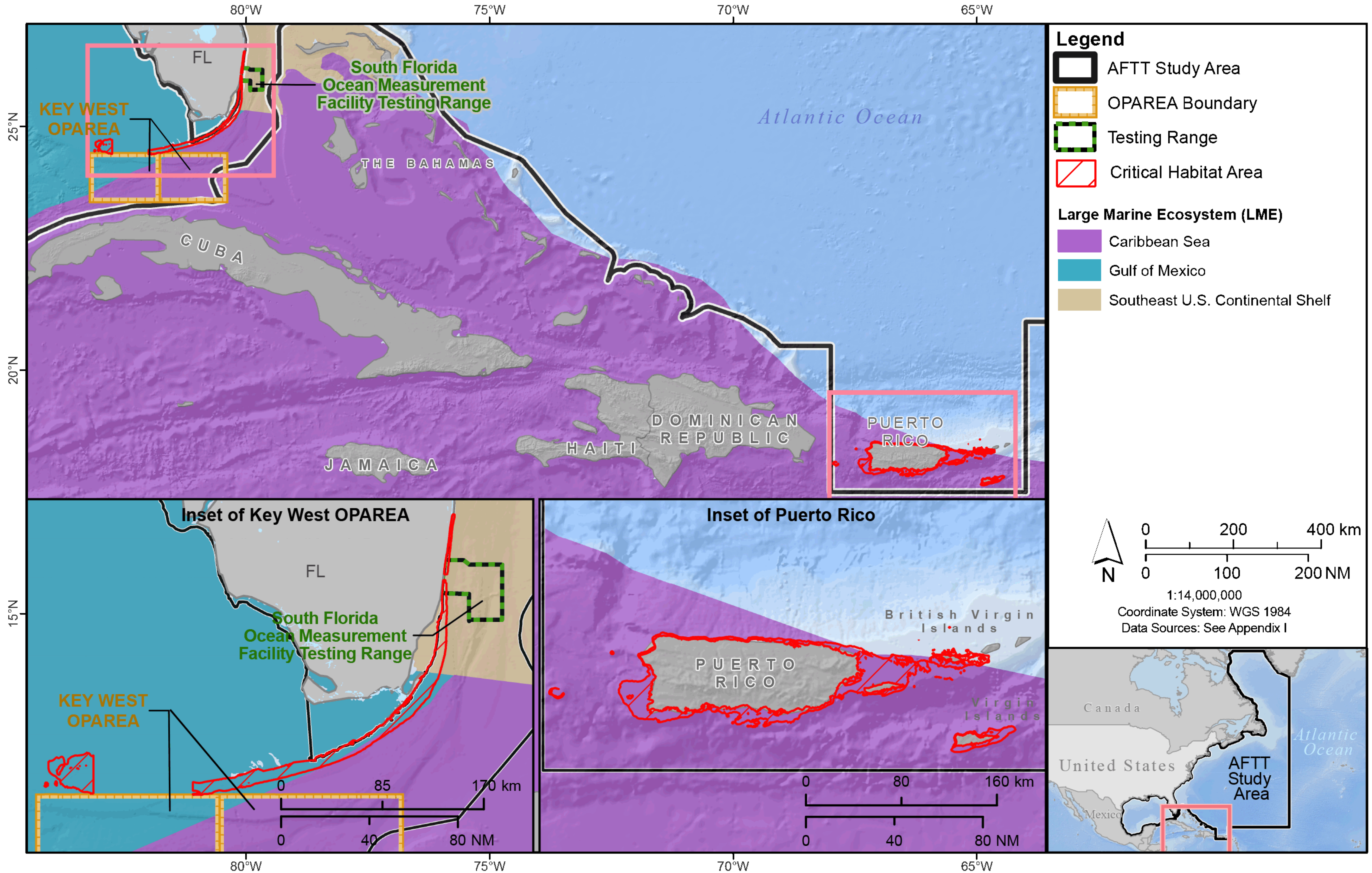
Research on the population status of elkhorn coral in particular indicates a drastic decline. Surveys of Carysfort Reef (1974 to 1982) and Molasses Reef (1981 and 1986) revealed slight declines or stable colonies (Jaap et al., 1988). It was not until the observation of a 93 percent decrease of coral in Looe Key (1983 to 2000) that the elkhorn coral populations mirrored the substantial decline of other coral species such as staghorn coral (Miller et al., 2002). Continued long-term monitoring in the Florida Keys and the U.S. Virgin Islands has found that elkhorn coral remains at less than 1 percent of all corals on reefs (Rothenberger et al., 2008), and the species' continued decline since 2004 is attributed principally to fragmentation, disease, and predation (Williams & Miller, 2011). Notwithstanding the additional focus provided by the 2006 decision to list elkhorn coral as threatened, the population has continued to decline by 50 percent or more, recruitment failure has been observed, and genetic studies have shown that approximately half of all colonies are clones, which reduces the number of genetically distinguishable individuals.

Elkhorn coral can reproduce sexually by spawning (once each year in August or September) (Boulon et al., 2005), or asexually by fragmentation (National Marine Fisheries Service, 2010). Although fragmentation of adult colonies helps maintain high growth rates (from 4 to 11 centimeters (cm) [approximately 2 to 4 inches (in.)] per year), fragmentation reduces the reproductive potential of elkhorn coral by delaying the production of eggs and sperm for 4 years after the damage occurs (Lirman, 2000). Furthermore, large intact colonies produce proportionally more gametes than small colonies (such as new colonies started from fragmentation) because tissue at growing portions of the base and branch tips is not fertile (National Marine Fisheries Service, 2015). During sexual reproduction, eggs and sperm immediately float to the sea surface where multiple embryos can develop from the fragmentation of a single embryo. Developing larvae travel at or near the sea surface for up to several weeks (Boulon et al., 2005) before actively seeking specific micro-habitats suitable for growth. Maturity is reached between 3 and 8 years, the average generation time is 10 years, and longevity is likely longer than 10 years based on average growth rates and size (Wallace, 1999). Combined with a severely reduced population, these factors restrict the species' capacity for recovery.

3.4.2.2.1.4 Predator and Prey Interactions

Predators of corals include sea stars, snails, and fishes (e.g., parrotfish and damselfish) (Boulon et al., 2005; Roff et al., 2011). The marine snail, *Coralliophila abbreviata*, and the bearded fireworm (*Hermodice carunculata*), are the primary predators on elkhorn coral (Boulon et al., 2005).

Corals feed on zooplankton, which are small organisms that inhabit the ocean water column. Corals capture prey with tentacles armed with stinging cells that surround the mouth or by employing a mucus-net to catch suspended prey. In addition to capturing prey, these corals also acquire nutrients through their symbiotic relationship with zooxanthellae. The coral host provides nitrogen in the form of waste to the zooxanthellae, and the zooxanthellae provide organic compounds produced by photosynthesis (the process by which sunlight is used to produce food) to the host (Brusca & Brusca, 2003; Schuhmacher & Zibrowius, 1985). Zooxanthellae also provide corals with their characteristic color.



Notes: AFTT: Atlantic Fleet Training and Testing; FL: Florida; NAS: Naval Air Station; OPAREA: Operating Area; UNDET: Underwater Detonation

Figure 3.4-1: Critical Habitat Areas for Elkhorn and Staghorn Coral Within the Study Area

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3.4.2.2.1.5 Species-Specific Threats

Elkhorn coral is more susceptible to disease than many other Caribbean corals (Pandolfi et al., 2003) (Patterson et al., 2002; Porter et al., 2001). In particular, elkhorn coral is susceptible to a disease named "white pox" or "acroporid serratiosis" caused by a human fecal bacterium (*Serratia marcescens*). The bacterium is present in other coral species, but causes disease only in elkhorn coral (Sutherland et al., 2011). Discharge of sewage from all oceangoing vessels therefore has the potential to expose elkhorn coral to this bacterium. Navy vessel discharges are managed according to established Uniform National Discharge Standards (refer to Section 3.2.1.2.2, Federal Standards and Guidelines, for more information). Elkhorn coral is also susceptible to the same suite of stressors that generally threaten corals (Section 3.4.2.1.4, General Threats).

NMFS evaluated the population's demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an "…extremely high risk of extinction with little chance for recovery…" by 2100 (Brainard et al., 2011). Elements that contribute to elkhorn coral's threatened listing are: high vulnerability to ocean warming, ocean acidification and disease, high vulnerability to sedimentation and elevated nutrient levels, uncommon abundance, decreasing trend in abundance, low relative recruitment rate, restricted geographic range, concentrated in the Caribbean, and inadequacy of regulatory mechanisms.

3.4.2.2.2 Staghorn Coral (*Acropora cervicornis*)

3.4.2.2.2.1 Status and Management

Staghorn coral is designated as a threatened species under the ESA. Staghorn coral shares the four areas of designated critical habitat with elkhorn coral, as well as the two exemptions at Navy facilities (refer to Section 3.4.2.2.1.1, Status and Management, for information on critical habitat for these two species). Exemptions from critical habitat designations include a small zone around Naval Air Station Key West and a small area within the South Florida Ocean Measurement Facility Testing Range. The exemption for Naval Air Station Key West was granted in accordance with a provision of the National Defense Authorization Act that allows such exemptions for installations with approved Integrated Natural Resources Management Plans. The exemption for the South Florida Ocean Measurement Facility was granted for national security reasons [73 *Federal Register* 229: 72210–72241, November 26, 2008].

3.4.2.2.2.2 Habitat and Geographic Range

Staghorn coral is commonly found in lagoons and the upper to mid-reef slopes, at depths of 1 to 20 m (3 to 66 ft.), and requires a salinity range of 34 to 37 parts per thousand (Aronson et al., 2008e; Boulon et al., 2005) (refer to Section 3.4.2.2.1.2, Habitat and Geographic Range, as habitat information provided for elkhorn coral applies to staghorn coral as well).

In the Study Area, staghorn distribution extends south from Palm Beach, Florida and along the east coast to the Florida Keys and Dry Tortugas (Jaap, 1984), in the southern part of the Gulf of Mexico Large Marine Ecosystem, the northern part of the Caribbean Sea Large Marine Ecosystem, and the southern part of the Southeast U.S. Continental Shelf Large Marine Ecosystem. Staghorn coral is known to occur in portions of the Key West Range Complex (Endangered and Threatened Wildlife and Plants: Proposed Listing Determinations for 82 Reef-Building Coral Species; Proposed Reclassification of *Acropora palmate* and *Acropora cervicornis* from Threatened to Endangered, 77 *Federal Register* 73219–73262 [December 7, 2012]).

3.4.2.2.2.3 Population Trends

Most population monitoring of shallow-water corals is focused on the Florida Keys, which straddle three large marine ecosystems: Southeast U.S. Continental Shelf, Caribbean Sea, and Gulf of Mexico. Because the Florida Keys comprise their own ecological subregion, most reports categorize coral data as Floridian versus Caribbean rather than distinguishing populations on one side of these artificial boundaries. Research on the population status of staghorn coral indicates a drastic decline throughout the Caribbean that peaked in the 1980s. At four long-monitored reefs in the Florida Keys, staghorn coral cover decreased as follows:

- 18 percent on Carysfort Reef (1974 to 1982) (Dustan & Halas, 1987)
- 96 percent on Molasses Reef (1981 to 1986) (Jaap et al., 1988)
- 98 percent on Looe Key (1983 to 2000) (Causey et al., 2002)
- 80 to 98 percent in the Dry Tortugas (Davis, 1982)

Continued long-term monitoring in the Florida Keys and the U.S. Virgin Islands has found that staghorn coral remains at 2 percent or less of all corals on reefs, a fraction of its former abundance (Boulon et al., 2005; Rothenberger et al., 2008) (refer to Section 3.4.2.2.1.3, Population Trends, for general population and abundance information regarding acroporid corals). Staghorn coral grown in “nurseries” to assist recovery programs had substantially higher survival rates after a catastrophic cold-water bleaching event in 2010, suggesting that restoration projects have potential for success (Schopmeyer et al., 2011). This same 2010 cold-water event killed an average of 15 percent of staghorn colonies at monitored reefs in the Florida Keys, a substantial decline in this remnant population (Lirman et al., 2011; National Oceanic and Atmospheric Administration, 2012a). Since the 2006 decision to list staghorn coral as threatened, some populations have continued to decline by 50 percent or more, and reliance on asexual fragmentation as a source of new colonies is not considered sufficient to prevent extinction (Endangered and Threatened Wildlife and Plants: Proposed Listing Determinations for 82 Reef-Building Coral Species; Proposed Reclassification of *Acropora palmate* and *Acropora cervicornis* from Threatened to Endangered, 77 *Federal Register* 73219–73262 [December 7, 2012]).

Growth rates for this species range from approximately 1 to 5 in. per year (Boulon et al., 2005). Reproductive strategies and characteristics are not materially different from elkhorn coral (Section 3.4.2.2.1.3, Population Trends).

3.4.2.2.2.4 Predator and Prey Interactions

Predators of corals include sea stars, snails, and fishes (e.g., parrotfish and damselfish) (Boulon et al., 2005; Roff et al., 2011). The marine snail, *Coralliophila abbreviata* (Grober-Dunsmore et al., 2006), and the bearded fireworm, are the primary predators on staghorn coral. Staghorn coral feeding strategies and symbioses are not materially different than those described for elkhorn coral (Section 3.4.2.2.1.4, Predator and Prey Interactions).

3.4.2.2.2.5 Species-Specific Threats

Staghorn coral has no species-specific threats. It is susceptible to the same suite of stressors that generally threaten corals (Section 3.4.2.2.1.5, Species-Specific Threats). However it is more susceptible to disease such as white band disease (Patterson et al., 2002; Porter et al., 2001), even though other diseases also can impact staghorn coral survival (National Marine Fisheries Service, 2015). A white band type II disease which is linked with the bacterial infection, *Vibrio carchariae* (also referred to as *V.*

charchariae or *V. harveyi*; (Gil-Agudelo et al., 2006)), has also been described. A transmissible disease that caused rapid tissue loss in staghorn corals in the Florida Keys was described in 2003 (Williams & Miller, 2005). Similar to white pox in *A. palmata*, the disease manifested with irregular multifocal tissue lesions with apparently healthy tissue remaining in between. Ciliate infections have also been documented at several locations in the Caribbean (Croquer et al., 2006).

NMFS evaluated the population's demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an "…extremely high risk of extinction with little chance for recovery…" by 2100 (Brainard et al., 2011). Elements that contribute to staghorn coral's threatened status include high vulnerability to ocean warming, ocean acidification and disease, high vulnerability to sedimentation and elevated nutrient levels, uncommon abundance, decreasing trend in abundance, low relative recruitment rate, restricted geographic range, and inadequacy of regulatory mechanisms.

3.4.2.2.3 Lobed Star Coral (*Orbicella annularis*)

3.4.2.2.3.1 Status and Management

Lobed star coral (*Orbicella* [formerly *Montastraea*] *annularis*) is listed as threatened under the ESA. *Orbicella annularis*, boulder star coral (*Orbicella franksi*) and mountainous star coral (*Orbicella faveolata*) have partially overlapping morphological characteristics, particularly in northern sections of their range, making identification less certain than for most other Caribbean corals. While there now is reasonable acceptance that these are three separate and valid species, decades of taxonomic uncertainty and difficult field identification have led many to consider these a single species complex. Consequently, many long-term monitoring data sets and previous ecological studies did not distinguish among the three species, instead pooling them together as "*M. annularis* complex" or "*M. annularis* sensu lato" (Brainard et al., 2011; Jaap et al., 2002; National Oceanic and Atmospheric Administration, 2012b; Somerfield et al., 2008).

3.4.2.2.3.2 Habitat and Geographic Range

Lobed star coral has been reported from depths of 0.5 to 20 m (2 to 66 ft.) (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012b). *Orbicella* species, including lobed star coral, occur in most reef habitat types, although less commonly on the reef flat and in the shallow zones formerly dominated by elkhorn coral (Brainard et al., 2011; Goreau, 1959; National Oceanic and Atmospheric Administration, 2012b). *Orbicella* species are key reef-builders. They are known throughout the Caribbean, Bahamas, and the Flower Garden Banks, but are uncommon or possibly absent from Bermuda.

Within the Study Area, lobed star coral is typically found in the southern and southeastern parts of the Gulf of Mexico Large Marine Ecosystem, the northern part of the Caribbean Sea Large Marine Ecosystem, and the southern part of the Southeast U.S. Continental Shelf Large Marine Ecosystem. Lobed star coral range includes most portions of the Study Area where shallow-water coral reefs occur. The principal areas of coincidence between lobed star coral habitat and the Study Area are near Puerto Rico and south Florida. Lobed star coral is known to occur in the South Florida Ocean Measurement Facility Testing Range, adjacent to the Naval Air Station Key West, and the Key West Range Complex. However, some of this geographic range information is based on ecological studies that identified the *O. annularis* complex rather than specifying *O. annularis* in particular.

3.4.2.2.3.3 Population Trends

Lobed star coral in the U.S. Virgin Islands declined 72 percent during the years from 1988 to 1999 (Edmunds & Elahi, 2007). Declines between 40 and 60 percent were recorded in Puerto Rico, and 80 to 95 percent declines were observed in Florida between the late 1970s and 2003 (Aronson et al., 2008c; Brainard et al., 2011). However, because many studies in Puerto Rico and Florida did not reliably distinguish between the three species, these changes in abundance should be assumed to apply generally to the *O. annularis* species complex (Brainard et al., 2011). In addition to these declines, the remnant population of *O. annularis* in the Florida Keys was decimated by the 2010 cold-water bleaching event that killed about 56 percent of all *O. annularis* colonies at monitored reefs (Lirman et al., 2011).

All three of the *O. annularis* complex species are hermaphroditic, spawning over 4 to 8 nights after the late summer full moon (typically September and October) (Brainard et al., 2011; Caribbean Marine Biological Institute, 2011). Buoyant gametes are fertilized at the surface. Larval development is typically 3 to 8 days and larvae are relatively small (Brainard et al., 2011; Caribbean Marine Biological Institute, 2011). Fertilization success is low and recruitment rates are extremely low, on the order of 1 per 10 square meters (m^2) every 10 years (Brainard et al., 2011). Asexual reproduction by fragmentation is occasionally successful, but in general, reproduction rates of this species are extremely low (Aronson et al., 2008c; Brainard et al., 2011). Genetic studies of boulder star coral found that populations in the eastern and western Caribbean are relatively genetically distinct, suggesting that regional differences in population trends or regulations for corals may influence their populations' genetic diversity (Foster et al., 2012).

Growth rates are approximately 1 cm per year for colonies at depths of less than 12 m (39 ft.) and growth rates decrease sharply as depth increases (Brainard et al., 2011). Slow growth coupled with low recruitment rates contribute to the three *O. annularis* complex species' vulnerability to extinction (Brainard et al., 2011).

3.4.2.2.3.4 Predator and Prey Interactions

Lobed star coral is much less susceptible to predation by snails than the *Acropora* species, and although preyed on by parrotfish, the species is not targeted (Brainard et al., 2011; Roff et al., 2011). Lobed star coral, as well as other species of *Orbicella*, is susceptible to yellow band disease (Closek et al., 2014). Yellow band disease progresses slowly, but can cause large die-offs over the course of several seasons. The disease is known to affect several other types of coral and is pervasive in the Caribbean (Closek et al., 2014). Lobed star coral feeding strategies and symbioses are not materially different than those described for elkhorn coral (Section 3.4.2.2.1.4, Predator and Prey Interactions).

3.4.2.2.3.5 Species-Specific Threats

All three species of the *O. annularis* complex are highly susceptible to thermal bleaching, both warm and cool extremes (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012a). Recently, lobed star coral and mountainous star coral (*O. faveolata*) were found to have higher susceptibility to coral bleaching than many other species (van Hooidonk et al., 2012). Among the 25 coral species assessed after a 2010 cold-water bleaching event in Florida, *O. annularis* was the most susceptible to mortality by a factor of almost two (Lirman et al., 2011). Otherwise, this coral has no species-specific threats, and is susceptible to the same suite of stressors that generally threaten corals (Section 3.4.2.1.4, General Threats). Disease and pollution (e.g., nutrients, herbicides, and pesticides) are the most damaging of the general threats (Brainard et al., 2011; Hughes et al., 2003; Pandolfi et al., 2005).

NMFS evaluated the population's demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an "…extremely high risk of extinction with little chance for recovery…" by 2100 (Brainard et al., 2011). Elements that contribute to lobed star coral's threatened status are: susceptibility to ocean temperature shifts, disease, sedimentation, elevated nutrient levels, and ocean acidification; susceptibility to trophic effects of fishing; inadequate existing regulatory mechanisms to address global threats; threats by human impacts; decreasing trend in abundance; low relative recruitment rate; narrow overall distribution (based on narrow geographic distribution and moderate depth distribution); the concentration of the species in the Caribbean; and shifts to small size classes via fission and partial mortality of older, larger colonies (National Marine Fisheries Service, 2014).

3.4.2.2.4 Boulder Star Coral (*Orbicella franksi*)

3.4.2.2.4.1 Status and Management

Boulder star coral is designated as a threatened species under the ESA.

This species, previously identified as *Montastraea franksi*, is part of the *O. annularis* complex (identified in Section 3.4.2.2.3, Lobed Star Coral [*Orbicella annularis*]), which also includes lobed star coral and mountainous star coral.

3.4.2.2.4.2 Habitat and Geographic Range

Boulder star coral is found at least as deep as 50 m (164 ft.) (Brainard et al., 2011), and is found in most reef environments. The *O. annularis* complex has been reported to at least 70 to 90 m (230 to 295 ft.), though only *O. faveolata* and *O. franksi* are likely to occur at these depths. The species is found in Bermuda but otherwise its geographic range is not materially different from *O. annularis*.

Boulder star coral is known to occur in the South Florida Ocean Measurement Facility Testing Range, adjacent to Naval Air Station Key West, and the Key West and Gulf of Mexico Range Complexes. However, some of this geographic range information is based on ecological studies that identified the *O. annularis* complex rather than specifying *O. franksi* in particular.

3.4.2.2.4.3 Population Trends

This species information is assumed not to be materially different from lobed star coral; however, differences may be masked since many ecological studies collected data at the *O. annularis* complex level rather than specifying *O. franksi* in particular.

3.4.2.2.4.4 Predator and Prey Interactions

This species information is assumed not to be materially different from lobed star coral; however, differences may be masked since many ecological studies collected data at the *O. annularis* complex level rather than specifying *O. franksi* in particular.

3.4.2.2.4.5 Species-Specific Threats

Boulder star coral was less susceptible to mortality after a 2010 cold-water bleaching event in Florida than any of its congeners by at least a factor of three (Lirman et al., 2011). Otherwise, susceptibility to threats is not assumed to be materially different from lobed star coral. However, differences may be masked because many ecological studies identified the *O. annularis* complex rather than specifying *O. franksi* in particular.

NMFS evaluated the population's demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an "…extremely high risk of extinction with little chance for recovery…" by 2100 (Brainard et al., 2011). Elements that contribute to boulder star coral's threatened status are: high susceptibility to ocean warming, disease, elevated nutrient levels, ocean acidification, and sedimentation; susceptibility to trophic effects of fishing; inadequate existing regulatory mechanisms to address global threats; threats by human impacts; decreasing trend in abundance; slow growth rate; low relative recruitment rate; moderate overall distribution (based on narrow geographic distribution and wide depth distribution); restriction to the Caribbean; and shifts to small size classes via fission and partial mortality of older, larger colonies (National Marine Fisheries Service, 2014).

3.4.2.2.5 Mountainous Star Coral (*Orbicella faveolata*)

3.4.2.2.5.1 Status and Management

Mountainous star coral is designated as a threatened species under the ESA.

The species was previously identified as *Montastraea faveolata*. Boulder star coral is part of the *O. annularis* complex (identified in Section 3.4.2.2.3.1, Status and Management), which also includes lobed star coral and boulder star coral.

3.4.2.2.5.2 Habitat and Geographic Range

Mountainous star coral occurs from 0.5 m (2 ft.) to at least as deep as 40 m (131 ft.) (Brainard et al., 2011), and like *O. annularis* it is more commonly found in the shallower portions of this range. The *O. annularis* complex has been reported to at least 70 to 90 m (230 to 295 ft.), though only *O. faveolata* and *O. franksi* are likely to occur at these depths. This species is found in Bermuda but otherwise its geographic range is not materially different from *O. annularis*.

Mountainous star coral is known to occur in the South Florida Ocean Measurement Facility Testing Range, adjacent to the Naval Air Station Key West, and the Key West Range Complex. However, some of this geographic range information is based on ecological studies that identified the *O. annularis* complex rather than specifying *O. faveolata* in particular.

3.4.2.2.5.3 Population Trends

This species information is assumed not to be materially different from lobed star coral; however, differences may be masked since many ecological studies collected data at the *O. annularis* complex level rather than specifying *O. faveolata* in particular.

3.4.2.2.5.4 Predator and Prey Interactions

This species information is assumed not to be materially different from lobed star coral; however, differences may be masked since many ecological studies collected data at the *O. annularis* complex level rather than specifying *O. faveolata* in particular.

3.4.2.2.5.5 Species-Specific Threats

This species information is assumed not to be materially different from lobed star coral; however, differences may be masked since many ecological studies collected data at the *O. annularis* complex level rather than specifying *O. faveolata* in particular.

NMFS evaluated the population's demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an "…extremely high risk of extinction with little chance for recovery…" by 2100 (Brainard et al., 2011). Elements that contribute to mountainous star coral's threatened status are: high susceptibility ocean warming, disease, sedimentation and elevated nutrient levels; susceptibility to trophic effects of fishing; inadequate existing regulatory mechanisms to address global threats; decreasing trend in abundance; low relative recruitment rate; late reproductive maturity; moderate overall distribution with concentration in areas of high human impact; and shifts to small size classes via fission and partial mortality of older, larger colonies (National Marine Fisheries Service, 2014).

3.4.2.2.6 Pillar Coral (*Dendrogyra cylindrus*)

3.4.2.2.6.1 Status and Management

Pillar Coral is designated as a threatened species under the ESA.

3.4.2.2.6.2 Habitat and Geographic Range

Pillar coral most frequently occurs at depths of 3 to 8 m (10 to 26 ft.) but has been documented at depths of 1 to 25 m (3 to 82 ft.) (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012a). It is found on rocky outcrops in areas of high wave activity (Marhaver et al., 2015). It is known to occur in south Florida as far north as Broward County and from one colony in Bermuda, but is not known to occur at the Flower Garden Banks or elsewhere in the northern or western Gulf of Mexico.

Within the Study Area, pillar corals are typically found in the southern and southeastern parts of the Gulf of Mexico Large Marine Ecosystem, the northern part of the Caribbean Sea Large Marine Ecosystem, and the southern part of the Southeast U.S. Continental Shelf Large Marine Ecosystem. Pillar coral range includes most portions of the Study Area where shallow-water coral reefs occur. The principal areas of coincidence between pillar coral habitat and the Study Area are near Puerto Rico and south Florida. Pillar coral is known to occur in portions of the South Florida Ocean Measurement Facility Testing Range, adjacent to the Naval Air Station Key West, and the Key West Range Complex.

3.4.2.2.6.3 Population Trends

Pillar coral is both rare and conspicuous (due to its growth form). It has a limited habitat preference and colonies are often dispersed and isolated throughout the habitat range (National Marine Fisheries Service, 2014). Because pillar coral colonies have been killed by warm and cold water bleaching, disease, and physical damage, it has been assumed that this rare species is in decline. In general, pillar coral is too rare for meaningful trends in abundance to be detected by typical reef monitoring programs (Brainard et al., 2011). However, recent studies on reproductive strategies and life history have shown low sexual recruitment rates and slow growth, adding further population and genetic diversity concerns for the species (Marhaver et al., 2015).

Growth rates for this species are typically 8 mm (0.3 in.) per year, though rates up to 20 mm (0.8 in.) per year have been reported (Brainard et al., 2011). Pillar coral spawns, and the first observation of spawning activity was recorded in August 2012, 3 to 4 days after a full moon. Further studies found this spawning activity to be consistent through 2014 (Marhaver et al., 2015). The rate of sexual reproduction is likely to be low because the species is so rare and colonies are gonochoric (i.e., a colony is either male or female); male and female colonies are unlikely to be in close enough proximity for reliable fertilization. For this reason, no juveniles of pillar coral have been observed in the past several decades, and fragmentation seems to be the only successful mode of reproduction for this species (National Oceanic and Atmospheric Administration, 2012b).

3.4.2.2.6.4 Predator and Prey Interactions

Predators of this species seem to be few, and though the corallivorous fireworm (*Hermodice carunculata*) feeds on diseased pillar coral, it does not seem to be a major predator (Brainard et al., 2011). A species of sea urchin (*Diadema antillarum*) has been known to cause partial mortality at the base of pillar coral colonies (National Marine Fisheries Service, 2014). Pillar coral is distinctive among Caribbean corals because its tentacles are extended for feeding on zooplankton during the day, while most other corals' tentacles are retracted during the day (Boulon et al., 2005; Brainard et al., 2011). Pillar coral feeding strategies and symbioses are not materially different than those described for elkhorn coral (Section 3.4.2.2.1.4, Predator and Prey Interactions).

3.4.2.2.6.5 Species-Specific Threats

Pillar coral has no species-specific threats. It is susceptible to the same suite of stressors that generally threaten corals (Section 3.4.2.1.4, General Threats); however, it was historically more susceptible to exploitation by the curio trade (Brainard et al., 2011). Low population density and separation of male and female colonies are the principal threats to the species (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012b).

NMFS evaluated the population's demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an "…extremely high risk of extinction with little chance for recovery…" by 2100 (Brainard et al., 2011). Elements that contribute to pillar coral's threatened status are: susceptibility to ocean warming, disease, acidification, elevated nutrient levels, sedimentation, and trophic effects of fishing; inadequate existing regulatory mechanisms to address global threats; threats by human impacts; rare general range-wide abundance; low relative recruitment rate; narrow overall distribution (based on narrow geographic distribution and moderate depth distribution); and restriction to the Caribbean (National Marine Fisheries Service, 2014).

3.4.2.2.7 Rough Cactus Coral (*Mycetophyllia ferox*)

3.4.2.2.7.1 Status and Management

Rough cactus coral is designated as a threatened species under the ESA.

3.4.2.2.7.2 Habitat and Geographic Range

Rough cactus coral is known to occur as deep as 80 to 90 m (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012b). Though reported to commonly occur at depths of 5 to 30 m (16 to 98 ft.) (Aronson et al., 2008d), this could be an artifact of scuba diver-based survey intensity, which decreases dramatically below 30 m (98 ft.). Rough cactus coral occurs in patch and fore reef habitat types, generally in lower energy parts of the reef (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012b). It is known from throughout the Caribbean and southern Gulf of Mexico, but is absent from the Flower Garden Banks, Bermuda, and the southeast United States north of south Florida (National Marine Fisheries Service, 2014).

Within the Study Area, rough cactus coral is typically found in the southern and southeastern parts of the Gulf of Mexico Large Marine Ecosystem, the northern part of the Caribbean Sea Large Marine Ecosystem, and the southern part of the Southeast U.S. Continental Shelf Large Marine Ecosystem. Rough cactus coral range includes most portions of the Study Area where shallow-water coral reefs occur. The principal areas of coincidence between rough cactus coral habitat and the Study Area are near Puerto Rico and south Florida. Rough cactus coral is known to occur in the South Florida Ocean

Measurement Facility Testing Range, adjacent to the Naval Air Station Key West, and the Key West Range Complex.

3.4.2.2.7.3 Population Trends

Though probably never abundant, rough cactus coral in the Florida Keys has declined by at least 80 percent since 1996 and perhaps by much more since the 1970s (Brainard et al., 2011). The abundance of rough cactus coral has been estimated to be at least hundreds of thousands of colonies in the Florida Keys and Dry Tortugas (National Marine Fisheries Service, 2014).

Rough cactus coral is a hermaphroditic brooder, releasing fully-developed larvae in the late winter (February to March) (Aronson et al., 2008b). Recruitment rates are extremely low or absent, as evidenced by observation of anchor-damaged site in the U.S. Virgin Islands over a 10-year period (Brainard et al., 2011). No colonies of rough cactus coral were observed to recruit to the site despite the presence of adults on an adjacent reef (National Marine Fisheries Service, 2014).

3.4.2.2.7.4 Predator and Prey Interactions

Rough cactus coral is not known to be particularly susceptible to predators (Brainard et al., 2011), and feeding strategies and symbioses are not materially different than those described for elkhorn coral (Section 3.4.2.2.1.4, Predator and Prey Interactions).

3.4.2.2.7.5 Species-Specific Threats

Though not especially susceptible to mortality from warm-water bleaching (Brainard et al., 2011; Lough & van Oppen, 2009), 15 percent of *Mycetophyllia* species were killed after a cold-water bleaching event in Florida (Lirman et al., 2011). Some coral diseases are characterized by the white-colored bands or pox they cause, but are otherwise difficult to discriminate (Porter et al., 2001). While diseases such as “white plague” do not seem to be species-specific (Porter et al., 2001), rough cactus coral in the Florida Keys has been particularly susceptible to this type of disease (Brainard et al., 2011).

NMFS evaluated the population’s demographic, spatial structure, and vulnerability factors to determine whether the species was likely to have an “…extremely high risk of extinction with little chance for recovery…” by 2100 (Brainard et al., 2011). Elements that contribute to rough cactus coral’s (*Mycetophyllia ferox*) threatened status are: high susceptibility to disease; susceptibility to ocean warming, acidification, trophic effects of fishing, elevated nutrient levels, and sedimentation; inadequate existing regulatory mechanisms to address global threats; threats by human impacts; rare general range-wide abundance; decreasing trend in abundance; low relative recruitment rate; moderate overall distribution (based on narrow geographic distribution and wide depth distribution); and restriction to the Caribbean (National Marine Fisheries Service, 2014).

3.4.2.3 Species Not Listed Under the Endangered Species Act

Thousands of invertebrate species occur in the Study Area; however, the only species with ESA status are seven coral species listed as threatened and one coral species designated as a species of concern. The variety of species spans many taxonomic groups (taxonomy is a method of classifying and naming organisms). Many species of marine invertebrates are commercially or recreationally fished as seafood. Several species are federally managed as part of fisheries under the Magnuson-Stevens Fishery Conservation and Management Act.

Marine invertebrates are classified within major taxonomic groups, generally referred to as a phylum. Major invertebrate phyla—those with greater than 1,000 species (Roskov et al., 2015; World Register of

Marine Species Editorial Board, 2015)—and the general zones they inhabit in the Study Area are listed in Table 3.4-2. Vertical distribution information is generally shown for adults; the larval stages of most of the species occur in the water column. In addition to the discrete phyla listed, there is a substantial variety of single-celled organisms, commonly referred to as protozoan invertebrates, that represent several phyla (Kingdom Protozoa in Table 3.4-2). Throughout the invertebrates section, organisms may be referred to by their phylum name or, more generally, as marine invertebrates.

Table 3.4-2: Major Taxonomic Groups of Marine Invertebrates in the Atlantic Fleet Training and Testing Study Area

Major Invertebrate Groups[1]		*Presence in the Study Area*[2]		
Common Name (Classification)[3]	***Description***[4]	***Open Ocean Areas***	***Large Marine Ecosystems***	***Inland Waters***
Foraminifera, radiolarians, ciliates (Kingdom Protozoa)	Benthic and planktonic single-celled organisms; shells typically made of calcium carbonate or silica.	Water column, bottom	Water column, bottom	Water column, bottom
Sponges (Porifera)	Mostly benthic animals; sessile filter feeders; large species have calcium carbonate or silica structures embedded in cells to provide structural support.	Bottom	Bottom	Bottom
Corals, anemones, hydroids, jellyfish (Cnidaria)	Benthic and pelagic animals with stinging cells; sessile corals are main builders of coral reef frameworks.	Water column, bottom	Water column, bottom	Water column, bottom
Flatworms (Platyhelminthes)	Mostly benthic; simplest form of marine worm with a flattened body.	Water column, bottom	Water column, bottom	Water column, bottom
Ribbon worms (Nemertea)	Benthic marine worms with an extendable, long tubular-shaped extension (proboscis) that helps capture food.	Water column, bottom	Bottom	Bottom
Round worms (Nematoda)	Small benthic marine worms; free-living or may live in close association with other animals.	Water column, bottom	Water column, bottom	Water column, bottom
Segmented worms (Annelida)	Mostly benthic, sedentary to highly mobile segmented marine worms (polychaetes); free-living and tube-dwelling species; predators, scavengers, herbivores, detritus feeders, deposit feeders, and filter or suspension feeders.	Bottom	Bottom	Bottom

Table 3.4-2: Major Taxonomic Groups of Marine Invertebrates in the Atlantic Fleet Training and Testing Study Area (continued)

Major Invertebrate Groups[1]		*Presence in the Study Area[2]*		
Common Name (Classification)[3]	***Description[4]***	***Open Ocean Areas***	***Large Marine Ecosystems***	***Inland Waters***
Bryozoans (Bryzoa)	Small, colonial animals with gelatinous or hard exteriors with a diverse array of growth forms; filter feeding; attached to a variety of substrates (e.g., rocks, plants, shells or external skeletons of invertebrates.	Bottom	Bottom	Bottom
Cephalopods, bivalves, sea snails, chitons (Mollusca)	Soft-bodied benthic or pelagic predators, filter feeders, detritus feeders, and herbivore grazers; many species have a shell and muscular foot; in some groups, a ribbon-like band of teeth is used to scrape food off rocks or other hard surfaces.	Water column, bottom	Water column, bottom	Water column, bottom
Shrimp, crabs, lobsters, barnacles, copepods (Arthropoda)	Benthic and pelagic predators, herbivores, scavengers, detritus feeders, and filter feeders; segmented bodies and external skeletons with jointed appendages.	Water column, bottom	Water column, bottom	Water column, bottom
Sea stars, sea urchins, sea cucumbers (Echinodermata)	Benthic animals with endoskeleton made of hard calcareous structures (plates, rods, spicules); five-sided radial symmetry; many species with tube feet; predators, herbivores, detritus feeders, and suspension feeders.	Bottom	Bottom	Bottom

[1] Major species groups (those with more than 1,000 species) are based on the World Register of Marine Species (World Register of Marine Species Editorial Board, 2015) and Catalogue of Life (Roskov et al., 2015).
[2] Presence in the Study Area includes open ocean areas; large marine ecosystems; and bays, rivers, and estuaries. Occurrence on or within seafloor (bottom or benthic) or water column (pelagic) pertains to juvenile and adult stages; however, many phyla may include pelagic planktonic larval stages.
[3] Classification generally refers to the rank of phylum, although Protozoa is a traditionally recognized group of several phyla of single-celled organisms (e.g., historically referred to as Kingdom Protozoa, which is still retained in some references, such as in the Integrated Taxonomic Information System).
[4] benthic = a bottom-dwelling organism associated with seafloor or substrate; planktonic = an organism (or life stage of an organism) that drifts in pelagic (water) environments; nekton = actively swimming pelagic organism.

Additional information on the biology, life history, and conservation of marine invertebrates can be found on the websites maintained by the following organizations:

- NMFS, particularly for ESA-listed species and species of concern
- United States Coral Reef Task Force

- MarineBio Conservation Society

3.4.2.3.1 Foraminifera, Radiolarians, Ciliates (Kingdom Protozoa)

Foraminifera, radiolarians, and ciliates are miniscule singled-celled organisms, sometimes forming colonies of cells, belonging to the kingdom Protozoa (Appeltans et al., 2010; Castro & Huber, 2000a). They are found in the water column and on the bottom of the world's oceans, and while most are microscopic, some species grow to approximately 20 cm (Hayward et al., 2016). In general, the distribution of foraminifera, radiolarians, and ciliates is patchy, occurring in regions with favorable growth conditions.

Foraminifera form diverse and intricate shells out of calcium carbonate, organic compounds, or sand or other particles cemented together (University of California Berkeley, 2010d). The shells of foraminifera that live in the water column eventually sink to the bottom, forming soft bottom sediments known as foraminiferan ooze. Foraminifera feed on diatoms and other small organisms. Their predators include copepods and other zooplankton.

Radiolarians are microscopic zooplankton that form shells made of silica. Radiolarian ooze covers large areas of soft bottom habitat on the ocean floor (Pearse et al., 1987; University of California Berkeley, 2010e). Many radiolarian species contain symbiotic dinoflagellates (a type of single-celled organism) or algae. Radiolarians may also trap small particles or other organisms (e.g., diatoms) that drift in the water column.

Ciliates are protozoans with small hair-like extensions that are used for feeding and movement. They are a critical food source for primary consumers and are considered important parasites of many marine invertebrates. Ciliates feed on bacteria and algae, and some species contain symbiotic algae.

3.4.2.3.2 Sponges (Phylum Porifera)

Sponges include approximately 8,550 marine species worldwide and are classified in the Phylum Porifera (Van Soest et al., 2012; World Register of Marine Species Editorial Board, 2015). Sponges are bottom-dwelling, multicellular animals that can be best described as an aggregation of cells that perform different functions. Sponges are largely sessile, and are common throughout the Study Area at all depths. Sponges are typically found on intermediate bottoms (unconsolidated substrate that is mostly gravel or cobble-sized) to hard bottoms, artificial structures, and biotic reefs. Sponges reproduce both sexually and asexually. Water flow through the sponge provides food and oxygen, and removes wastes (Pearse et al., 1987; University of California Berkeley, 2010b). This filtering process is an important coupler of processes that occur in the water column and on the bottom (Perea-Bla´zquez et al., 2012). Many sponges form calcium carbonate or silica spicules or bodies embedded in cells to provide structural support (Castro & Huber, 2000b; Van Soest et al., 2012). Sponges provide homes for a variety of animals including shrimp, crabs, barnacles, worms, brittle stars, sea cucumbers, and other sponges (Colin & Arneson, 1995a). Within the western Atlantic coral reef and related ecosystems, there are 117 genera of sponges (Spalding et al., 2001). Some sponge species are harvested commercially. For example, the sheepswool sponge (*Hippiospongia lachne*) and yellow sponge (*Cleona celata*) are commercially harvested in Florida waters located in the Gulf of Mexico Large Marine Ecosystem (Stevely & Sweat, 2008).

Most sponges do not form reefs because their skeletons do not persist intact after the colony's death. However, the skeletal structure of a few hexactinellid sponge species may form reefs or mounds. Sponge reefs are currently only known off the western coast of Canada. Hexactinellid sponges were documented on bottom features along the shelf break and on Mytilus Seamount in the Northeast U.S. Continental Shelf Large Marine Ecosystem, but reef structures were not reported (Quattrini et al., 2015). Known threats to reef-building sponges are physical strike and disturbance from anthropogenic activities (Whitney et al., 2005).

3.4.2.3.3 Corals, Hydroids, Jellyfish (Phylum Cnidaria)

There are over 10,000 marine species within the phylum Cnidaria worldwide (World Register of Marine Species Editorial Board, 2015), although there is taxonomic uncertainty within some groups (Veron, 2013). Cnidarians are organized into four classes: Anthozoa (corals, sea anemones, sea pens, sea pansies), Hydrozoa (hydroids and hydromedusae), Scyphozoa (true jellyfish), and Cubozoa (box jellyfish, sea wasps). Individuals are characterized by a simple digestive cavity with an exterior mouth surrounded by tentacles. Microscopic stinging capsules known as nematocysts are present (especially in the tentacles) in all cnidarians and are a defining characteristic of the phylum. The majority of species are carnivores that eat zooplankton, small invertebrates, and fishes. However, many species suspension feed on plankton and dissolved organic matter, or contain symbiotic dinoflagellate algae (zooxanthellae) that produce nutrients by photosynthesis (Brusca & Brusca, 2003; Dubinsky & Berman-Frank, 2001; Lough & van Oppen, 2009; National Oceanic and Atmospheric Administration & NOAA's Coral Reef Conservation Program, 2016). Representative predators of cnidarians include sea slugs, snails, crabs, sea stars, coral- and jellyfish-eating fish, and marine turtles. Cnidarians may be solitary or may form colonies.

Cnidarians have many diverse body shapes, but may generally be categorized as one of two basic forms: polyp and medusa. The polyp form is tubular and sessile, attached at one end with the mouth surrounded by tentacles at the free end. Corals and anemones are examples of the polyp form. The medusa form is bell- or umbrella-shaped (e.g., jellyfish), with tentacles typically around the rim. The medusa form generally is pelagic, although there are exceptions. Many species alternate between these two forms during their life cycle. All cnidarian species are capable of sexual reproduction, and many cnidarians also reproduce asexually. The free-swimming larval stage is usually planktonic, but is benthic in some species.

A wide variety of cnidarian species occur throughout the Study Area at all depths and in most habitats, including hard and intermediate shores; soft, intermediate, and hard bottom; aquatic vegetation beds; and artificial substrates. Some cnidarians form biotic habitats that harbor other animals and influence ecological processes, the primary examples being shallow-water and deep-water corals.

ESA-listed coral species are primarily associated with shallow-water coral reefs. In the Study Area, shallow-water coral reefs occur in the southern part of the Gulf of Mexico Large Marine Ecosystem, throughout the Caribbean Sea Large Marine Ecosystem, and in the southern part of the Southeast U.S. Continental Shelf Large Marine Ecosystem, including southeast Florida and the Bahamas (Spalding et al., 2001). In the central and eastern part of the Gulf of Mexico Large Marine Ecosystem, coral reefs occur in the Flower Garden Banks National Marine Sanctuary (not part of the Study Area), Pulley Ridge Ecological Reserve, Dry Tortugas Ecological Reserve, and Florida Keys (Monaco et al., 2008; Spalding et al., 2001; U.S. Department of the Navy, 2007; U.S. Geological Survey, 2013). In the Southeast U.S. Continental Shelf Large Marine Ecosystem, shallow-water coral reefs occur throughout the Florida Keys and southeast Florida (Burke & Maidens, 2004). Reefs also occur in the Caribbean Sea Large Marine Ecosystem surrounding Puerto Rico and the U.S. Virgin Islands. Several Caribbean coral species are listed under the ESA (Sections 3.4.2.2.1, Elkhorn Coral [*Acropora palmata*] to Section 3.4.2.2.7, Rough Cactus Coral [*Mycetophyllia ferox*]).

Corals that are associated with tropical shallow reefs and temperate rocky habitats are vulnerable to a range of threats, including fishing impacts, pollution, erosion/sedimentation, coral harvesting, vessel damage, temperature increase, and climate change. Fishing practices such as blast fishing and trapping may be particularly destructive to coral reefs. In addition, removal of herbivorous fishes may result in overgrowth of coral reefs by algae (DeMartini & Smith, 2015). Corals associated with shallow-water reefs in the Florida Keys and some areas of the Caribbean have been substantially degraded by human activities and other factors. Threats are further discussed in Section 3.4.2.1.4 (General Threats) and in the individual descriptions of ESA-listed coral species. Because corals are slow growing and can survive for hundreds of years (Love et al., 2007; Roberts & Hirshfield, 2003), recovery from damage could take many years. Corals that occur in association with shallow-water coral reefs are protected by Executive Order 13089, Coral Reef Protection, and managed by the Coral Reef Task Force (Executive Order 13089: Coral Reef Protection, 63 *Federal Register* 32701–32703 [June 16, 1998]). The Navy is the DoD representative to the United States Coral Reef Task Force and also carries out the Coral Reef Protection Implementation Plan (Lobel & Lobel, 2000).

Deep-water corals are azooxanthellate (lack symbiotic algae) and thus do not form consolidated biogenic substrate, but rather form mounds of intermediate substrate over hard bottom areas. Deep-water coral taxa in the Study Area include stony corals, black corals, gold corals, gorgonians, true soft corals, sea pens (Pennatulaceans), and calcified hydroids (Stylasterids) (Brooke & Schroeder, 2007; Lutz & Ginsburg, 2007; Packer et al., 2007; Ross & Nizinski, 2007). Up to 24 coral species were identified in various habitats in deep areas (water depths of approximately 500 to 3,000 m) from the Gulf of Maine to Cape Hatteras, North Carolina (Quattrini et al., 2015). However, two species, ivory tree coral and *Lophelia pertusa*, are the most common off the Atlantic coast. Due to their occurrence in areas that lack water temperatures sufficient to support coralline algae (which form the hard consolidated material of biogenic reefs), these corals do not build reef structures but either occur as a layer on hard rocky substrate or form lithoherms.

Ivory tree coral distribution in the Study Area includes the Southeast U.S. Continental Shelf Large Marine Ecosystem and Gulf of Mexico Large Marine Ecosystem at depths of 30 to 150 m, but extensive reefs are known only offshore of the central east coast of Florida (National Oceanic and Atmospheric Administration, 2010a). *Lophelia pertusa* reefs occur throughout the Study Area at depths of 200 to 800 m, with the exception of the West Greenland Shelf Large Marine Ecosystem and the Labrador Current Open Ocean Area (though Freiwald et al. (2004) suggest that this is not a true absence but rather reflects insufficient survey intensity) (National Oceanic and Atmospheric Administration, 2010c; Reed et al., 2006). Although *Lophelia pertusa* is uncommon in the vicinity of the Grand Banks, extensive soft coral gardens occur at depths of 600 to 1,300 m (Murillo et al., 2011). Relative to other parts of the Study Area, *Lophelia pertusa* distribution in the vicinity of Navy training areas of the Jacksonville Range Complex is exceptionally well mapped (U.S. Department of the Navy, 2009). In the Jacksonville Operating Area (OPAREA), deep-water corals are found along the continental slope between 200 and 1,000 m (Reed et al., 2006). Communities of *Lophelia pertusa* have also been found to inhabit substrate at relatively shallow depths of 180 to 250 m off the coast of northeastern Florida in the Jacksonville Range Complex (Ross et al., 2015; U.S. Department of the Navy, 2010a). Deep-water corals are likely absent from the open ocean biogeographic zone due to their occurrence below the aragonite saturation zone (in the case of stony corals) and the scarcity of planktonic food in the abyssal zone (Morris et al., 2013). An exception could be the seamounts located seaward of the Northeast U.S. Continental Shelf Large Marine Ecosystem. The results of habitat suitability modeling of seamounts located in less than 2,500 m water depth and rising at least 1,000 m off the bottom suggest the potential for deep-water corals to occur at seamounts located off the northeast U.S. continental shelf (Tittensor et al., 2009), which is consistent with the observation of corals on Mytilus Seamount in the Northeast U.S. Continental Shelf Large Marine Ecosystem (Quattrini et al., 2015).

The greatest threat to deep-water coral is physical strike and disturbance resulting from human activities. Deep corals are susceptible to physical disturbance due to the branching and fragile growth form of some species, slow growth rate (colonies can be hundreds of years old), and low reproduction and recruitment rates. For example, studies of the of the black coral *Leiopathes glaberrima* in the northern Gulf of Mexico suggest that bathymetry and water circulation patterns could limit larval dispersal and recovery in the event of a large disturbance (Cardona et al., 2016). Fishing activities, particularly trawling, are the primary threats to deep corals (Brooke & Schroeder, 2007; National Oceanic and Atmospheric Administration, 2010a; Packer et al., 2007; Reed et al., 2007; Ross & Nizinski, 2007). It has been estimated that only about 10 percent of ivory tree coral habitat remains intact off Florida's eastern coast, presumably due mostly to trawling (Koenig et al., 2005). Marine debris, including a fishing trap, fishing line, balloon remnants, and ribbon, was observed either lying on or wrapped around deep-sea corals (Quattrini et al., 2015). Other potential human-caused threats to deep-water corals include hydrocarbon exploration and extraction, petroleum contamination, cable and pipeline installation, and other various bottom-disturbing activities (Brooke & Schroeder, 2007; Chuenpagdee et al., 2003; Packer et al., 2007; Parrish & Baco, 2007; Ross & Nizinski, 2007). Natural threats consist of sedimentation and bioerosion of the substrate.

3.4.2.3.4 Flatworms (Phylum Platyhelminthes)

Flatworms include between 12,000 and 20,000 marine species worldwide (World Register of Marine Species Editorial Board, 2015) and are the simplest form of marine worm (Castro & Huber, 2000b). The largest single group of flatworms are parasites commonly found in fishes, seabirds, and marine mammals (Castro & Huber, 2000b; University of California Berkeley, 2010c). The life history of parasitic flatworms plays a role in the regulation of populations of the marine vertebrates they inhabit. Ingestion by the host organism is the primary dispersal method for parasitic flatworms. Parasitic forms are not typically found in the water column outside of a host organism. The remaining groups are non-parasitic carnivores, living without a host. A large number of flatworm species from numerous families are found in various habitats throughout the Study Area. Several species of wrasses and other reef fish prey on flatworms (Castro & Huber, 2000a, 2000b).

3.4.2.3.5 Ribbon Worms (Phylum Nemertea)

Ribbon worms include over 1,300 marine species worldwide (World Register of Marine Species Editorial Board, 2015). Ribbon worms, with their distinct gut and mouth parts, are more complex than flatworms (Castro & Huber, 2000b). A unique feature of ribbon worms is the extendable proboscis (an elongated, tubular mouth part), which can be ejected to capture prey, to aid in movement, or for defense (Brusca & Brusca, 2003). Most ribbon worms are active, bottom-dwelling predators of small invertebrates such as annelid worms and crustaceans (Brusca & Brusca, 2003; Castro & Huber, 2000a). Some are scavengers or symbiotic (parasites or commensals). Some ribbon worms are pelagic, with approximately 100 pelagic species identified from all oceans (Roe & Norenburg, 1999). Pelagic species generally drift or slowly swim by undulating the body. Ribbon worms exhibit a variety of reproductive strategies, including direct development with juveniles hatching from egg cases and indirect development from planktonic larvae

(Brusca & Brusca, 2003). In addition, many species are capable of asexual budding or regeneration from body fragments. Ribbon worms have a relatively small number of predators, including some birds, fishes, crabs, molluscs, squid, and other ribbon worms (McDermott, 2001). Ribbon worms are found throughout the Study Area. They occur in most marine environments, although usually in low abundances. They occur in embayments; soft, intermediate, and rocky shores and subtidal habitats of coastal waters; and deep-sea habitats. Some are associated with biotic habitats such as mussel clumps, coral reefs, kelp holdfasts, seagrass beds, and worm burrows (Thiel & Kruse, 2001). Approximately 50 species of ribbon worms are known along the Atlantic coast of North America (Encyclopedia of Life, 2017), and 24 species are known from Florida and the Virgin Islands (Aguilar, 2009; Correa, 1961). Approximately 40 species of nemerteans occur in the Gulf of Mexico (Norenburg, 2009).

3.4.2.3.6 Round Worms (Phylum Nematoda)

Round worms include over 7,000 marine species (World Register of Marine Species Editorial Board, 2015). Round worms are small and cylindrical, are abundant in sediment habitats such as soft to intermediate shores and soft to intermediate bottoms, and can also be found in host organisms as parasites (Castro & Huber, 2000b). Round worms are some of the most widespread marine invertebrates, with population densities of up to 1 million or more organisms per square meter of sediment (Levinton, 2009). This group has a variety of food preferences, including algae, small invertebrates, annelid worms, and organic material from sediment. Like parasitic flatworms, parasitic nematodes play a role in regulating populations of other marine organisms by causing illness or mortality. Species in the family Anisakidae infect marine fish, and may cause illness in humans if fish are consumed raw without proper precautions (Castro & Huber, 2000b). Round worms are found throughout the Study Area.

3.4.2.3.7 Segmented Worms (Phylum Annelida)

Segmented worms include approximately 12,000 marine species worldwide in the phylum Annelida, although most marine forms are in the class Polychaeta (World Register of Marine Species Editorial Board, 2015). Polychaetes are the most complex group of marine worms, with a well-developed respiratory and gastrointestinal system (Castro & Huber, 2000b). Different species of segmented worms may be highly mobile or burrow in the bottom (soft to intermediate shore or bottom habitats) (Castro & Huber, 2000a). Polychaete worms exhibit a variety of life styles and feeding strategies, and may be predators, scavengers, deposit-feeders, filter-feeders, or suspension feeders (Jumars et al., 2014). The variety of feeding strategies and close connection to the bottom make annelids an integral part of the marine food web (Levinton, 2009). Burrowing and agitating the sediment increases the oxygen content of bottom sediments and makes important buried nutrients available to other organisms. This allows bacteria and other organisms, which are also an important part of the food web, to flourish on the bottom. Benthic polychaetes also vary in their mobility, including sessile attached or tube-dwelling worms, sediment burrowing worms, and mobile surface or subsurface worms. Some polychaetes are commensal or parasitic. Many polychaetes have planktonic larvae.

Polychaetes are found throughout the Study Area inhabiting rocky, sandy, and muddy areas of the bottom, vegetated habitats, and artificial substrates. Some are associated with biotic habitats such as mussel clumps, coral reefs, and worm burrows. Some species of worms build rigid (e.g., *Diopatra* spp.) or sand-encrusted (*Phragmatapoma* spp.) tubes, and aggregations of these tubes form a structural habitat. Giant tube worms (*Riftia pachyptila*) are chemosynthetic (using a primary production process without sunlight) reef-forming worms living on hydrothermal vents of the abyssal oceans. Their distribution is poorly known in the Study Area, although hydrothermal vents are more likely to occur in association with seamounts and the Mid-Atlantic Ridge.

The reef-building tube worm (*Phragmatopoma caudata*, synonymous with *P. lapidosa*) constructs shallow-water worm reefs in some portions of the Study Area (Read & Fauchald, 2012). Large pseudocolonies of worms (formed from large numbers of individual larvae that settle in close proximity and undergo fusion to form complex habitats) develop relatively smooth mounds up to 2 m high (Zale & Merrifield, 1989). In the Study Area, the species is particularly common in the Southeastern U.S. Continental Shelf Large Marine Ecosystem along Florida's east coast, at depths up to 2 m; however, colonies are found infrequently to depths of 100 m in areas with strong currents (South Atlantic Fishery Management Council, 1998; Zale & Merrifield, 1989).

3.4.2.3.8 Bryozoans (Phylum Bryozoa)

Bryozoans include approximately 6,000 marine species worldwide (World Register of Marine Species Editorial Board, 2015). They are small box-like, colony-forming animals that make up the "lace corals." Colonies can be encrusting, branching, or free-living. Bryozoans may form habitat similar in complexity to sponges (Buhl-Mortensen et al., 2010). Bryozoans attach to a variety of surfaces, including intermediate and hard bottom, artificial structures, and algae, and feed on particles suspended in the water (Hoover, 1998b; Pearse et al., 1987; University of California Berkeley, 2010a). Bryozoans are of economic importance for bioprospecting (the search for organisms for potential commercial use in pharmaceuticals). As common biofouling organisms, bryozoans also interfere with boat operations and clog industrial water intakes and conduits (Hoover, 1998b; Western Pacific Regional Fishery Management Council, 2001). Bryozoans occur throughout the Study Area but are not expected at depths beyond the continental slope (Ryland & Hayward, 1991). Habitat-forming species are most common on temperate continental shelves with relatively strong currents (Wood et al., 2012).

3.4.2.3.9 Squid, Bivalves, Sea Snails, Chitons (Phylum Mollusca)

The phylum Mollusca includes approximately 45,000 marine species worldwide (World Register of Marine Species Editorial Board, 2015). These organisms occur throughout the Study Area, including open ocean areas, at all depths. Sea snails and slugs (gastropods), clams and mussels (bivalves), chitons (polyplacophorans), and octopus and squid (cephalopods) are examples of common molluscs in the Study Area. Snails and slugs occur in a variety of soft, intermediate, hard, and biogenic habitats. Chitons are typically found on hard bottom and artificial structures from the intertidal to littoral zone but may also be found in deeper water and on substrates such as aquatic plants. Many molluscs possess a muscular organ called a foot, which is used for mobility. Many molluscs also secrete an external shell (Castro & Huber, 2000b), although some molluscs have an internal shell or no shell at all (National Oceanic and Atmospheric Administration, 2015). Sea snails and slugs eat fleshy algae and a variety of invertebrates, including hydroids, sponges, sea urchins, worms, other snails, and small crustaceans, as well as detritus (Castro & Huber, 2000b; Colin & Arneson, 1995b; Hoover, 1998c). Clams, mussels, and other bivalves are filter feeders, ingesting suspended food particles (e.g., phytoplankton, detritus) (Castro & Huber, 2000b). Chitons, sea snails, and slugs use rasping tongues, known as radula, to scrape food (e.g., algae) off rocks or other hard surfaces (Castro & Huber, 2000a; Colin & Arneson, 1995b). Squid and octopus are active swimmers at all depths and use a beak to prey on a variety of organisms including fish, shrimp, and other invertebrates (Castro & Huber, 2000b; Hoover, 1998c; Western Pacific Regional Fishery Management Council, 2001). Octopuses mostly prey on fish, shrimp, eels, and crabs (Wood & Day, 2005).

Important commercial, ecological, and recreational species of molluscs in the Study Area include: Atlantic scallop (*Placopecten megallanicus*), Atlantic surfclam (*Spisula solidissima*), ocean quahog (*Arctica islandica*), and several squid species (Mid-Atlantic Fishery Management Council, 2016; New England Fishery Management Council, 2013; Voss & Brakoniecki, 1985). Some mollusc species, principally bivalves, are habitat-forming organisms, forming sedentary invertebrate beds and biotic reefs. Examples include mussels of the genus *Mytilus*, found in intertidal areas, and the genus *Bathymodiolus*, which occur at deep-sea hydrothermal vents. Oysters in general, and principally the eastern oyster (*Crassostrea virginica*), may form extensive reefs, or beds, in estuarine waters of the Atlantic Ocean and Gulf of Mexico. Oyster reefs are highly productive habitats in inter-tidal or shallow subtidal ecosystems, providing many of the same habitat values as coral reefs.

3.4.2.3.10 Shrimp, Crab, Lobster, Barnacles, Copepods (Phylum Arthropoda)

Shrimp, crabs, lobsters, barnacles, and copepods are animals with an exoskeleton, which is a skeleton on the outside of the body (Castro & Huber, 2000b), and are classified as crustaceans in the Phylum Arthropoda. The exoskeletons are made of a polymer called chitin, similar to cellulose in plants, to which the animals add other compounds to achieve flexibility or hardness. There are over 57,000 marine arthropod species, with about 53,000 of these belonging to the subphylum Crustacea (World Register of Marine Species Editorial Board, 2015). These organisms occur throughout the Study Area at all depths. Crustaceans may be carnivores, omnivores, predators, or scavengers, preying on molluscs (primarily gastropods), other crustaceans, echinoderms, small fishes, algae, and seagrass (Waikiki Aquarium, 2009a, 2009b; Waikiki Aquarium & University of Hawaii-Manoa, 2009; Western Pacific Regional Fishery Management Council, 2009). Barnacles and some copepods are filter feeders, extracting algae and small organisms from the water (Levinton, 2009). Copepods may also be parasitic, affecting most phyla of marine animals (Walter & Boxshall, 2017). As a group, arthropods occur in a wide variety of habitats. Shrimp, crabs, lobsters, and copepods may be associated with soft to hard substrates, artificial structures, and biogenic habitats. Barnacles inhabit hard and artificial substrates.

Important commercial, ecological, and recreational species of the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico include various crab species (e.g., red crab [*Chaceon quinquedens*] and golden crab [*Chaceon fenneri*]), shrimp species (e.g., white shrimp [*Litopenaeus setiferus*] and royal red shrimp [*Pleoticus robustus*], and spiny lobster (*Panulirus argus*) (Gulf of Mexico Fishery Management Council, 2015; New England Fishery Management Council, 2010; South Atlantic Fishery Management Council, 2016). The American lobster (*Homarus americanus*) is a commercially and recreationally important crustacean that has increased dramatically in population due, in part, to successful fishery management (National Marine Fisheries Service, 2012).

3.4.2.3.11 Sea Stars, Sea Urchins, Sea Cucumbers (Phylum Echinodermata)

Organisms in this phylum include over 7,000 marine species, such as sea stars, sea urchins, and sea cucumbers (World Register of Marine Species Editorial Board, 2015). Asteroids (e.g., sea stars), echinoids (e.g., sea urchins), holothuroids (e.g., sea cucumbers), ophiuroids (e.g., brittle stars and basket stars), and crinoids (e.g., feather stars and sea lilies) are symmetrical around the center axis of the body (Mah & Blake, 2012). Echinoderms occur at all depth ranges from the intertidal zone to the abyssal zone and are almost exclusively benthic, potentially found on all substrates and structures. Most echinoderms have separate sexes, but a few species of sea stars, sea cucumbers, and brittle stars have both male and female reproductive structures. Many species have external fertilization, releasing gametes into the water to produce planktonic larvae, but some brood their eggs and release free-swimming larvae (Mah & Blake, 2012; McMurray et al., 2012). Many echinoderms are either scavengers or predators on sessile organisms such as algae, stony corals, sponges, clams, and oysters. Some species, however, filter food particles from sand, mud, or water (Hoover, 1998a). Predators of echinoderms include a variety of fish species (e.g., triggerfish, eels, rays, sharks), crabs, shrimps, octopuses, birds, and other echinoderms (sea stars).

Echinoderms are found throughout the Study Area. An important commercial echinoderm species in the Northeast U.S. Continental Shelf Large Marine Ecosystem is the green sea urchin (*Strongylocentrotus drobachiensis*) (Maine Department of Marine Resources, 2010), although this species is not federally managed.

3.4.3 Environmental Consequences

This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact invertebrates known to occur within the Study Area. Table 2.6-1 (Proposed Training Activities per Alternative) through Table 2.6-4 (Office of Naval Research Proposed Testing Activities per Alternative) present the proposed training and testing activity locations for each alternative (including number of activities). General characteristics of all Navy stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis), and living resources' general susceptibilities to stressors were introduced in Section 3.0.3.6 (Biological Resource Methods). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors analyzed for invertebrates are:

- **Acoustics** (sonar and other transducers; air guns; pile driving; vessel noise; weapons noise)
- **Explosives**
- **Energy** (in-water electromagnetic devices; high-energy lasers)
- **Physical disturbance and strikes** (vessels and in-water devices; military expended materials; seafloor devices; pile driving)
- **Entanglement** (wires and cables; decelerators/parachutes; biodegradable polymers)
- **Ingestion** (military expended materials - munitions; military expended materials other than munitions)
- **Secondary stressors** (impacts to habitat; impacts to prey availability)

The analysis includes consideration of the mitigation that the Navy will implement to avoid potential impacts on invertebrates from explosives, and physical disturbance and strikes. Mitigation for invertebrates will be coordinated with NMFS through the ESA consultation process.

3.4.3.1 Acoustic Stressors

Assessing whether sounds may disturb or injure an animal involves understanding the characteristics of the acoustic sources, the animals that may be near the sound, and the effects that sound may have on the physiology and behavior of those animals. Marine invertebrates are likely only sensitive to water particle motion caused by nearby low-frequency sources, and likely do not sense distant or mid- and high-frequency sounds (Section 3.4.2.1.3, Sound Sensing and Production). Compared to some other taxa of marine animals (e.g., fishes, marine mammals), little information is available on the potential impacts on marine invertebrates from exposure to sonar and other sound-producing activities (Hawkins et al., 2015). Historically, many studies focused on squid or crustaceans and the consequences of exposures to broadband impulsive air guns typically used for oil and gas exploration. More recent investigations have included additional taxa (e.g., molluscs) and sources, although extensive information is not available for all potential stressors and impact categories. The following Background sections discuss the currently available information on acoustic effects to marine invertebrates. These effects range from physical injury to behavioral or stress response. Aspects of acoustic stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities).

3.4.3.1.1 Background

A summary of available information related to each type of effect is presented in the following sections. Some researchers discuss effects in terms of the acoustic near field and far field. The near field is an area near a sound source where considerable interference between sound waves emerging from different parts of the source is present. Amplitude may vary widely at different points within this acoustically complex zone, and sound pressure and particle velocity are generally out of phase. The far field is the distance beyond which sound pressure and particle velocity are in phase, all sound waves appear to originate from a single point, and pressure levels decrease predictably with distance. The boundary between the near and far field is frequency-dependent, with the near field extending further at lower frequencies. It has been estimated that the near field for a sound of 500 Hz (intensity not specified) would extend about 3 m from the source (Myberg, 2001).

3.4.3.1.1.1 Injury

Injury refers to the direct effects on the tissues or organs of an animal due to exposure to pressure waves or particle motion. Available information on injury to invertebrates resulting from acoustic sources pertains mostly to damage to the statocyst, an organ sensitive to water particle motion and responsible for balance and orientation in some invertebrates. A few studies have also investigated effects to appendages and other organs.

Researchers have investigated the effects of American lobsters exposed to air gun firings in an aquarium and in the field (Payne et al., 2007). Lobsters in the aquarium were placed about 3.5 m from the air guns and exposed to sound levels of about 200 dB (peak-to-peak). Caged lobsters in the field were located 2 m from the air guns and were exposed to higher-intensity sound levels (about 230 dB peak-to-peak). No physical damage to appendages and no effects on balance or orientation (indicating no damage to statocysts) were observed in any lobsters. No visible evidence of damage to hepatopancreata (digestive glands) or ovaries were found. Caged snow crabs (*Chionoecetes opilio*) were exposed to repeated air gun firings in the field (Christian et al., 2003). Crabs exposed to a single air gun were placed at depths of 2 to 15 m, while crabs exposed to air gun arrays were placed at depths of 4 to 170 m. Air guns were fired during multiple sessions, with each session consisting of a firing every 10 seconds for 33 minutes. Peak received levels were up to 207 dB re 1 μPa and 187 decibels referenced to 1 squared micropascal (dB re 1 $μPa^2$) (single gun), and 237 dB re 1 μPa and 175 dB re 1 $μPa^2$ (array). Post-experimental examination showed no physical damage to statocycts, hepatopancreata, heart muscle or surrounding tissue, carapace, or appendages. As a comparison, air guns operated at full capacity during Navy activities would produce a SPL of approximately 206 dB re 1 μPa rms and a sound exposure level (SEL) of 185 to 196 dB re 1 $μPa^2$-s at a distance 1 m from the air gun. Air guns are also operated at less than full capacity, decreasing the sound levels produced.

In three instances, seismic air gun use has been hypothesized as the cause of giant squid strandings. This was based on the proximity in time and space of the squid and operating seismic vessels and, in two of the events, to physical injuries considered consistent with exposure to impulsive acoustic waves (Guerra et al., 2004; Guerra & Gonzales, 2006; Leite et al., 2016). However, because the animals were not observed at the time of potential impact, the cause of the injuries and strandings cannot be stated conclusively.

Physiological studies of wild captured cephalopods found progressive damage to statocysts in squid and octopus species after exposure to 2 hours of low frequency (50 to 400 Hz) sweeps (100 percent duty cycle) at SPL of 157 to 175 dB re 1 µPa (André et al., 2011; Sole et al., 2013). It is noted that the animals were in the near field (distance was not specified in the report, but animals were likely within a few to several feet of the sound source based on the experiment description) where there is significant particle motion. In a similar experiment designed to control for possible confounding effects of experimental tank walls, common cuttlefish (*Sepia officinalis*) were exposed to 2 hours of low-frequency sweeps (100 to 400 Hz; 100 percent duty cycle with a 1-second sweep period) in an offshore environment (Sole et al., 2017) (Sole et al., 2017). Sounds were produced by a transducer located near the surface, and caged experimental animals were placed at depths between 7 and 17 m. Received sound levels ranged from 139 to 142 dB re 1 µPa^2. Maximum particle motion of 0.7 meter per squared second was recorded at the cage nearest the transducer (7.1 m between source and cage). Progressive damage to sensory hair cells of the statocycts were found immediately after and 48 hours after sound exposure, with the severity of effects being proportional to distance from the transducer. The authors suggest that whole-body vibrations resulting from particle motion were transmitted to the statocysts, causing damage to the structures. Statocyst damage was also found in captive individuals of two jellyfish species (Mediterranean jellyfish [*Cotylorhiza tuberculata*] and barrel jellyfish [*Rhizostoma pulmo*]) under the same exposure parameters (50 to 400 Hz sweeps; 2 hour exposure time; 100 percent duty cycle with a 1-secong sweep period; approximately 157 to 175 dB re 1 µPa received SPL) (Sole et al., 2016). In the context of overall invertebrate population numbers, most animals exposed to similar sound levels during Navy activities would be in the far field, and exposure duration would be substantially less than 2 hours.

This limited information suggests that the potential for statocyst damage may differ according to the type of sound (impulsive or continuous) or among invertebrate taxa (e.g., crustaceans and cephalopods). Therefore, a definitive statement on potential impacts to invertebrates in general is unsupported. Although invertebrate occurrence varies based on location, depth, season, and time of day (for example, the rising of the deep scattering layer which contains numerous invertebrate taxa), individuals could be present in the vicinity of impulsive or non-impulsive sounds produced by Navy activities. Estimation of invertebrate abundance at any particular location would generally not be feasible, but there is a general pattern of higher abundances in relatively productive estuarine and nearshore waters. The number of individuals affected would be influenced by sound sensing capabilities. As discussed in Section 3.4.2.1.3 (Sound Sensing and Production), invertebrate acoustic sensing is probably limited to the particle motion component of sound. Water particle motion is most detectable near a sound source and at lower frequencies, which likely limits the range at which invertebrates can detect sound.

3.4.3.1.1.2 Physiological Stress

Stress response consists of one or more physiological changes (e.g., production of certain hormones) that help an organism cope with a stressor. However, if the magnitude or duration of the stress response is too great or too prolonged, there can be negative consequences to the organism. Physiological stress is typically evaluated by measuring the levels of relevant biochemicals.

The results of two investigations of physiological stress in adult invertebrates caused by impulsive noise varied by species. Some biochemical stress markers and changes in osmoregulation were observed in American lobsters exposed to air gun firings at distances of approximately 2 to 4 m from the source (Payne et al., 2007). Increased deposits of carbohydrates suggesting possible stress response were noted in digestive gland cells 4 months after exposure. Conversely, repeated air gun exposures caused no changes in biochemical stress markers in snow crabs located from 2 to 170 m from the source (Christian et al., 2003).

Several investigations of physiological reactions of captive adult invertebrates exposed to boat noise playback and other continuous noise have been conducted. Continuous exposure to boat noise playback resulted in changes to some biochemical levels indicating stress in common prawns (*Palaemon serratus*, Pennant 1777) (30 minutes exposure to sound levels of 100 to 140 dB re 1 µPa rms) and European spiny lobsters (30 minutes exposure to sound levels up to 125 dB re 1µPa rms) (Celi et al., 2015; Filiciotto et al., 2014; Filiciotto et al., 2016). Increased oxygen consumption, potentially indicating stress, was found in shore crabs exposed to ship-noise playback of 148 to 155 dB re 1 µPa for 15 minutes (Wale et al., 2013b). Red swamp crayfish (*Procambarus clarkii*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 25 kHz, peak amplitude of 148 dB rms at 12 kHz) showed changes in some biochemical levels indicating stress (Celi et al., 2013). Captive sand shrimp (*Crangon crangon*) exposed to low-frequency noise (30 to 40 dB above ambient) continuously for 3 months demonstrated decreases in growth rate and reproductive rate (Lagardère, 1982).

In addition to experiments on adult invertebrates, some studies have investigated the effects of impulsive and non-impulsive noise (air guns, boat noise, turbine noise) on invertebrate eggs and larvae. Data on similar effects resulting from sonar are currently unavailable. Developmental delays and body malformations were reported in New Zealand scallop (*Pecten novaezelandiae*) larvae exposed to seismic air gun playbacks at frequencies of 20 Hz to 22 kHz with SPL of 160 to 164 dB re 1 µPa (Aguilar de Soto et al., 2013). Although uncertain, the authors suggested physiological stress as the cause of the effects. Larvae in the relatively small (2 m diameter) experimental tank were considered close enough to the acoustic source to experience particle motion, which would be unlikely at the same pressure levels in the far field. Playbacks occurred once every 3 seconds and the larvae were periodically examined over the course of 90 hours. Snow crab (*Chionoecetes opilio*) eggs located in 2 m water depth and exposed to repeated firings of a seismic air gun (peak received SPL was 201 dB re 1 µPa) had slightly increased mortality and apparent delayed development (Christian et al., 2003). However, dungeness crab (*Metacarcinus magister*) zoeae were not affected by repeated exposures to an air gun array (maximum distance of about 62 ft. slant distance) (Pearson et al., 1994), and exposure of southern rock lobster (*Jasus edwardsii*) eggs to air gun SELs of up to 182 dB re 1 μPa^2-s did not result in embryonic developmental effects (Day et al., 2016). An investigation of the effects of boat noise playback on the sea hare (*Stylocheilus striatus*) found reduced embryo development and increased larvae mortality, but no effect on the rate of embryo development (Nedelec et al., 2014). Specimens were exposed to boat-noise playback for 45 seconds every 5 minutes over a 12-hour period. Continuous playback of simulated underwater tidal and wind turbine sounds resulted in delayed metamorphosis in estuarine crab larvae (*Austrohelice crassa* and *Hemigrapsus crenulatus*) that were observed for up to about 200 hours (Pine et al., 2016).

Overall, the results of these studies indicate the potential for physiological effects in some (but not all) adult invertebrates exposed to air guns near the source (about 2 to 4 m) and to boat and other continuous noise for durations of 15 to 30 minutes or longer. Larvae and egg development effects were reported for impulsive (distance from source of about 2 m) and non-impulsive noise exposures of extended duration (intermittently or continuously for several to many hours) and for air gun playback and field exposure, although air gun noise had no effect in one study. Exposure to continuous noise such as vessel operation during Navy training or testing events would generally occur over a shorter duration and sound sources would be more distant. Adverse effects resulting from short exposure times have not been shown experimentally. A range to effects was not systematically investigated for air gun use. Experiments using playback of air gun and boat noise were conducted in relatively small tanks where particle motion (which decreases rapidly with distance) could have been significant. Marine invertebrate egg and larval abundance is high relative to the number of adults, and eggs and larvae are typically subject to high natural mortality rates. These factors decrease the likelihood of population-level effects resulting from impacts to eggs and larvae.

3.4.3.1.1.3 Masking

Masking occurs when one sound interferes with the detection or recognition of another sound. Masking can limit the distance over which an organism can communicate or detect biologically relevant sounds. Masking can also potentially lead to behavioral changes.

Comparatively little is known about how marine invertebrates use sound in their environment. Some studies show that crab, lobster, oyster, and coral larvae and post-larvae may use nearby reef sounds when in their settlement phase. Orientation and movement toward reef sounds was found in larvae located at 60 to 80 m from a sound source in open water, and in experimental tanks (distance from the sound source was about 150 cm in one laboratory study) (Radford et al., 2007; Stanley et al., 2010; Vermeij et al., 2010). The component of reef sound used is generally unknown, but an investigation found that low frequency sounds (200 to 1,000 Hz) produced by fish at dawn and dusk on a coral reef were the most likely sounds to be detectable a short distance from the reef (Foster et al., 2012) (Kaplan & Mooney, 2016). Similarly, lobed star coral larvae were found to have increased settlement on reef areas with elevated sound levels, particularly in the frequency range of 25 to 1,000 Hz (Lillis et al., 2016). Mountainous star coral larvae in their settlement phase were found to orient toward playbacks of reef sounds in an experimental setup, where received sound levels were about 145 to 149 dB re 1 µPa and particle acceleration was about 9×10^{-8} meters per second (Vermeij et al., 2010). Playback speakers were located approximately 1 to 2 m from the larvae, although the authors suggest marine invertebrates may also use sound to communicate and avoid predators (Popper et al., 2001). Crabs (*Panopeus* species) exposed to playback of predatory fish vocalizations reduced foraging activity, presumably to avoid predation risk (Hughes et al., 2014). The authors suggest that, due to lack of sensitivity to sound pressure, crabs are most likely to detect fish sounds when the fish are nearby. Anthropogenic sounds could mask important acoustic cues such as detection of settlement cues or predators, and potentially affect larval settlement patterns or survivability in highly modified acoustic environments (Simpson et al., 2011). Low-frequency sounds could interfere with perception of low-frequency rasps or rumbles among crustaceans, particularly when conspecific sounds are produced at the far end of the hearing radius. Navy activities occurring relatively far from shore would produce transient sounds potentially resulting in only intermittent, short-term masking, and would be unlikely to impact the same individuals within a short time. Training and testing activities would generally not occur at known reef sites within the probable reef detection range of larvae. Impacts could be more likely in locations where anthropogenic noise occurs frequently within the perceptive range of invertebrates (e.g., pierside locations in estuaries). There are likely many other non-Navy noise sources present in such areas.

3.4.3.1.1.4 Behavioral Reactions

Behavioral reactions refer to alterations of natural behaviors due to exposure to sound. Most investigations involving invertebrate behavioral reactions have been conducted in relation to air gun use, pile driving, and vessel noise. Studies of air gun impacts on marine invertebrates have typically been conducted with equipment used for seismic exploration, and the limited results suggest responses may vary among taxa (crustaceans and cephalopods). Snow crabs placed 48 m below a seismic air gun array did not react behaviorally to repeated firings (peak received SPL was 201 dB re 1 µPa) (Christian et al., 2003). Studies of commercial catch of rock lobsters (*Panulirus cygnus*) and multiple shrimp species in the vicinity of seismic prospecting showed no long-term adverse effects to catch yields, implying no detectable long-term impacts on abundance from intermittent anthropogenic sound exposure over long periods (Andriguetto-Filho et al., 2005; Parry & Gason, 2006). Conversely, squid have exhibited various behavioral reactions when exposed to impulsive noise such as air gun firing (McCauley et al., 2000a; McCauley et al., 2000b). Some squid showed strong startle responses, including inking, when exposed to the first shot of broadband sound from a nearby seismic air gun (received SEL of 174 dB re 1 µPa rms). Strong startle response was not seen when sounds were gradually increased, but the squid exhibited alarm responses at levels above 156 dB re 1 µPa rms (McCauley et al., 2000a; McCauley et al., 2000b). Southern reef squids (*Sepioteuthis australis*) exposed to air gun noise displayed alarm responses at levels above 147 dB re 1 μPa^2-s (Fewtrell & McCauley, 2012).

Pile driving produces sound pressure that moves through the water column and into the substrate, which may therefore affect pelagic and benthic invertebrates. Impact pile driving produces a repetitive impulsive sound, while vibratory pile extraction produces a nearly continuous sound at a lower source level. Although few investigations have been conducted regarding impacts to invertebrates resulting from impact pile driving and extraction, the effects are likely similar to those resulting from other impulsive and vibrational (e.g., drilling) sources. When an underwater sound encounters the substrate, particle motion can be generated, resulting in vibration. Invertebrates may detect and respond to such vibrations. Playback of impact pile driving sound (137 to 152 dB re 1 µPa peak to peak) in the water column near chorusing snapping shrimp resulted in an increase in the snap number and amplitude (Spiga, 2016). When exposed to playback of broadband impulsive pile driving sound of 150 dB SEL, Japanese carpet shell clams (*Ruditapes philippinarum*) exhibited reduced activity and valve closing, while Norway lobsters (*Nephrops norvegicus*) repressed burying, bioirrigation, and locomotion activity (Solan et al., 2016). Brittlestars (*Amphiura filiformis*) included in the experiment exhibited no overall statistically detectable behavioral changes, although the authors note that a number of individuals exhibited changes in the amount of sediment reworking activity. Invertebrates exposed to vibrations of 5 to 410 Hz (which is a proxy for the effects of vibratory pile removal) at various particle acceleration amplitudes in the substrate of a holding tank for 8-second intervals exhibited behavioral reactions ranging from valve closure (common mussel [*Mytilus edulis*]) to antennae sweeping, changes in locomotion, and exiting the shell (common hermit crab [*Pagurus bernhardus*]) (Roberts et al., 2015; Roberts et al., 2016). Sensitivity was greatest at 10 Hz and at particle acceleration of 0.1 meter per squared second. The authors analyzed data on substrate acceleration produced by pile driving in a river and found levels that would be detectable by the hermit crabs at 17 and 34 m from the source. Measurements were not available for other distances or in marine environments. Similarly, underwater construction-related detonations of about 14-pound (lb.) charge weight (presumably in fresh water) resulted in substrate vibrations 297 m from the source that would likely be detected by crabs.

Common prawns and European spiny lobsters exposed to 30 minutes of boat noise playback in frequencies of 200 Hz to 3 kHz (sound levels of approximately 100 to 140 dB SPL [prawns] and 75 to 125 dB SPL [lobsters]) showed behavioral responses including changes in movement velocity, and distance moved, as well as time spent inside a shelter (Filiciotto et al., 2014; Filiciotto et al., 2016). Common cuttlefish exposed to playback of underwater ferry engine noise for 3.5 minutes (maximum sound level of about 140 dB re 1 µPa SPL) changed color more frequently, swam more, and raised their tentacles more often than control specimens or individuals exposed to playback of wave sounds (Kunc et al., 2014). Shore crabs (*Carcinus maenas*) exposed to ship noise playback did not exhibit changes in the ability or time required to find food, but feeding was often suspended during the playback (Wale et al., 2013a). Japanese carpet shell clams and Norway lobsters exposed to playback of ship noise for 7 days at received levels of 135 to 140 dB re 1 µPa exhibited reactions such as reduced activity, movement, and valve closing (Solan et al., 2016). Brittlestars (*A. filiformis*) included in the study showed no overall statistically detectable behavioral changes, although individual animals were affected. Antarctic krill (*Euphausia superba*) did not respond to a research vessel approaching at 2.7 knots (source level below 150 dB re 1 µPa) (Brierley et al., 2003).

A limited number of studies have investigated behavioral reactions to non-impulsive noise other than that produced by vessels. Red swamp crayfish (*Procambarus clarkii*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 25 kHz, peak amplitude of 148 dB rms at 12 kHz) exhibited changes in social behaviors (Celi et al., 2013). Caribbean hermit crabs (*Coenobita clypeatus*) delayed reaction to an approaching visual threat when exposed to continuous noise (Chan et al., 2010a; Chan et al., 2010b). The delay potentially put them at increased risk of predation, although the studies did not address possible simultaneous distraction of predators.

The results of these studies indicate that invertebrates of at least some taxa would respond behaviorally to various levels of sound and substrate vibration produced within their detection capability. Comprehensive investigations of the range to effects of different sound and vibration sources and levels are not available. However, sound source levels for Navy pile diving and air gun use are within the range of received levels that have caused behavioral effects in some species. Analysis of pile driving noise for a previous Elevated Causeway System training event found that a sound level of 150 dB SEL, a level found to cause behavioral reactions in clams and lobsters (Solan et al., 2016), extended 3.4 km from the source. The low-frequency component of vessel noise would likely be detected by some invertebrates, although the number of individuals affected would be limited to those near enough to a source to experience particle motion.

3.4.3.1.2 Impacts from Sonar and Other Transducers

Many non-impulsive sounds associated with training and testing activities would be produced by sonar. Other transducers include items such as acoustic projectors and countermeasure devices. Most marine invertebrates do not have the capability to sense sound pressure; however, some are sensitive to nearby low-frequency sounds, such as could be approximated by some low-frequency sonars. As described in Section 3.4.2.1.3 (Sound Sensing and Production), invertebrate species detect sound through particle motion, which diminishes rapidly from the sound source. Therefore, the distance at which they may detect a sound is probably limited. Most activities using sonar or other transducers would be conducted in deep-water, offshore areas of the Study Area and are not likely to affect most benthic invertebrate species (including ESA-listed coral species), although invertebrates in the water column could be affected. However, portions of the range complexes and testing ranges overlap nearshore waters of the continental shelf, and it is possible that sonar and other transducers could be used and affect benthic invertebrates in these areas. Sonar is also used in shallow water during pierside testing and maintenance testing.

Invertebrate species generally have their greatest sensitivity to sound below 1 to 3 kHz (Kunc et al., 2016) and would therefore not be capable of detecting mid- or high-frequency sounds, including the majority of sonars, or distant sounds in the Study Area. Studies of the effects of continuous noise such as boat noise, acoustic sweeps, and tidal/wind turbine sound (information specific to sonar use was not available) on invertebrates have found statocyst damage, elevated levels of biochemicals indicative of stress, changes in larval development, masking, and behavioral reactions under experimental conditions (see Section 3.4.3.1.1, Background). Noise exposure in the studies generally lasted from a few minutes to 30 minutes. The direct applicability of these results is uncertain because the duration of sound exposure in many of the studies is greater than that expected to occur during Navy activities, and factors such as environmental conditions (captive versus wild conditions) may affect individual responses (Celi et al., 2013). Individuals of species potentially susceptible to statocyst damage (e.g., some cephalopods) could be physically affected by nearby noise. Available research has shown statocyst damage to occur after relatively long-duration exposures (2 hours), which would be unlikely to occur to individual invertebrates due to transiting sources and potential invertebrate movement. An exception is pierside sonar testing and maintenance testing, where invertebrates (particularly sessile or slow-moving taxa such as bivalve molluscs, hydroids, and marine worms) could be exposed to sound for longer time periods compared to at-sea activities. Some studies also indicate the potential for impacts to invertebrate larval development resulting from exposure to non-impulsive noise (continuous or intermittent exposures over time periods of 12 to 200 hours) although, similar to stress effects, sonar has not specifically been studied. Masking could affect behaviors such as larvae settlement, communication, predator avoidance, and foraging in mollusc, crustacean, and coral species.

3.4.3.1.2.1 Impacts from Sonar and Other Transducers Under Alternative 1

Impacts from Sonar and Other Transducers Under Alternative 1 for Training Activities

Under Alternative 1, marine invertebrates would be exposed to low-, mid-, and high-frequency sonar and sound produced by other transducers during training activities. These activities could occur throughout the Study Area, including all range complexes except the Key West Range Complex, where the majority of shallow-water coral habitat is located. The locations and number of activities proposed for training under Alternative 1 are shown in Table 2.6-1 (Proposed Training Activities per Alternative) of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during training are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Invertebrates would likely only sense low-frequency sonar or the low frequency component of nearby sounds associated with other transducers. Sonar and other transducers are often operated in deep water, where impacts would be more likely for pelagic species than for benthic species. Most individuals would not be close enough to the most intense sound level to experience impacts to sensory structures such as statocysts. Any marine invertebrate that detects low-frequency sound produced during training activities may alter its behavior (e.g., change swim speed, move away from the sound, or change the type or level of activity). Given the limited distance to which marine invertebrates are sensitive to sound, only a small number of individuals relative to overall population sizes would likely have the potential to be impacted. Because the distance over which most marine invertebrates are expected to detect any sounds is limited and because most sound sources are transient or intermittent (or both), any physiological effects, masking, or behavioral responses would be short-term and brief. Without prolonged exposures to nearby sound sources, adverse impacts to individual invertebrates are not expected, and there would therefore be no effects at the population level. Sonar and other sounds may result in brief, intermittent impacts to individual marine invertebrates and groups of marine invertebrates close to a sound source, but they are unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Training activities using sonar and other tranducers would not intersect the Key West Range Complex and would therefore not impact ESA-listed coral species. In addition, training activities would not occur in elkhorn and staghorn critical habitat that is designated in shallow waters along southern Florida and around Puerto Rico. Pursuant to the ESA, the use of sonar and other transducers during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Sonar and Other Transducers Under Alternative 1 for Testing Activities

Under Alternative 1, marine invertebrates could be exposed to low-, mid-, and high-frequency acoustic sources during testing activities. Testing activities using sonar and other transducers could occur throughout the Study Area, including all range complexes; at Naval Undersea Warfare Center Division, Newport Testing Range; Naval Surface Warfare Center, Panama City Division Testing Range; South Florida Ocean Measurement Facility Testing Range; and pierside at Navy ports (Little Creek, Virginia; Kings Bay, Georgia; and Port Canaveral, Florida), naval shipyards, and Navy-contractor shipyards. The locations and number of activities proposed for testing under Alternative 1 are shown in Tables 2.6-2, 2.6-3, and 2.6-4 (respectively, Naval Air Systems Command, Naval Sea Systems Command, and Office of Naval Research Proposed Testing Activities per Alternative) of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during testing are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Invertebrates would likely only sense low-frequency sonar or the low frequency component of nearby sounds associated with other transducers. Sonar and other transducers are often operated in deep water, where impacts would be more likely for pelagic species than for benthic species. Therefore, most individuals would not be close enough to the most intense sound level to experience impacts to sensory structures such as statocysts. Any marine invertebrate that senses nearby or low-frequency sounds could react behaviorally. However, given the limited distance to which marine invertebrates are sensitive to sound, only a small number of individuals would likely be impacted. With the exception of pierside sonar testing, most sound sources are transient, and any physiological or behavioral responses or masking would be short-term and brief. During pierside testing, invertebrates could be exposed to sound for longer time periods compared to at-sea testing. Pierside testing events generally occur over several hours of intermittent use. Sessile species or species with limited mobility located near pierside activities would be exposed multiple times. Species with greater mobility could potentially be exposed multiple times, depending on the time between testing events and the activity of individual animals. The limited information available suggests that sessile marine invertebrates repeatedly exposed to sound could experience physiological stress or react behaviorally (e.g., shell closing). However, recent survey work by the Virginia Institute of Marine Science suggests large populations of oysters inhabit Navy piers in the Chesapeake Bay that have persisted despite a history of sonar use in the area (Horton, 2016). In general, during use of sonar and other transducers, impacts would be more likely for sessile or limited-mobility taxa (e.g., sponges, bivalve molluscs, and echinoderms) than for mobile species (e.g., squids). Overall, given the limited distance to which marine invertebrates are sensitive to sound and the transient or intermittent nature (or both) of most sound sources, sonar and other sounds may result in brief, intermittent impacts to individual marine invertebrates and groups of marine invertebrates close to a sound source. The number of individuals affected would likely be small relative to overall population sizes. Sonar and other sounds are unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Testing activities using sonar and other transducers are not proposed in ESA-listed elkhorn and staghorn critical habitat designated in shallow waters along southern Florida and around Puerto Rico. Pierside sonar testing at Port Canaveral would not result in sound exposure to shallow-water corals. Sonar would be used during testing activities at the South Florida Ocean Measurement Facility Testing Range and could therefore expose corals to underwater sound. However, activities using low-frequency sonar would not be conducted within the coastal zone (3 nautical miles [NM] from shore), and coral exposure would therefore not be expected. The distribution of corals in the South Florida Ocean Measurement Facility Testing Range is limited to a relatively narrow band very close to shore. In general, sound exposure would be temporary, from primarily mobile sources, and ESA-listed corals would therefore not be subjected to prolonged sonar exposure in any portion of the Study Area. Pursuant to the ESA, the use of sonar and other transducers during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species because of the following:

- Prolonged pierside sonar testing would not intersect the distribution of shallow-water coral species in the Study Area.
- Testing of sonar and other transducers from mobile platforms in mostly deeper water (away from areas where ESA-listed corals would most likely occur) would result in a temporary exposure only very close to the near surface sources affecting primarily pelagic invertebrates. Effects to benthic corals would not be expected. Although coral larvae may occur near the surface, brief exposure to a transient source would result in no detectable behavioral or physiological impacts, including larvae settlement.
- Corals are only known to be able to detect low-frequency sounds, meaning only low-frequency sonar would have the potential for coral detection. However, in the South Florida Ocean Measurement Facility Testing Range, low-frequency sonar would not be used within 3 NM of shore, and coral exposure would therefore not be expected.

3.4.3.1.2.2 Impacts from Sonar and Other Transducers Under Alternative 2

Impacts from Sonar and Other Transducers Under Alternative 2 for Training Activities

Under Alternative 2, marine invertebrates would be exposed to low-, mid-, and high-frequency sonar and sound produced by other transducers during training activities. The location of training activities would be the same as those described for Alternative 1, and are shown in Table 2.6.1 (Proposed Training Activities per Alternative) of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during training are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Potential impacts to invertebrates would be similar to those discussed for training activities under Alternative 1. The only difference in sonar and other transducer use between Alternatives 1 and 2 is that the number of sonar hours used would be greater under Alternative 2 (Table 3.0-2, Sonar and Transducer Sources Quantitatively Analyzed). While the types of expected impacts to any individual invertebrate or group of invertebrates capable of detecting sonar or other sounds produced during training activities would remain the same, more animals would likely be affected. Most individuals would not be close enough to the most intense sound level to experience impacts to sensory structures such as statocysts. Sonar and other sounds could result in stress, masking, or behavioral effects to marine invertebrates occurring close to a sound source. These effects would generally be short-term and brief, and a small number of individuals would be affected relative to overall population sizes. Physiological or behavioral effects resulting from sonar and other sounds are unlikely to impact survival, growth, recruitment, or reproduction of invertebrate populations or subpopulations.

Training activities using sonar and other transducers would not intersect the Key West Range Complex and would therefore not impact ESA-listed coral species. In addition, training activities would not occur in elkhorn and staghorn critical habitat that is designated in shallow waters along southern Florida and around Puerto Rico. Pursuant to the ESA, the use of sonar and other transducers during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Sonar and Other Transducers Under Alternative 2 for Testing Activities

Under Alternative 2, marine invertebrates would be exposed to low-, mid-, and high-frequency acoustic sources during testing activities. The location of testing activities using sonar and other transducers would be the same as those described for Alternative 1 and are shown in Tables 2.6-2, 2.6-3, and 2.6-4 (respectively, Naval Air Systems Command, Naval Sea Systems Command, and Office of Naval Research Proposed Testing Activities per Alternative) of Chapter 2 (Description of Proposed Action and Alternatives). Sounds produced during testing are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

Potential impacts to invertebrates would be similar to those discussed for testing activities under Alternative 1. The only difference in sonar and other transducer use between Alternatives 1 and 2 is that the number of sonar hours used would be greater under Alternative 2 (Table 3.0-2, Sonar and Transducer Sources Quantitatively Analyzed). The increase is associated with mid-frequency and high-frequency sonar, which is probably outside the detection capability of most marine invertebrates. While the types of expected impacts to any individual invertebrate or group of invertebrates capable of detecting sonar or other sounds produced during testing activities would remain the same, more animals could potentially be affected. Most individuals would not be close enough to the most intense sound level to experience impacts to sensory structures such as statocysts. Sonar and other sounds could result in stress, masking, or behavioral effects to marine invertebrates occurring close to a sound source. These effects would generally be short-term and brief, and a small number of individuals would be affected relative to overall population sizes. Physiological or behavioral effects resulting from sonar and other sounds are unlikely to impact survival, growth, recruitment, or reproduction of invertebrate populations or subpopulations. Testing activities using sonar and other transducers are not proposed in ESA-listed elkhorn and staghorn critical habitat designated in shallow waters along southern Florida and around Puerto Rico. Pierside sonar testing at Port Canaveral would not result in sound exposure to shallow-water corals. Sonar would be used during testing activities at the South Florida Ocean Measurement Facility Testing Range. However, activities using low-frequency sonar would not be conducted within the coastal zone (3 NM from shore), and coral exposure would therefore not be expected because the distribution of corals in the South Florida Ocean Measurement Facility Testing Range is limited to a relatively narrow band very close to shore. In general, sound exposure would be temporary, from primarily mobile sources, and ESA-listed corals would therefore not be subjected to prolonged sonar exposure in any portion of the Study Area. Pursuant to the ESA, the use of sonar and other transducers during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species because of the following:

- Prolonged pierside sonar testing would not intersect the distribution of shallow-water coral species in the Study Area.

Testing of sonar and other transducers from mobile platforms in mostly deeper water (away from shallow areas where ESA-listed corals would most likely occur) would result in a temporary exposure only very close to the near surface sources affecting primarily pelagic invertebrates. Effects to benthic corals would not be expected. Although coral larvae may occur near the surface, brief exposure to a transient source would result in no detectable behavioral or physiological impacts, including larvae settlement.

Corals are only known to be able to detect low-frequency sounds, meaning only low-frequency sonar would have the potential for coral detection. However, in the South Florida Ocean Measurement Facility Testing Range, low-frequency sonar would not be used within three NM of shore, and coral exposure would therefore not be expected.

3.4.3.1.2.3 Impacts from Sonar and Other Transducers Under the No Action Alternative

Impacts from Sonar and Other Transducers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., sonar and other transducers) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.3 Impacts from Air Guns

Air guns produce shock waves that are somewhat similar to those produced by explosives (see Section 3.4.3.2.1, Impacts from Explosives) but of lower intensity and slower rise times. An impulsive sound is generated when pressurized air is released into the surrounding water. Some studies of air gun impacts on marine invertebrates have involved the use of an array of multiple seismic air guns, although arrays are not used during Navy activities. The volume capacity of air guns used for Navy testing (60 cubic inches at full capacity) is generally within the volume range of single air guns used in seismic exploration (typically 20 to 800 cubic inches). However, seismic air guns are used in arrays with a total volume of several thousands of cubic inches, which is far more than would be associated with any Navy activities. Generated impulses would have short durations, typically a few hundred milliseconds. The root-mean-squared SPL and SEL at a distance of 1 m from the air gun would be approximately 200 to 210 dB re 1 μPa and 185 to 195 dB re 1 μPa^2-s, respectively.

The results of studies of the effects of seismic air guns on marine invertebrates, described in detail in Section 3.4.3.1 (Acoustic Stressors), suggest possible differences between taxonomic groups and life stages. Physical injury has not been reported in adult crustaceans (crabs, shrimp, and lobsters) exposed to seismic air guns at received levels comparable to the source level of Navy air guns operated at full capacity. Evidence of physiological stress was not found in crabs exposed to sound levels up to 187 dB re 1 μPa^2. However, stress response was reported for lobsters located about 3.5 m from the source, where particle motion was likely detectable. While behavioral reaction to air guns has not been documented for crustaceans, squid have exhibited startle and alarm responses at various sound levels. Squid have shown startle response at received levels of 156 to 174 dB re 1 μPa rms (distance from sound source is unclear but presumed to be 30 m based on experimental description), although the reactions were less intense when ramp-up procedures (beginning with lower-intensity sound and progressing to higher levels) were used. In one study, onset of alarm response occurred at 147 dB re 1 µPa^2-s; distance from the source was not provided. Developmental effects to crab eggs and scallop larvae zoeae were found at received levels of 210 and 164 dB 1 µPa SPL (about 7 ft. from the source). Conversely, crab zoeae located 62 ft. from an air gun source showed no developmental effects. Air gun use could also result in substrate vibration, which could cause behavioral effects in nearby benthic invertebrates.

3.4.3.1.3.1 Impacts from Air Guns Under Alternative 1

Impacts from Air Guns Under Alternative 1 for Training Activities

There would be no air gun use associated with training activities. Therefore, air guns are not analyzed in this subsection.

Impacts from Air Guns Under Alternative 1 for Testing Activities

Air guns would be used in the Northeast, Gulf of Mexico, and Virginia Capes Range Complexes, the Naval Surface Warfare Center, Panama City Division and Naval Underwater Warfare Center, Newport, Testing Ranges, and pierside at Newport, Rhode Island (Section 3.0.3.3.1.2, Air Guns; Table A.3.2.7.7, Appendix A). Sounds produced by air guns are described in Section 3.0.3.3.1.2 (Air Guns).

Compared to offshore areas, air gun use at pierside locations would potentially affect a greater number of benthic and sessile invertebrates due to proximity to the bottom and structures that may be colonized by invertebrates (e.g., pilings). Invertebrates such as sponges, hydroids, worms, bryozoans, bivalves, snails, and numerous types of crustaceans and echinoderms could be exposed to sound. Air gun use in offshore areas has greater potential to affect pelagic invertebrates such as jellyfish and squid. Available information indicates that injury to crustacean species would not be expected. Potential injury to squid species located very near the source has been suggested but not demonstrated. It is unlikely that air guns would affect egg or larvae development due to the brief time that they would be exposed to impulsive sound (a few hundred milliseconds per firing). However, activities conducted at pierside locations could potentially expose the same individuals to impulsive sound, particularly sessile species or species with limited mobility. Air gun use in offshore areas would be unlikely to affect the same individuals. Some number of invertebrates of various taxa exposed to air gun noise could experience a physiological stress response and would likely show startle reactions or short-term behavioral changes. For example, squid exposed to air gun noise would probably react behaviorally (e.g., inking, jetting, or changing swim speed or location in the water column), as these behaviors were observed in animals exposed to sound levels lower than the source levels of Navy air guns (distance from the source associated with these reactions was not provided). The results of one study suggests that affected individuals may exhibit less intense reactions when exposed to multiple air gun firings (McCauley et al., 2000a). In shallow water where air gun firing could cause sediment vibration, nearby benthic invertebrates could react behaviorally (e.g., shell closing or changes in foraging activity). Adult crustaceans may be less affected than other life stages.

Sound and sediment vibrations caused by air gun events would be brief, although multiple firings would occur per event. In addition, testing activities would be conducted infrequently. Although some individuals would be affected, the number would be small relative to overall population sizes, and activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Testing activities involving air guns would not occur in the Key West Range Complex or South Florida Ocean Measurement Facility Testing Range, and would not intersect elkhorn or staghorn coral critical habitat. Pursuant to the ESA, the use of air guns during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.1.3.2 Impacts from Air Guns Under Alternative 2

Impacts from Air Guns Under Alternative 2 for Training Activities

There would be no air gun use associated with training activities. Therefore, air guns are not analyzed in this subsection.

Impacts from Air Guns Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with air gun use would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.1.3.1 (Impacts from Air Guns Under Alternative 1) for a discussion of impacts on invertebrates.

Testing activities involving air guns would not occur in the Key West Range Complex or South Florida Ocean Measurement Facility Testing Range, and would not intersect elkhorn or staghorn coral critical habitat. Pursuant to the ESA, the use of air guns during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.1.3.3 Impacts from Air Guns Under the No Action Alternative

Impacts from Air Guns Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed testing activities in the Study Area. Various acoustic stressors (e.g., air guns) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.4 Impacts from Pile Driving

Pile driving and removal involves both impact and vibratory methods. Impact pile driving produces repetitive, impulsive, broadband sound with most of the energy in lower frequencies where invertebrate hearing sensitivity is greater. Vibratory pile removal produces nearly continuous sound at a lower source level. See Section 3.0.3.3.1.3, Pile Driving, for a discussion of sounds produced during impact pile driving and vibratory pile removal.

Impacts on invertebrates resulting from pile driving and removal are considered in the context of impulsive sound and substrate vibration. Impact pile driving produces a pressure wave that is transmitted to the water column and the sediment (Reinhall & Dahl, 2011). The pressure wave may cause vibration within the sediment. Most acoustic energy would be concentrated below 1,000 Hz, which is within the general sound sensing range of invertebrates. Available information indicates that invertebrates may respond to particle motion and substrate vibration produced by pile driving or removal. As discussed in Section 3.4.3.1 (Acoustic Stressors), recent investigations have found effects to crustacean and mollusc species resulting from pile driving noise playback and substrate vibration (Roberts et al., 2015; Roberts et al., 2016; Solan et al., 2016; Spiga, 2016). Responses include changes in chorusing (snapping shrimp), valve closing (clams and mussels), and changes in activity level (clams, lobsters, and hermit crabs). However, no statistically detectable changes were observed in brittlestars, suggesting that impacts may vary among taxa or species. While one study was conducted in a sheltered coastal area (Spiga, 2016), the others used small experimental tanks with maximum dimension of about 20 inches. Therefore, many of the effects were observed very close to the sound sources. Navy scientists are in the early stages of observing the response of marine life to pile driving in their unconfined environment using an adaptive resolution imaging sonar that allows observations in low visibility estuarine waters. Samples acquired to date include the response (or lack thereof) of various crabs to Navy pile driving in the Mid-Atlantic region.

3.4.3.1.4.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Under Alternative 1, pile driving and removal associated with elevated causeway system placement would occur once per year in the nearshore and surf zone at one of the following locations: Virginia Capes Range Complex (Joint Expeditionary Base Little Creek, Virginia or Joint Expeditionary Base Fort Story, Virginia) or Navy Cherry Point Range Complex (Marine Corps Base Camp Lejeune, North Carolina) (Section 3.0.3.3.1.3, Pile Driving). Marine invertebrates in the area around a pile driving and vibratory removal site would be exposed to multiple impulsive sounds and other disturbance intermittently over an estimated 20 days during installation and 10 days during removal. Invertebrates could be exposed to impact noise for a total of 60 minutes per 24-hour period during installation, and could be exposed to noise and substrate vibration for a total of 36 minutes per day during pile removal. It may be theorized that repeated exposures to impulsive sound could damage the statocyst of individuals of some taxa (e.g., crustaceans and cephalopods); however, experimental data on such effects are not available. Exposure to impulsive sound and substrate vibration would likely cause behavioral reactions in invertebrates located in the water column or on the bottom for some distance from the activities. For example, a sound level of 150 dB SEL, which was found to cause behavioral reactions in clams and lobsters, was modeled at 3.4 km from the source for pile driving during a previous event. Reactions such as valve closure or changes in activity could affect feeding, and auditory masking could affect other behaviors such as communication and predator avoidance. Repetitive impulses and substrate vibration may also cause short-term avoidance of the affected area by mobile invertebrates. Available experimental results do not provide estimates of the distance to which such reactions could occur. Although some number of individuals would experience physiological and behavioral effects, the activities would occur intermittently (one event occurring intermittently over approximately 30 days per year) in very limited areas and would be of short duration (maximum of 60 minutes per 24-hour period). Therefore, the number of invertebrates affected would be small compared to overall population numbers. Pile driving and removal activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

ESA-listed coral species and critical habitat do not occur in areas proposed for pile driving. Pursuant to the ESA, the use of pile driving during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

There would be no pile driving or removal associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.1.4.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with pile driving and removal would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.1.4.1 (Impacts from Pile Driving Under Alternative 1) for a discussion of impacts on invertebrates.

ESA-listed coral species and critical habitat do not occur in areas proposed for pile driving. Pursuant to the ESA, the use of pile driving during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

There would be no pile driving or removal associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.1.4.3 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training activities in the AFTT Study Area. Various acoustic stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.5 Impacts from Vessel Noise

As described in Section 3.0.3.3.1.4 (Vessel Noise), naval vessels (including ships and small craft) produce low-frequency, broadband underwater sound that ranges over several sound levels and frequencies. Some invertebrate species would likely be able to detect the low-frequency component of vessel noise. Several studies, described in detail in Section 3.4.3.1 (Acoustic Stressors), have found physiological and behavioral responses in some invertebrate species in response to playback of vessel noise, although one study found no reaction by krill to an approaching vessel. Physiological effects included biochemical changes indicative of stress in crustacean species, decreased growth and reproduction in shrimp, and changes in sea hare embryo development. It is also possible that vessel noise may contribute to masking of relevant environmental sounds, such as predator detection or reef sounds. Low-frequency reef sounds are used as a settlement cue by the larvae of some invertebrate species. Behavioral effects resulting from boat noise playback have been observed in various crustacean, cephalopod, and bivalve species and include shell closing and changes in feeding, coloration, swimming, and other movements. Exposure to other types of non-impulsive noise (and therefore potentially relevant to vessel noise effects), including continuous sweeps and underwater turbine noise playback, has resulted in statocyst damage (squid and octopus), physiological stress, effects to larval development, and behavioral reactions. Noise exposure in several of the studies using boat and other continuous noise sources occurred over a duration of 3.5 to 30 minutes to captive individuals unable to escape the stimulus. In other studies, noise playback ranged from hours to days (and up to 3 months in one investigation) of continuous or intermittent exposure. Given the duration of exposure, direct applicability of the results to Navy training and testing activities is uncertain for mobile species. However, it is possible that invertebrates in the Study Area that are exposed to vessel noise could exhibit similar reactions.

While commercial vessel traffic and associated noise is relatively steady over time, Navy traffic is episodic in the ocean. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours to a few weeks. Vessels engaged in training and testing may consist of a single vessel involved in unit-level activity for a few hours or multiple vessels involved in a major training exercise that could last a few days within a given area. In the East Coast Exclusive Economic Zone, Navy ships are estimated to contribute only roughly 1 percent of the total large vessel broadband energy noise (Mintz & Filadelfo, 2011). However, the percentage of Naval vessel traffic in port areas with Naval installations, such as Norfolk and Mayport, is probably greater than 1 percent.

3.4.3.1.5.1 Impacts from Vessel Noise Under Alternative 1

Impacts from Vessel Noise Under Alternative 1 for Training Activities

Under Alternative 1, naval vessels would be used during many of the proposed activities, and naval vessel noise associated with training could occur in all of the range complexes and inland waters throughout the Study Area. Activities that occur in the offshore component of the Study Area may last from a few hours to a few weeks, and vessels would generally be widely dispersed. However, exposure to naval vessel noise would be greatest in the areas of highest naval vessel traffic, which generally occurs in the Virginia Capes and Jacksonville Range Complexes. Noise exposure would be particularly concentrated near naval port facilities, especially around and between the ports of Norfolk, Virginia, and Jacksonville, Florida. Activities that occur in inland waters can last from a few hours to up to 12 hours of daily movement per vessel per activity, and can involve speeds greater than 10 knots. Vessels that would operate within inland waters are generally smaller than those in offshore waters (small craft less than 50 ft.). Vessel movements in the inland waters of the Study Area occur on a more regular basis than the offshore activities, and generally occur in more confined waterways (primarily in the Lower Chesapeake Bay and James River). Information on the number and location of activities using vessels, as well as the number of hours of operation for inland waters, is provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices).

Any marine invertebrate capable of sensing sound may alter its behavior or experience masking of other sounds if exposed to vessel noise. Because the distance over which most marine invertebrates are expected to detect sounds is limited and because most vessel noise is transient or intermittent (or both), most behavioral reactions and masking effects from Navy activities would likely be short term, ceasing soon after Navy vessels leave an area. An exception would be areas in and around port navigation channels and inland waters that receive a high volume of ship or small craft traffic, where sound disturbance would be more frequent. The relatively high frequency and intensity of vessel traffic in many inshore training areas may have given organisms an opportunity to adapt behaviorally to a noisier environment. For example, recent survey work by the Virginia Institute of Marine Science suggests that large populations of oysters inhabit Navy piers in the Chesapeake Bay that have persisted despite a history of chronic vessel noise (Horton, 2016). Without prolonged exposure to nearby sounds, measurable impacts are not expected. In general, intermittent vessel noise produced during training activities may briefly impact some individuals, but exposures are not expected to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations. Concentrated vessel operation in areas such as port navigation channels could result in repeated noise exposure and chronic physiological or behavioral effects to individuals of local invertebrate subpopulations, particularly sessile species, located near the sound source. However, relative to population sizes, impacts to subpopulations would not have measureable effects to invertebrate populations overall.

Some adults of ESA-listed corals could potentially detect the low-frequency component of nearby vessel noise, although there are no studies of the effects of vessel noise on corals. Coral larvae exposed to vessel noise near a reef could experience temporary masking and brief disruption of settlement cues. Mapped areas of shallow water coral reefs, live hard bottom, artificial reefs, and shipwrecks would be avoided during precision anchoring, explosive mine countermeasure and neutralization activities. In addition, mapped areas of shallow water coral reefs would be avoided during explosive and non-explosive gunnery, missile, and bombing activities. Avoidance of these areas would decrease vessel transit and associated vessel noise through areas supporting shallow-water corals, including ESA-listed staghorn and elkhorn corals. Vessel noise would not affect the physical components designated critical habitat for elkhorn coral and staghorn coral. Pursuant to the ESA, vessel noise produced during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Vessel Noise Under Alternative 1 for Testing Activities

Under Alternative 1, naval vessels would be used during many of the proposed activities, and naval vessel noise associated with testing could occur in all of the range complexes and testing ranges throughout the Study Area, and in some inland waters. However, exposure to naval vessel noise would be greatest in the areas of highest naval vessel traffic, which generally occurs in the Virginia Capes and Jacksonville Range Complexes. Noise exposure would be particularly concentrated near naval port facilities, especially around and between the ports of Norfolk, Virginia, and Jacksonville, Florida. Information on the number and location of activities using vessels, as well as the number of hours of operation for inland waters, is provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices).

Any marine invertebrate capable of sensing sound may alter its behavior or experience masking of other sounds if exposed to vessel noise. Because the distance over which most marine invertebrates are expected to detect sounds is limited and because most vessel noise is transient or intermittent (or both), most behavioral reactions and masking effects from Navy activities would likely be short-term, ceasing soon after Navy vessels leave an area. An exception would be areas in and around port navigation channels and inland waters that receive a high volume of ship or small craft traffic, where sound disturbance would be more frequent. The relatively high frequency and intensity of vessel traffic in many inshore areas may have given organisms an opportunity to adapt behaviorally to a noisier environment. For example, recent survey work by the Virginia Institute of Marine Science suggests that large populations of oysters inhabit Navy piers in the Chesapeake Bay that have persisted despite a history of chronic vessel noise (Horton, 2016). Without prolonged exposure to nearby sounds, measurable impacts are not expected. In general, intermittent vessel noise produced during testing activities may briefly impact some individuals, but exposures are not expected to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations. Concentrated vessel operation in areas such as port navigation channels could result in repeated noise exposure and chronic physiological or behavioral effects to individuals of local invertebrate subpopulations, particularly sessile species, located near the sound source. However, relative to population sizes, impacts to subpopulations would not have measureable effects to invertebrate populations overall.

Some adults of ESA-listed corals could potentially detect the low-frequency component of nearby vessel noise, and coral larvae exposed to vessel noise near a reef could experience temporary masking and brief disruption of settlement cues. Mapped areas of shallow water coral reefs, live hard bottom, artificial reefs, and shipwrecks would be avoided during numerous types of activities, which would decrease vessel transit and associated vessel noise through areas supporting shallow-water corals. Vessel noise would not affect the physical components of designated critical habitat for elkhorn coral and staghorn coral. Pursuant to the ESA, vessel noise produced during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.1.5.2 Impacts from Vessel Noise Under Alternative 2

Impacts from Vessel Noise Under Alternative 2 for Training Activities

Under Alternative 2, potential impacts to invertebrates resulting from vessel noise associated with training activities would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (about 1 percent) due to differences in the number of events such as Composite Training Unit Exercises. However, the increase would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.1.5.1 (Impacts from Vessel Noise Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.1.5.1 (Impacts from Vessel Noise under Alternative 1), pursuant to the ESA, vessel noise produced during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Vessel Noise Under Alternative 2 for Testing Activities

Under Alternative 2, potential impacts to invertebrates resulting from vessel noise associated with testing activities would be similar to those discussed for activities under Alternative 1. Vessel use in the Study Area would increase by a very small amount (less than 1 percent). However, the increase would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.1.5.1 (Impacts from Vessel Noise Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.1.5.1 (Impacts from Vessel Noise under Alternative 1), pursuant to the ESA, vessel noise produced during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.1.5.3 Impacts from Vessel Noise Under the No Action Alternative

Impacts from Vessel Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., vessel noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.6 Impacts from Aircraft Noise

Aircraft and missile overflight noise is not applicable to invertebrates due to the very low transmission of sound pressure across the air/water interface and will not be analyzed further in this section.

3.4.3.1.7 Impacts from Weapons Noise

As discussed in Section 3.0.3.3.1.6 (Weapon Noise), noise associated with weapons firing and the impact of non-explosive munitions could occur during training or testing events. In-water noise would result from naval gunfire (muzzle blast), bow shock waves from supersonic projectiles, missile and target launch, and vibration from a blast propagating through a ship's hull. In addition, larger non-explosive munitions could produce low-frequency impulses when striking the water, depending on the size, weight, and speed of the object at impact. Small- and medium-caliber munitions would not produce substantial impact noise.

Underwater sound produced by weapons firing, launch, and impact of non-explosive practice munitions would be greatest near the surface and would attenuate with depth. However, the potential for in-air weapons noise to impact invertebrates would be small. Much of the energy produced by muzzle blasts and flying projectiles is reflected off the water surface. As discussed in Section 3.0.3.3.1.6 (Weapon Noise), sound generally enters the water only in a cone beneath the blast or projectile trajectory (within 13 to 14 degrees of vertical for muzzle blast noise, and 65 degrees for projectile shock waves). An SEL of 180 to 185 dB re 1 µPa^2-s was measured at water depth of 5 ft. directly below the muzzle blast of the largest gun analyzed, at the firing position closest to the water. Different weapons and angles of fire would produce less sound in the water. Bow waves from supersonic projectiles produce a brief “crack” noise at the surface, but transmission of sound into the water is minimal. Launch noise fades rapidly as the missile or target moves downrange and the booster burns out. Hull vibration from large-caliber gunfire produces only a small level of underwater noise. For example, analysis of 5-inch gun firing found that energy transmitted into the water by hull vibration is only 6 percent of that produced by the muzzle blast. Compared to weapons firing, launches, and hull vibration, impulsive sound resulting from non-explosive practice munition strikes on the water surface could affect a somewhat larger area, though far less than an explosive blast. Underwater sound would generally be associated only with relatively large munitions impacting at high speed.

Based on the discussion above, invertebrates would likely only be affected by noise produced by muzzle blasts and impact of large non-explosive practice munitions. Impacts would likely be limited to pelagic invertebrates, such as squid, jellyfish, and zooplankton, located near the surface. Injury and physiological stress has not been found in limited studies of invertebrates exposed to impulsive sound levels comparable to those produced beneath the muzzle blast of a 5-inch gun. Behavioral reactions have not been found in crustaceans, but have been observed for squid species. While squid could display short-term startle response, behavioral reactions in response to sound is not known for jellyfish or zooplankton. Zooplankton may include gametes, eggs, and larval forms of various invertebrate species, including corals. Although prolonged exposure to repeated playback of nearby impulsive sound (air guns) has resulted in developmental effects to larvae and eggs of some invertebrate species, brief exposure to a single or limited number of muzzle blasts or munition impacts would be unlikely to affect development. Other factors would limit the number and types of invertebrates potentially affected. Most squid are active near the surface at night, when most weapons firing and launch do not occur. Weapons firing and launch typically occurs greater than 12 NM from shore, which would substantially limit the sound level reaching the bottom. Therefore, impacts to benthic invertebrates (e.g., bivalve molluscs, worms, and crabs) are unlikely.

3.4.3.1.7.1 Impacts from Weapons Noise Under Alternative 1

Impacts from Weapons Noise Under Alternative 1 for Training Activities

Under Alternative 1, invertebrates would be exposed to noise primarily from weapons firing and impact of non-explosive practice munitions during training activities. Noise associated with these activities could be produced throughout the Study Area, including when ships are in transit, but would typically be concentrated in the Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes. Noise associated with large caliber weapons firing and the impact of non-explosive practice munitions or kinetic weapons would typically occur at locations greater than 12 NM from shore. Small caliber weapons firing could occur throughout the Study Area.

Noise produced by these activities would consist of a single or several impulses over a short period. Impulses resulting from muzzle blasts and non-explosive practice munitions impact would likely affect only individuals near the surface, and are not likely to result in injury. Some invertebrates may exhibit startle reactions (e.g., abrupt changes in swim speed or direction). For example, based on observed reactions to other impulsive sounds (air guns), squid located near the surface in the vicinity of a firing event could show startle reactions such as inking or jetting. Impacts of non-explosive practice munitions could affect a comparatively larger volume of water and associated invertebrates. The number of organisms affected would depend on the area exposed and the invertebrate density. Squid and zooplankton are typically more abundant near the surface at night, when most weapon firing would not occur. In addition, most weapons firing would take place in offshore waters, decreasing the potential for impacts to benthic invertebrates and coral eggs and larvae.

Impacts would be of brief duration and would be limited to a relatively small volume of water near the surface. Compared to overall population sizes, it is expected that only a small number of pelagic invertebrates (e.g., squid, jellyfish, and zooplankton) would be exposed to weapons firing and impact noise. Squid and zooplankton would be less abundant during the day, when weapons firing typically occurs, and jellyfish are not known to react to sound. The activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

ESA-listed coral species and designated critical habitat would not likely be exposed to noise from weapons firing, launch, and impact of non-explosive practice munitions during training activities because those activities are generally conducted in offshore waters where shallow-water corals do not typically occur. Noise produced at the surface or as a result of vessel hull vibration would be unlikely to cause physiological or behavioral responses in corals due to their limited sound detection range. Noise produced by weapons firing, launch, and impact of non-explosive practice items would not affect the characteristics of elkhorn coral and staghorn coral critical habitat. Pursuant to the ESA, weapons noise produced during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Weapons Noise Under Alternative 1 for Testing Activities

Under Alternative 1, invertebrates would be exposed to noise primarily from weapons firing and impact of non-explosive practice munitions during testing activities. Testing activities would be concentrated in the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes, and could also occur in the Naval Surface Warfare Center, Panama City testing range. Noise associated with large caliber weapons firing and the impact of non-explosive practice munitions or kinetic weapons would typically occur at locations greater than 12 NM from shore. Small caliber weapons firing could occur throughout the Study Area.

Noise produced by these activities would consist of a single or several impulses over a short period. Impulses resulting from muzzle blasts and non-explosive practice munitions impact would likely affect only individuals near the surface, and are not likely to result in injury. Some invertebrates may exhibit startle reactions (e.g., abrupt changes in swim speed or direction). For example, based on observed reactions to other impulsive sounds (air guns), squid located near the surface in the vicinity of a firing event could show startle reactions such as inking or jetting. Impacts of non-explosive practice munitions could affect a comparatively larger volume of water and associated invertebrates. The number of organisms affected would depend on the area exposed and the invertebrate density. Squid and zooplankton are typically more abundant near the surface at night, when most weapon firing would not occur. In addition, most weapons firing would take place in offshore waters, decreasing the potential for impacts to benthic invertebrates and coral eggs and larvae.

Impacts would be of brief duration and would be limited to a relatively small volume of water near the surface. Compared to overall population sizes, it is expected that only a small number of pelagic invertebrates (e.g., squid, jellyfish, and zooplankton) would be exposed to weapons firing and impact noise. Squid and zooplankton would be less abundant during the day, when weapons firing typically occurs, and jellyfish are not known to react to sound. The activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

Testing activities would be conducted in the Key West Range Complex, where ESA-listed corals (and associated coral eggs and larvae) and elkhorn and staghorn coral critical habitat occur. However, ESA-listed coral species and designated critical habitat would not likely be exposed to noise from weapons firing, launch, and impact of non-explosive practice munitions during testing activities because those activities are generally conducted in offshore waters where shallow-water corals do not typically occur. Noise produced at the surface or as a result of vessel hull vibration would be unlikely to cause physiological or behavioral responses in corals due to their limited sound detection range. Noise produced by weapons firing, launch, and impact of non-explosive practice items would not affect the characteristics of elkhorn coral and staghorn coral critical habitat. Pursuant to the ESA, weapons noise produced during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.1.7.2 Impacts from Weapons Noise Under Alternative 2

Impacts from Weapons Noise Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with weapons firing, launch, and non-explosive practice munition impact noise for training activities would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.1.5.1 (Impacts from Weapons Noise Under Alternative 1) for a discussion of impacts on invertebrates.

Pursuant to the ESA, weapons noise produced during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Weapons Noise Under Alternative 2 for Testing Activities

Under Alternative 2, the location of testing activities would be the same as those described for Alternative 1, and potential impacts to invertebrates would be similar (refer to Section 3.4.3.1.5.1, Impacts from Weapons Noise Under Alternative 1). The only difference between Alternatives 1 and 2 is that the number of munitions used would be greater under Alternative 2. While the types of expected impacts to any individual invertebrate or group of invertebrates capable of detecting sounds produced during testing activities would remain the same, more animals could be affected. Compared to overall population sizes, it is expected that only a small number of pelagic invertebrates (e.g., squid, jellyfish, and zooplankton) would be exposed. Squid and zooplankton would be less abundant near the surface during the day, when weapons firing typically occurs, and jellyfish are not known to react to sound. The activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

ESA-listed coral species and designated critical habitat would not likely be exposed to noise from weapons firing, launch, and impact of non-explosive practice munitions during testing activities because those activities are generally conducted in offshore waters where shallow-water corals do not typically occur. Noise produced at the surface or as a result of vessel hull vibration would be unlikely to cause physiological or behavioral responses in corals due to their limited sound detection range. Noise produced by weapons firing, launch, and impact of non-explosive practice munitions would not affect the characteristics of elkhorn coral and staghorn coral critical habitat. Pursuant to the ESA, weapons noise produced during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.1.7.3 Impacts from Weapons Noise Under the No Action Alternative

Impacts from Weapons Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., weapons firing, launch, and non-explosive practice impact noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.1.7 Summary of Potential Acoustic Impacts

Invertebrates would be exposed to potential acoustic stressors resulting from sonar and other transducers; pile driving; air guns; weapons firing, launch, and non-explosive practice munition impact noise; and vessel noise. Based on currently available information, invertebrates would only sense water particle motion near a sound source and at low frequencies, which limits the range to which individuals would respond. The potential for injury would be limited to invertebrates occurring very close to an impulsive sound such as an air gun. Impacts would primarily consist of physiological stress or behavioral reactions. Most sound exposures would occur in offshore areas and near the surface, where pelagic species such as squid, jellyfish, and zooplankton would be affected. Squid and some zooplankton species do not typically occur at the surface during the day, when most Navy activities would take place. Overall, there would be comparatively fewer impacts to benthic species. Exceptions would include pierside sonar and air gun use, and concentration of vessel operation in certain areas, where sessile or sedentary individuals could be repeatedly exposed to acoustic stressors. Most sound exposures would be brief and transient and would affect a small number of individuals relative to overall population sizes.

3.4.3.2 Explosive Stressors

Background

Aspects of explosive stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities). Explosions produce pressure waves with the potential to cause injury or physical disturbance due to rapid pressure changes, as well as loud, impulsive, broadband sounds. Impulsive sounds are characterized by rapid pressure rise times and high peak pressures (Appendix D, Acoustic Primer). Potential impacts on invertebrates resulting from the pressure wave and impulsive sound resulting from a detonation are discussed in this section. When explosive munitions detonate, fragments of the weapon are thrown at high velocity from the detonation point, which can injure or kill invertebrates if they are struck. However, the friction of the water quickly slows these fragments to the point where they no longer pose a threat. The small range of effects due to fragments would result in a negligible impact on invertebrate populations. Therefore, the potential for fragmentation to impact invertebrates is not discussed further in this analysis.

Explosions may impact invertebrates at the water surface, in the water column, or on the bottom. The potential for impacts is influenced by typical detonation scenarios and invertebrate distribution. The majority of explosions would occur in the air or at the surface, with relatively few at the bottom (Appendix A, Navy Activity Descriptions), which would decrease the potential for impacts to benthic species. Surface explosions typically occur during the day at offshore locations more than 12 NM from shore. There is a general pattern of higher invertebrate abundance in relatively productive estuarine and nearshore waters, which decreases the overall number of invertebrates potentially exposed to detonation effects. In addition, many of the invertebrates that occur near the surface (e.g., squid and numerous zooplankton species) typically move up in the water column at night, making them less vulnerable to explosions at the surface occurring predominantly during the day.

In general, an explosion may result in direct trauma and mortality due to the associated rapid pressure changes. For example, gas-containing organs such as the swim bladder in many fish species and the lungs of marine mammals are subject to rapid contraction and overextension (potentially causing rupture) when exposed to explosive shock waves. Most marine invertebrates lack air cavities and are therefore comparatively less vulnerable to damaging effects of pressure waves. Limited studies of crustaceans have examined mortality rates at various distances from detonations in shallow water (Aplin, 1947; Chesapeake Biological Laboratory, 1948; Gaspin et al., 1976). Similar studies of molluscs have shown them to be more resistant than crustaceans to explosive impacts (Chesapeake Biological Laboratory, 1948; Gaspin et al., 1976). Other invertebrates, such as sea anemones, polychaete worms, isopods, and amphipods, were observed to be undamaged in areas near detonations (Gaspin et al., 1976). Data from these experiments were used to develop curves that estimate the distance from an explosion beyond which at least 90 percent of certain adult benthic marine invertebrates would survive, depending on the weight of the explosive (Young, 1991) (Figure 3.4-2). For example, 90 percent of crabs would survive a 200-lb. explosion if they are greater than about 350 ft. away from the source. Similar information on the effects of explosions to planktonic invertebrates and invertebrate larvae is not available.

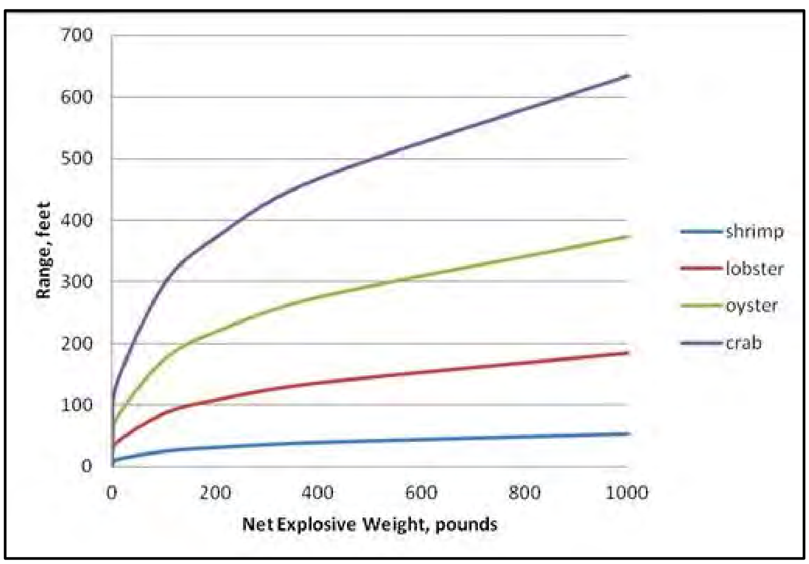

Figure 3.4-2: Prediction of Distance to 90 Percent Survivability of Marine Invertebrates Exposed to an Underwater Explosion (Young, 1991)

Charges detonated in shallow water or near the bottom, including explosive munitions disposal charges and some explosions associated with mine warfare, could kill and injure marine invertebrates on or near the bottom, depending on the species and the distance from the explosion. Taxonomic groups typically associated with the bottom, such as sponges, marine worms, crustaceans, echinoderms, corals, and molluscs, could be affected. Net explosive weight (NEW) for these types of activities is relatively low. Most detonations occurring on or near the bottom would have a NEW of 60 lb. or less, although some explosives would be up to 3,625 lb. NEW. Based on the estimates shown on Figure 3.4-2, most benthic marine invertebrates beyond approximately 275 ft. from a 60-lb. blast would survive. The potential mortality zone for some taxa (e.g., shrimp, lobsters, worms, amphipods) would be substantially smaller. A blast near the bottom could disturb sessile invertebrates such as mussels and hard substrate suitable for their colonization. A blast in the vicinity of hard corals could cause direct impact to coral polyps or early life-stages of pre-settlement corals, or fragmentation and siltation of the corals. For example, in one study, recovery from a single small blast directly on a reef took 5 to 10 years (Fox & Caldwell, 2006).

Impacts to benthic invertebrates in deeper water would be infrequent because most offshore detonations occur in the air or at the surface. Benthic invertebrates in the abyssal zone (generally considered to be deeper than about 6,000 ft.) seaward of the coastal large marine ecosystems are sparsely distributed and tend to be concentrated around hydrothermal vents and cold seeps. These topographic features are typically associated with steep or high-relief areas of the continental shelf break (e.g., canyons, outcrops) or open ocean (e.g., seamounts, Mid-Atlantic Ridge).

The results of a series of underwater surveys of a Navy bombing range in the Pacific Ocean (Farallon De Medinilla) conducted from 1999 to 2012 generally indicated there were few adverse impacts to benthic invertebrates (Smith & Marx, 2016). Although Farallon De Medinilla is a land range, bombs and other munitions occasionally strike the water. A limited number of observations of explosion-related effects were reported, and the results are summarized here to provide general information on the types of impacts that may occur. The effects are not presumed to be broadly applicable to Navy training and testing activities. During the 2010 survey, it was determined that a blast of unknown size (and therefore of unknown applicability to proposed training and testing activities) along the waterline of a cliff ledge caused mortality to small oysters near the impact point. Corals occurring within 3 m of the affected substrate were apparently healthy. A blast crater on the bottom that was 5 m in diameter and 50 cm deep, presumably resulting from a surface detonation, was observed during one survey in water depth of 12 m. Although it may be presumed that corals or other invertebrates located within the crater footprint would have been damaged or displaced, evidence of such impacts was not observed. The blast occurred in an area of sparse coral coverage and it is therefore unknown whether coral was present in the crater area prior to the blast.

The applicability of the mortality distance estimates shown on Figure 3.4-2 to invertebrates located in the water column is unknown. However, detonations that occur near the surface release a portion of the explosive energy into the air rather than the water, reducing impacts to invertebrates in the water column. In addition to effects caused by a shock wave, organisms could be killed or injured in an area of cavitation that forms near the surface above a large underwater detonation. Cavitation is where the reflected shock wave creates a region of negative pressure followed by a collapse, or water hammer (see Appendix D, Acoustic Primer). The number of organisms affected by explosions at the surface or in the water column would depend on the size of the explosive, the distance of organisms from the explosion, and the specific geographic location within the Study Area. As discussed previously, many invertebrates that occur near the surface (e.g., squid and zooplankton) typically move up in the water column at night, making them less vulnerable to explosions during the day, when most Navy activities involving detonations occur.

Marine invertebrates beyond the range of mortality or injurious effects may detect the impulsive sound produced by an explosion. At some distance, impulses lose their high pressure peak and take on characteristics of non-impulsive acoustic waves. Invertebrates that detect impulsive or non-impulsive sounds may experience stress or exhibit behavioral reactions in response to the sound (see Section 3.4.3.1.1, Background). Repetitive impulses during multiple explosions, such as during a surface firing exercise, may be more likely to cause avoidance reactions. However, the distance to which invertebrates are likely to detect sounds is limited due to their sensitivity to water particle motion caused by nearby low-frequency sources. Sounds produced in water during training and testing activities, including activities that involve multiple impulses, occur over a limited duration. Any auditory masking, in which the sound of an impulse could prevent detection of other biologically relevant sounds, would be very brief.

3.4.3.2.1 Impacts from Explosives

3.4.3.2.1.1 Impacts from Explosives Under Alternative 1

<u>Impacts from Explosives Under Alternative 1 for Training Activities</u>

Under Alternative 1, marine invertebrates would be exposed to surface and underwater explosions and associated underwater impulsive sounds from high-explosive munitions (including bombs, missiles, torpedoes, and naval gun shells), mines, and demolition charges. Explosives would be used throughout the Study Area, but most typically in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems and in the Gulf Stream Open Ocean Area. The only underwater explosions that would occur on or near the bottom in the Key West Range Complex would result from use of 5- to 20-lb. charges. A discussion of explosives, including explosive source classes, is provided in Section 3.0.3.3.2 (Explosive Stressors). The largest source class proposed for training under Alternative 1 is E12 (650 to 1,000 lb. NEW), used during bombing exercises (air-to-surface) and sinking exercises.

In general, explosive events would consist of a single explosion or a few smaller explosions over a short period, and would occur infrequently over the course of a year. With the exception of mine warfare, demolition, and a relatively small number of other training events that occur in shallow water close to shore (typically in the same locations that are regularly disturbed), most detonations would occur in water depths greater than 200 ft. (but still at the surface) and greater than 3 NM from shore. As water depth increases away from shore, benthic invertebrates would be less likely to be impacted by detonations at or near the surface. Relatively few invertebrates occur at or near the surface and consist primarily of squid, jellyfish, and zooplankton. Squid and zooplankton are typically active near the surface at night, when most explosions do not occur. In addition, detonations near the surface would release a portion of their explosive energy into the air, reducing the potential for impacts to pelagic invertebrates.

Mine warfare activities are typical examples of activities involving detonations on or near the bottom in nearshore waters. Invertebrates in these areas are adapted to frequent disturbance from storms and associated sediment redistribution. Studies of the effects of large-scale sediment disturbance such as dredging and sediment borrow projects have found recovery of benthic communities over a period of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2012). Recovery time is variable and may be influenced by multiple factors, but is generally faster in areas dominated by sand and moderate to strong water movement. The area of bottom habitat disturbed by explosions would be less than that associated with dredging or other large projects, and would occur mostly in soft bottom areas that are regularly disturbed by natural processes such as water currents and waves. It is therefore expected that areas affected by detonations would rapidly be recolonized (potentially weeks) by the surrounding invertebrate community. Craters resulting from detonations in the soft bottom would be filled and smoothed by waves and long-shore currents over time, resulting in no permanent change to bottom profiles that could affect invertebrate species assemblages. The time required to fill craters would depend on the size and depth, with deeper craters likely filling more slowly (U.S. Army Corps of Engineers, 2001). The amount of bottom habitat impacted by explosions would be a very small percentage of the habitat available in the Study Area. As discussed in Section 3.5.3.2.1.1 (Impacts from Explosives Under Alternative 1), the total bottom area potentially disturbed by explosions over a 5-year period would be 44.2 acres. Of this total, less than 0.6 percent of available hard, intermediate, and soft habitat type would be affected, and less than 0.01 percent of hard bottom would be impacted. This affected area occurs within the context of over 100 million acres of undersea space encompassed by the range complexes associated with mine neutralization training activities (Gulf of Mexico, Jacksonville, Key West, Navy Cherry Point, and Virginia Capes Range Complexes).

Many corals and hard bottom invertebrates are sessile, fragile, and particularly vulnerable to shock wave impacts. Many of these organisms are slow-growing and could require decades to recover (Precht et al., 2001). However, most explosions would occur at or near the water surface and offshore, reducing the likelihood of bottom impacts on shallow-water corals.

In summary, explosives produce pressure waves that can harm invertebrates in the vicinity of where they typically occur: mostly offshore surface waters where only zooplankton, squid, and jellyfish are prevalent mostly at night when testing activities do not typically occur. Exceptions occur where explosives are used on the bottom within nearshore or inland waters on or near sensitive hard bottom communities that are currently not mapped or otherwise protected; shallow-water coral reefs are protected from such explosions whereas other hard bottom communities are protected to the extent they are included in current mitigation measures. Soft bottom communities are resilient to occasional disturbances. Accordingly, the overall impacts of explosions on widespread invertebrate populations would not likely be detectable. Although individual marine invertebrates would likely be injured or killed during an explosion, the number of invertebrates affected would be small relative to overall population sizes, and activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by ESA-listed coral species.

Due to the mitigation described above, the probability of shallow-water corals being exposed to detonation effects is low. Exposure would occur only if explosions inadvertently occurred near unmapped coral reefs or other substrate potentially supporting shallow-water corals. Although such a scenario is unlikely, there is a small potential for exposure. Pursuant to the ESA, the use of explosives during training activities as described under Alternative 1 may affect ESA-listed coral species. Explosives would not be used on the bottom within designated critical habitat for ESA-listed elkhorn and staghorn coral. Therefore, there would be no effect to critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Explosives Under Alternative 1 for Testing Activities

Under Alternative 1, marine invertebrates could be exposed to surface and underwater explosions from high-explosive munitions (including bombs, missiles, torpedoes, and naval gun shells), mines, demolition charges, explosive sonobuoys, and ship shock trial charges. Explosives would be used throughout the Study Area, but most typically in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and in the Gulf Stream Open Ocean Area. The largest source classes proposed for testing under Alternative 1 would be used in the Northeast U.S. Continental Shelf Large Marine Ecosystem, Southeast U.S. Continental Shelf Large Marine Ecosystem, or in the Gulf Stream Open Ocean Area during ship shock trials in the Virginia Capes, Jacksonville, or Gulf of Mexico Range Complexes. Large ship shock trials could use charges up to source class E17 (14,500 to 58,000 lb. NEW), while small ship shock trials could use charges up to source class E16 (7,250 to 14,500 lb. NEW). Each full ship shock trial would use up to four of these charges in total (each one detonated about a week apart, although smaller charges may be detonated on consecutive days). Use of explosives is described in Section 3.0.3.3.2 (Explosive Stressors).

In general, explosive events would consist of a single explosion or a few smaller explosions over a short period, and would occur infrequently over the course of a year. With the exception of mine warfare, demolition charges, and line charge testing events that occur in shallow water close to shore (typically in the same locations that are regularly disturbed), most detonations would occur in water depths greater than 200 ft. (but still at the surface) and greater than 3 NM from shore. Ship shock charges would occur off the continental shelf in water greater than 600 ft. As water depth increases away from shore, benthic invertebrates would be less likely to be impacted by detonations at or near the surface. Relatively few invertebrates occur at or near the surface and consist primarily of squid, jellyfish, and zooplankton. Squid and zooplankton are typically active near the surface at night, when most explosions do not occur. In addition, detonations near the surface would release a portion of their explosive energy into the air, reducing the potential for impacts to pelagic invertebrates.

Mine warfare activities are typical examples of activities involving detonations on or near the bottom in nearshore waters. Invertebrates in these areas are adapted to frequent disturbance from storms and associated sediment redistribution. Studies of the effects of large-scale sediment disturbance such as dredging and sediment borrow projects have found recovery of benthic communities over a period of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2012). Recovery time is variable and may be influenced by multiple factors, but is generally faster in areas dominated by sand and moderate to strong water movement. The area of bottom habitat disturbed by explosions would be less than that associated with dredging or other large projects, and would occur mostly in soft bottom areas that are regularly disturbed by natural processes such as water currents and waves. It is therefore expected that areas affected by detonations would rapidly be recolonized (potentially weeks) by the surrounding invertebrate community. Craters resulting from detonations in the soft bottom would be filled and smoothed by waves and long-shore currents over time, resulting in no permanent change to bottom profiles that could affect invertebrate species assemblages. The time required to fill craters would depend on the size and depth, with deeper craters likely filling more slowly (U.S. Army Corps of Engineers, 2001). The amount of bottom habitat impacted by explosions would be a very small percentage of the habitat available in the Study Area.

In summary, explosives produce pressure waves that can harm invertebrates in the vicinity of where they typically occur: mostly offshore surface waters where only zooplankton, squid, and jellyfish are prevalent mostly at night when testing activities do not typically occur. Exceptions occur where explosives are used on the bottom within nearshore or inland waters on or near sensitive hard bottom communities that are currently not mapped or otherwise protected; shallow-water coral reefs are protected from such explosions whereas other hard bottom communities are protected to the extent they are included in current mitigation measures. Soft bottom communities are resilient to occasional disturbances. Accordingly, the overall impacts of explosions on widespread invertebrate populations would not likely be detectable. Although individual marine invertebrates would likely be injured or killed during an explosion, the number of invertebrates affected would be small relative to overall population sizes, and activities would be unlikely to impact survival, growth, recruitment, or reproduction of marine invertebrate populations or subpopulations.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including several areas inhabited by ESA-listed coral species.

The only in-water explosions in the Key West Range Complex, where ESA-listed corals are known to occur, would result from sonobuoys and torpedoes. Due to the mitigation described above, the probability of shallow-water corals being exposed to detonation effects is low. Exposure would occur only if explosions inadvertently occurred near unmapped coral reefs or other substrate potentially supporting shallow-water corals. Although unlikely, there is a small potential for exposure. Pursuant to the ESA, the use of explosives during testing activities as described under Alternative 1 may affect ESA-listed coral species and designated critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.2.1.2 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with explosives would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.2.1.1 (Impacts from Explosives Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.2.1.1 (Impacts from Explosives under Alternative 1), pursuant to the ESA, the use of explosives during training activities as described under Alternative 2 may affect ESA-listed coral species. There would be no effect to designated elkhorn and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Explosives Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with explosives would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.2.1.1 (Impacts from Explosives Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.2.1.1 (Impacts from Explosives under Alternative 1), pursuant to the ESA, the use of explosives during testing activities as described under Alternative 2 may affect ESA-listed coral species and designated critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.2.1.3 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Explosive stressors would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.3 Energy Stressors

This section analyzes the potential impacts of the various types of energy stressors that can occur during training and testing activities within the Study Area. This section includes analysis of the potential impacts from: (1) in-water electromagnetic devices, (2) in-air electromagnetic devices, and (3) high-energy lasers. Aspects of energy stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.2 (Conceptual Framework for Assessing Effects from Energy-Producing Activities).

3.4.3.3.1 Impacts from In-Water Electromagnetic Devices

Several different types of electromagnetic devices are used during training and testing activities. Information on the types of activities that use in-water electromagnetic devices is provided in Appendix B (Activity Stressor Matrices).

Little information is available regarding marine invertebrates' susceptibility to electromagnetic fields. Magnetic fields are not known to control spawning or larval settlement in any invertebrate species. Existing information suggests sensitivity to electric and magnetic fields in at least three marine invertebrate phyla: Mollusca, Arthropoda, and Echinodermata (Lohmann et al., 1995; Lohmann & Lohmann, 2006; Normandeau et al., 2011). A possible magnetic sense has been suggested in jellyfish as well, although this has not been demonstrated experimentally (Fossette et al., 2015). Much of the available information on magnetic field sensitivity of marine invertebrates pertains to crustaceans. For example, a magnetic compass sense has been demonstrated in the spiny lobster (*Panulirus argus*) (Lohmann et al., 1995; Lohmann & Lohmann, 2006), and researchers suggest subtle behavioral response to magnetic fields of about 1 millitesla (1,000 microtesla) in the Dungeness crab and American lobster (*Homarus americanus*) (Woodruff et al., 2013). A review of potential effects of undersea power cables on marine species provides a summary of numerous studies of the sensitivity of various invertebrate species to electric and magnetic fields (Normandeau et al., 2011). Electric field sensitivity is reported in the summary for only two freshwater crayfish species, while magnetic field sensitivity is reported for multiple marine invertebrate species, including molluscs, crustaceans, and echinoderms. Sensitivity thresholds range from 300 to 30,000 microtesla, depending on the species. Most responses consisted of behavioral changes, although non-lethal physiological effects were noted in two sea urchin species in a 30,000 microtesla field (embryo development) and a marine mussel exposed to 300 to 700 microtesla field strength (cellular processes). Marine invertebrate community structure was not found to be affected by placement of energized underwater power cables with field strengths of 73 to 100 microtesla (Love et al., 2016). Effects to eggs of the sea urchin *Paracentrotus lividus* and to brine shrimp (*Artemia* spp.) cysts have been reported at relatively high magnetic field strengths (750 to 25,000 microtesla) (Ravera et al., 2006; Shckorbatov et al., 2010).The magnetic field generated by the Organic Airborne and Surface Influence Sweep (a typical electromagnetic device used in Navy training and testing) is about 2,300 microtesla at the source. Field strength drops quickly with distance from the source, decreasing to 50 microtesla at 4 m, 5 microtesla at 24 m, and 0.2 microtesla at 200 m from the source. Therefore, temporary disruption of navigation and directional orientation is the primary impact considered in association with magnetic fields.

Studies of the effects of low-voltage direct electrical currents in proximity to marine invertebrates suggest a beneficial impact to at least some species at appropriate current strength. American oysters (*Crassostrea virginica*) and various stony and soft corals occurring on substrates exposed to low-voltage currents (between approximately 10 and 1,000 microamperes) showed increased growth rates and survival (Arifin et al., 2012; Goreau, 2014; Jompa et al., 2012; Shorr et al., 2012). It is thought that the benefits may result from a combination of more efficient uptake of calcium and other structure-building minerals from the surrounding seawater, increased cellular energy production, and increased pH near the electrical currents. The beneficial effects were noted in a specific range of current strength; higher or lower currents resulted in either no observable effects or adverse effects. The moderate voltage and current associated with the Organic Airborne and Surface Influence Sweep are not expected to result in adverse effects to invertebrates. In addition, due to the short-term, transient nature of electromagnetic device use, there would be no beneficial effects associated with small induced electrical currents in structures colonized by invertebrates.

3.4.3.3.1.1 Impacts from In-Water Electromagnetic Devices Under Alternative 1

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), under Alternative 1, training activities involving in-water electromagnetic devices would occur in the Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes. A small number of activities could also occur in any of 13 inland water locations (Table 3.0-14, Number and Location of Activities in Inland Waters Including In-Water Electromagnetic Devices).

The impact of electromagnetic devices to marine invertebrates would depend upon the sensory capabilities of a species and the life functions that its magnetic or electric sensory systems support (Normandeau et al., 2011). The primary potential effect would be temporary directional disorientation for individuals encountering a human-produced magnetic field. For example, an individual could be confused or change its movement direction while exposed to a field. However, a limited number of studies suggest other effects such as changes in embryo development are possible within relatively strong fields for an extended time (10 to 150 minutes). Electromagnetic devices used in Alternative 1 would only affect marine invertebrates located within a few feet of the source. In addition, most electromagnetic devices are mobile and would produce detectable magnetic fields for only a short time at any given location. Further, due to the exponential drop in field strength with distance, it is unlikely that benthic invertebrates such as lobsters and crabs would be affected. For example, operation of the Organic Airborne and Surface Influence Sweep in 13 ft. water depth would produce field strength at the bottom that is an order of magnitude lower than any field strength associated with behavioral or physiological effects in the available study reports. Therefore, exposed species would be those typically found in the water column such as jellyfish, squid, and zooplankton, and mostly at night when squid and zooplankton have migrated up in the water column. Although a small number of invertebrates would be exposed to electromagnetic fields, exposure is not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

In-water electromagnetic devices would not be used in the Key West Range Complex and would therefore not expose ESA-listed coral species to electromagnetic fields. There is no overlap of electromagnetic device use in the Key West Range Complex with designated critical habitat for elkhorn and staghorn coral. Therefore, electromagnetic devices would not affect elkhorn and staghorn coral critical habitat. Pursuant to the ESA, the use of in-water electromagnetic devices during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), under Alternative 1, testing activities involving in-water electromagnetic devices would occur within the Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes. In addition, activities would occur at the Naval Undersea Warfare Center, Newport Testing Range, Naval Surface Warfare Center, Panama City Testing Range, South Florida Ocean Measurement Facility Testing Range, and one inland water location

The impact of electromagnetic devices to marine invertebrates would depend upon the sensory capabilities of a species and the life functions that it's magnetic or electric sensory systems support (Normandeau et al., 2011). The primary potential effect would be temporary directional disorientation for individuals encountering a human-produced magnetic field. For example, an individual could be confused or change its movement direction while exposed to a field. However, a limited number of studies suggest other effects such as changes in embryo development are possible within relatively strong fields for an extended time (10 to 150 minutes). Electromagnetic devices used in Alternative 1 would only affect marine invertebrates located within a few feet of the source. In addition, most electromagnetic devices are mobile and would produce detectable magnetic fields for only a short time at any given location. Further, due to the exponential drop in field strength with distance, it is unlikely that benthic invertebrates such as lobsters and crabs would be affected. For example, operation of the Organic Airborne and Surface Influence Sweep in 13 ft. water depth would produce field strength at the bottom that is an order of magnitude lower than any field strength associated with behavioral or physiological effects in the available study reports. Therefore, exposed species would be those typically found in the water column such as jellyfish, squid, and zooplankton, and mostly at night when squid and zooplankton have migrated up in the water column. Although a small number of invertebrates would be exposed to electromagnetic fields, exposure is not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

ESA-listed coral species occur in the South Florida Ocean Measurement Facility Testing Range and would have the potential to be exposed to electromagnetic fields, but the exposure from predominantly mobile sources would be very temporary and unlikely based on the narrow band of coral distribution in the testing range and navigation hazard presented by coral reefs that could be close enough to surface for exposure The electromagnetic devices used to trigger mines during testing activities are towed by helicopters near the surface and away from potential obstructions. Portions of the range are exempt from designation of elkhorn and staghorn coral critical habitat. In addition, electromagnetic devices would not affect important characteristics of critical habitat. The available research on the effects of electromagnetic energy on invertebrates suggests there would be no meaningful impact on invertebrates, including ESA-listed coral species even in the highly unlikely event of exposure for a prolonged duration. Pursuant to the ESA, the use of in-water electromagnetic devices during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.3.1.2 Impacts from In-Water Electromagnetic Devices Under Alternative 2

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1), pursuant to the ESA, the use of in-water electromagnetic devices during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.1.1 (Impacts from In-Water Electromagnetic Devices Under Alternative 1), pursuant to the ESA, the use of in-water electromagnetic devices during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.3.1.3 Impacts from In-Water Electromagnetic Devices Under the No Action Alternative

Impacts from In-Water Electromagnetic Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various energy stressors (e.g., in-water electromagnetic devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.3.2 Impacts from In-Air Electromagnetic Devices

In-air electromagnetic devices are not applicable to invertebrates because of the lack of transmission of electromagnetic radiation across the air/water interface and will not be analyzed further in this section.

3.4.3.3.3 Impacts from High-Energy Lasers

This section analyzes the potential impacts of high-energy lasers on invertebrates. As discussed in Section 3.0.3.3.3.3 (Lasers), high-energy laser weapons are designed to disable surface targets, rendering them immobile. The primary concern is the potential for an invertebrate to be struck with the laser beam at or near the water's surface, where extended exposure could result in injury or death.

Marine invertebrates could be exposed to the laser only if the beam misses the target. Should the laser strike the sea surface, individual invertebrates at or near the surface, such as jellyfish, floating eggs, and larvae could potentially be exposed. The potential for exposure to a high-energy laser beam decreases rapidly as water depth increases and with time of day, as many zooplankton species migrate away from the surface during the day. Most marine invertebrates are not susceptible to laser exposure because they occur beneath the sea surface.

3.4.3.3.3.1 Impacts from High-Energy Lasers Under Alternative 1

Impacts from High-Energy Lasers Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.3.3 (Lasers), under Alternative 1, training activities involving high-energy lasers would occur within the Virginia Capes and Jacksonville Range Complexes. Invertebrates that do not occur at or near the sea surface would not be exposed due to the attenuation of laser energy with depth. Surface invertebrates such as squid, jellyfish, and zooplankton (which may include invertebrate larvae) exposed to high-energy lasers could be injured or killed, but the probability is low based on the relatively low number of events, very localized potential impact area of the laser beam, and the temporary duration of potential impact (seconds). Activities involving high-energy lasers are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level because of the relatively small number of individuals that could be impacted.

Training activities that include high-energy lasers would not be conducted in areas where ESA-listed coral species or designated critical habitat occur. Pursuant to the ESA, the use of high-energy lasers during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from High-Energy Lasers Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.3.3 (Lasers), under Alternative 1, testing activities involving high-energy lasers would occur within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes. In addition, activities would occur within the Naval Undersea Warfare Center, Newport Testing Range, Naval Surface Warfare Center, Panama City Testing Range, and South Florida Ocean Measurement Facility Testing Range. Most activities would occur in the Virginia Capes Range Complex.

Invertebrates that do not occur at or near the sea surface would not be exposed due to the attenuation of laser energy with depth. Surface invertebrates such as squid, jellyfish, and zooplankton (which may include invertebrate larvae) exposed to high-energy lasers could be injured or killed, but the probability is low based on the relatively low number of events, very localized potential impact area of the laser beam, and the temporary duration of potential impact (seconds). Activities involving high-energy lasers are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level because of the relatively small number of individuals that could be impacted.

ESA-listed coral species occur in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range. High-energy lasers would not impact adult corals because the laser intensity would attenuate in the water column and would likely be undetectable to benthic species. Potential for impacts would be associated with eggs or larvae of ESA-listed coral species that could occur at the surface. Any eggs or larvae exposed could be injured or killed. As discussed above for invertebrates in general, the probability of impacting coral eggs or larvae is low based on the relatively low number of events, very localized potential impact area of the laser beam, and the temporary duration of potential exposure (seconds). High-energy lasers would not affect important characteristics of designated elkhorn and staghorn critical habitat. Pursuant to the ESA, the use of high-energy lasers during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.3.3.2 Impacts from High-Energy Lasers Under Alternative 2

Impacts from High-Energy Lasers Under Alternative 2 for Training Activities

The locations, number of events, and potential effects associated with high-energy lasers would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.3.1 (Impacts from High-Energy Lasers Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.1.1 (In-Water Electromagnetic Devices Under Alternative 1), pursuant to the ESA, the use of high-energy lasers during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from High-Energy Lasers Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with high-energy lasers would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.3.3.1 (Impacts from High-Energy Lasers Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.3.3.1 (Impacts from High-Energy Lasers Under Alternative 1), pursuant to the ESA, the use of high-energy lasers during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.3.3.3 Impacts from High-Energy Lasers Under the No Action Alternative

Impacts from High-Energy Lasers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. High-energy laser use is not a part of ongoing Navy activities in the Study Area and this energy stressor would not be introduced into the marine environment under the No Action Alternative. Therefore, no change in baseline conditions of the existing environment would occur.

3.4.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts of the various types of physical disturbance and strike stressors that could result from Navy training and testing activities within the Study Area. For a list of locations and numbers of activities that may cause physical disturbance and strikes refer to Section 3.0.3.3.4 (Physical Disturbance and Strike Stressors). Aspects of physical disturbance and strike stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.3 (Conceptual Framework for Assessing Effects from Physical Disturbance or Strike). The physical disturbance and strike stressors that may impact marine invertebrates include: (1) vessels and in-water devices, (2) military expended materials, (3) seafloor devices, and (4) pile driving.

Most marine invertebrate populations extend across wide areas containing hundreds or thousands of discrete patches of suitable habitat. Sessile invertebrate populations may be connected by complex currents that carry adults and young from place to place. Impacts to such widespread populations are difficult to quantitatively evaluate in terms of Navy training and testing activities that occur intermittently and in relatively small patches in the Study Area. Sedentary invertebrate habitats, such as hard bottom, cover enormous areas (Section 3.5, Habitats). In this context, a physical strike or disturbance would impact individual organisms directly or indirectly, but not to the extent that viability of populations or common species would be impacted.

With few exceptions, activities involving vessels and in-water devices are not intended to contact the bottom due to potential damage to equipment and the resulting safety risks for vessel personnel. The potential for strike impact and disturbance of benthic or habitat-forming marine invertebrates would result from amphibious activities, bottom-crawling unmanned underwater vehicles, military expended materials, seafloor devices, and pile driving. For environmental and safety reasons, amphibious landings and other nearshore activities would avoid areas where corals are known to occur.

With the exception of habitat-forming benthic taxa (e.g., corals, sea pens, sponges), most small invertebrate populations recover quickly from non-extractive disturbance. Many large invertebrates, such as crabs, shrimps, and clams, undergo massive disturbance during commercial and recreational harvests, storms, or beach restoration activities. Invertebrates that occur in the high-energy surf zone are typically resilient to dynamic processes of sediment erosion and accretion, although some community effects may occur due to rapid and relatively large-scale changes such as those associated with beach renourishment projects (U.S. Army Corps of Engineers, 2001).

Biogenic habitats such as shallow coral reefs, deep-water coral, and sponge communities may take decades to regrow following a strike or disturbance (Jennings & Kaiser, 1998; Precht et al., 2001). In soft-bottom areas, recovery of benthic invertebrate populations after substantial human disturbance depends on factors such as size of the area disturbed, bottom topography, hydrodynamics of the affected area, seasonality of the disturbance, and the size and typical growth rate of affected species. Most studies of the effects of beach sand nourishment projects (which a proxy for impacts due to amphibious landings) have reported initial decline in benthic invertebrate populations due to burial and increased turbidity (which may affect filter-feeding capability), but subsequent recovery over time scales of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2001, 2012; Wilber et al., 2009). Recovery is typically greatest at nourishment sites when there is a close match in grain size between the existing and supplied sediment. However, species composition may be altered in the recolonized area, and overall invertebrate biomass may not recover for many years. Researchers found that trawling off the California coast resulted in no statistical difference in the abundance of sessile or mobile benthic invertebrates (Lindholm et al., 2013). However, repeated and intense bottom fishing disturbance can result in a shift from communities dominated by relatively high-biomass individuals towards dominance by high abundance of small-sized organism (Kaiser et al., 2002). If activities are repeated at the same site, the benthic invertebrate community composition could be altered over time (years), especially for sessile invertebrates (e.g., coral). Some bottom-disturbing activities, such as mine countermeasures and neutralization training and testing, precision anchoring, and placement of the elevated causeway system, may occur in the same locations or near the same locations yearly.

3.4.3.4.1 Impacts from Vessels and In-Water Devices

Vessels

The majority of the training and testing activities under all the alternatives involve vessels. For a discussion of the types of activities that use vessels and where they are used, refer to Appendix B (Activity Stressor Matrices). See Table 3.0-16 (Representative Vessel Types, Lengths, and Speeds) for a representative list of Navy vessel types, lengths, and speeds. Figure 3.0-11 (Relative Distribution of U.S. Navy Vessel Traffic in AFTT Study Areas) depicts the relative intensity of Navy vessel use in the Study Area.

Vessels could impact adults and other life stages of marine invertebrates by directly striking organisms, or by disturbing the water column or sediments (Bishop, 2008). Species that occur at or near the surface (e.g., jellyfish, squid) would have the potential to be exposed to direct vessel strikes. Exposure to propeller-generated turbulence was found to result in mortality in a zooplankton species (the copepod

Acartia tonsa) located near the surface (Bickel et al., 2011). However, many pelagic invertebrates such as squid and zooplankton move away from the surface during the day. Many vessel hulls have a hydrodynamic shape, and pelagic marine invertebrates are therefore generally disturbed, rather than struck, as the water flows around a vessel. Zooplankton are ubiquitous in the water column and typically experience high mortality rates.

In addition to zooplankton and possibly adult invertebrates, vessel hull strikes and propeller cavitation and turbulence could displace, damage, injure, or kill invertebrate eggs and larvae in the upper portion of the water column throughout the Study Area. For example, turbulent water was found to decrease successful fertilization and resulted in abnormal development and low survival in eggs of the broadcast spawning purple sea urchin (*Strongylocentrotus purpuratus*) (Mead & Denny, 1995). In some areas, vessels could transit through water containing coral gametes, eggs, embryonic stages, or planula larvae of broadcast spawning species. These life stages would be most likely to occur in the Caribbean Sea, Gulf of Mexico, and Southeast U.S. Continental Shelf Large Marine Ecosystems. Eggs of cluster coral (*Acropora millepora*) were found to disintegrate into irregular groups or individual blastomeres when subjected to even very light shearing forces and turbulence (Heyward & Negri, 2012). Such dissociation can be beneficial through creation of more juveniles, but may also cause mortality. Early embryonic development of broadcast spawning coral species has reportedly been affected by handling of captive-reared embryos (Guest et al., 2010). Although the available information indicates that developmental stages of numerous invertebrate species could be physically impacted, broadcast-spawning invertebrates produce very high numbers of eggs and planktonic larvae that typically experience high mortality rates under normal conditions (Nybakken, 1993). Any impacts resulting from Navy vessel operation would be biologically insignificant by comparison.

Invertebrates on or near the bottom could also be affected by sediment disturbance, or direct strike during amphibious landings. The average water depth of the OPAREAs in the Study Area is 3,650 ft. Propeller wash (water displaced by propellers used for propulsion) of even the deepest draft vessels operated over the continental shelf is likely indistinguishable from the water motion associated with periodic storm events, and vessel operation in deeper waters beyond the shelf break would not affect the bottom. Therefore, the potential for vessels to disturb invertebrates on or near the bottom would occur mostly during nearshore and inshore training or testing activities, and along dredged navigation channels. Few sources of information are available on the impact of non-lethal chronic vessel disturbance to marine invertebrates. One study of seagrass-associated marine invertebrates, such as amphipods and polychaetes, found that chronic disturbance from vessel wakes resulted in the long-term displacement of some marine invertebrates from the impacted shallow-water area (Bishop, 2008). However, invertebrates that typically occur in areas associated with nearshore or inshore activities, such as shorelines, are highly resilient to vessel disturbance. They are regularly disturbed by natural processes such as high-energy waves and longshore currents, and generally recover quickly. Potential exceptions include sessile or encrusting invertebrates (primarily oysters) that occur along sheltered shorelines that are subject to a high frequency of boat propeller- or wake-induced erosion (Grizzle et al., 2002; Zabawa & Ostrom, 1980). Increased erosion of shoreline banks or suspension of bottom sediments may cause turbidity that settles on oysters and causes the oysters to ingest more non-food particles.

Non-amphibious vessels avoid contact with the bottom in order to prevent damage to the vessels and benthic habitat that supports encrusting organisms. The encrusting organisms (e.g., hard corals) living on hard substrate in the ocean are exposed to strong currents under natural conditions and would not likely be affected by propeller wash. Many activities occur in offshore areas, although small-caliber gunnery exercises, blank firing, and smoke grenade use may occur proximate to Navy homeports in Jacksonville, Florida and Norfolk, Virginia. Many Navy vessel movements in nearshore waters are concentrated in established channels and ports or predictable transit corridors, and shallow-water vessels typically operate in defined boat lanes with sufficient depths to avoid propeller or hull strikes on the bottom. Exceptions include small vessel training in navigable inland waters, where propeller movement may disturb sediments and associated benthic invertebrate communities in sheltered areas.

Activities that occur in inland waters can last from a few hours to up to 12 hours of daily movement per vessel per activity, and can involve speeds greater than 10 knots. Vessel movements in the inland waters of the Study Area occur on a more regular basis than the offshore activities, and generally occur in more confined waterways (primarily in the Lower Chesapeake Bay and James River). Information on the number and location of activities using vessels, as well as the number of hours of operation for inland waters, is provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices).

The only source of shallow-water vessel movement in the Study Area with known direct impacts to benthic invertebrates is amphibious landings, which are conducted in the Navy Cherry Point and Jacksonville Range Complexes (Appendix A, Navy Activity Descriptions). Amphibious vessels would contact the bottom in the surf zone during amphibious assault and amphibious raid operations. Benthic invertebrates of the surf zone, such as mole crabs, clams, and polychaete worms, within the disturbed area could be displaced, injured, or killed during amphibious operations. Burrowing species such as ghost shrimp are present on many beaches, and individuals in relatively shallow burrows located just above harder sand layers could be injured or killed if amphibious vessels compress the sand above them. Passage of amphibious vessels could cause some elevated turbidity in the nearshore zone seaward of the surf zone. However, the sediment along landing beaches is constantly being reworked by nearshore wave energy and, to a lesser extent (although more frequently than disturbance caused by amphibious landings), storm events. Benthic invertebrates inhabiting these areas are adapted to a naturally disturbed environment and are expected to rapidly re-colonize similarly disturbed areas by immigration and larval recruitment. Studies indicate that benthic communities of high-energy sandy beaches recover relatively quickly (typically within 2 to 7 months) following beach nourishment. Researchers found that the macrobenthic (visible organisms on the bottom) community required between 7 and 16 days to recover following excavation and removal of sand from a 200 m^2 quadrant from the intertidal zone of a sandy beach (Schoeman et al., 2000). The impacts of amphibious vehicle operations on benthic communities would therefore likely be minor, short-term, and local.

Other than organisms occurring at amphibious landing sites, invertebrates that occur on the bottom, including shallow-water corals, organisms associated with hard bottom, and deep-water corals, are not likely to be exposed to vessel strikes. Propeller movement has the potential to disrupt sediments that could affect shallow-water corals and hard bottom communities. However, shallow-water corals do not occur along the shoreline adjacent to the Navy Cherry Point or Jacksonville Range Complexes, where amphibious landings are conducted. Therefore, corals would not likely be affected by vessel movements.

In-Water Devices

Some of the training and testing activities under all the action alternatives involve the use of in-water devices such as remotely operated vehicles, unmanned surface vehicles, unmanned underwater vehicles, motorized autonomous targets, and towed devices. For a discussion of the types of activities that use in-water devices, see Appendix B (Activity Stressor Matrices). See Table 3.0-20 (Representative

Types, Sizes, and Speeds of In-Water Devices) for the types, sizes, and speeds of representative Navy in-water devices used in the Study Area.

In-water devices can operate from the water's surface to the benthic zone. The devices could potentially impact marine invertebrates by directly striking organisms or by disturbing the water column. As discussed for vessel use, most invertebrates in the water column would be disturbed, rather than struck, as water flows around a device due to the hydrodynamic shape. In addition, in-water devices are smaller than most Navy vessels, decreasing the surface area in which invertebrates could be struck. The potential for direct strike is reduced for some types of devices because they are operated at relatively low speeds (e.g., unmanned underwater vehicles, which are typically operated at speeds of 1 to 15 knots). Unmanned surface vehicles are operated at the greatest speeds (up to 50 knots or more) and therefore have greater potential to strike invertebrates. However, relatively few invertebrates occur at the surface and consist mostly of squid, jellyfish, and zooplankton. Squid and many zooplankton species move away from the surface during the day (Nybakken, 1993), when unmanned surface vehicles are typically operated. In-water devices do not normally collide with invertebrates on the bottom because the devices are operated in relatively deep water and contact with the bottom is avoided. Devices operated very near the bottom could potentially disturb sediments and associated invertebrates through propeller wash. However, such disturbance would be infrequent and would affect a small area, and disturbed areas would be quickly reoccupied by benthic invertebrates.

As discussed for vessels, zooplankton and invertebrate eggs and larvae could be displaced, damaged, injured, or killed by propeller wash or turbulence resulting from water flow around in-water devices. Effects due to turbulence would generally increase with increasing speed of the device. Many zooplankton species migrate away from the surface during the day, decreasing the potential for impacts in the upper portions of the water column. Zooplankton and planktonic eggs and larvae can be abundant in the water column and typically experience high mortality rates. The number of individuals affected would be small in comparison to overall populations, and the affected species generally exhibit rapid growth and recovery rates.

3.4.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

The number and location of activities that include vessels is shown in Table 3.0-17 (Number and Location of Activities Including Vessels) and Table 3.0-18 (Number and Location of Activities in Inland Waters Including Vessels), and the number and location of activities that include in-water devices is shown in Table 3.0-21 (Number and Location of Activities Including In-Water Devices) and Table 3.0-22 (Number and Location of Activities in Inland Waters Including In-Water Devices). The majority of Navy training activities include vessels, while a lower number of activities include in-water devices. As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), vessel operation would be widely dispersed throughout the Study Area, but would be more concentrated near ports, naval installations, and range complexes. The majority of vessel use would occur in the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. In particular, Navy training vessel traffic would be concentrated in the Northeast U.S. Continental Shelf Large Marine Ecosystem near Naval Station Norfolk in Norfolk, Virginia, and in the Southeast U.S. Continental Shelf Large Marine Ecosystem near Naval Station Mayport in Jacksonville, Florida. Vessel operation in inland waters would occur in numerous areas but would be concentrated in the Lower Chesapeake Bay and James River. Amphibious landings would be restricted to designated beaches. There is no seasonal differentiation in Navy vessel use. Large vessel movement primarily occurs within the U.S. Exclusive Economic Zone, with the majority of the traffic moving between Naval Stations Norfolk and Mayport.

Similar to vessel operation, activities involving in-water devices could be widely dispersed throughout the Study Area, but would be more concentrated near naval ports, piers, and ranges. Training activities would occur in the Northeast and Southeast U.S. Continental Shelf and Gulf of Mexico Large Marine Ecosystems, as well as the Gulf Stream Open Ocean Area. However, most events would occur within the Virginia Capes Range Complex.

As discussed in Section 3.4.3.4.1 (Impacts from Vessels and In-Water Devices), invertebrates located at or near the surface could be struck or disturbed by vessels, and invertebrates throughout the water column could be similarly affected by in-water devices. There would be a higher likelihood of vessel and in-water device strikes over the continental shelf than in the open ocean portions of the Study Area because of the concentration of activities in those areas. However, direct strikes would generally be unlikely for most species. Exceptions would include amphibious landings, where vessels contact the bottom and may directly impact invertebrates. Organisms inhabiting these areas are expected to rapidly re-colonize disturbed areas. Other than during amphibious landings, purposeful contact with the bottom would be avoided. The potential to disturb invertebrates on or near the bottom would occur mostly during vessel nearshore and onshore training activities, and along dredged navigation channels. Invertebrates that typically occur in areas associated with nearshore or onshore activities, such as shorelines, are highly resilient to vessel disturbance. Potential exceptions include sessile invertebrates that occur along sheltered shorelines that are subject to vessel-induced erosion. Propeller wash and turbulent water flow could damage or kill zooplankton and invertebrate gametes, eggs, embryonic stages, or larvae. Zooplankton, larvae, and other invertebrate life stages are abundant in the water column and impacts would be biologically insignificant by comparison. Overall, the area exposed to vessel and in-water device disturbance would be a very small portion of the surface and water column in the Study Area, and only a small number of individuals would be affected compared to overall abundance. Therefore, the impact of vessels and in-water devices on marine invertebrates would be inconsequential. Activities are not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Species that do not occur near the surface within the Study Area, including all ESA-listed coral species, would not be exposed to vessel or in-water device strikes. There is no overlap of vessels or in-water devices within designated critical habitat for elkhorn and staghorn coral (Section 3.4.2.2.1.1, Status and Management) because the vessels and devices are not expected to contact the bottom during training activities. Amphibious vehicles are an exception, but elkhorn and staghorn coral critical habitat does not include locations where amphibious vehicles come in contact. In-water devices would not be used in the Key West Range Complex. Therefore, vessels and in-water devices would not affect elkhorn and staghorn coral critical habitat. Pursuant to the ESA, the use of vessels and in-water devices during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

The number and location of activities that include vessels is shown in Table 3.0-17 (Number and Location of Activities Including Vessels) and Table 3.0-18 (Number and Location of Activities in Inland Waters Including Vessels), and the number and location of activities that include in-water devices is shown in Table 3.0-21 (Number and Location of Activities Including In-Water Devices) and Table 3.0-22

(Number and Location of Activities in Inland Waters Including In-Water Devices). As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), vessel operation would be widely dispersed throughout the Study Area, but would be more concentrated near ports, naval installations, testing ranges, and range complexes. Vessel movements would occur throughout the Study Area but would be concentrated in the Virginia Capes and Jacksonville Range Complexes. Similarly, as indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), in-water devices would be used throughout the Study Area but would be concentrated in the Virginia Capes and Jacksonville Range Complexes, and the Naval Undersea Warfare Center, Newport Testing Range.

As discussed in Section 3.4.3.4.1 (Impacts from Vessels and In-Water Devices), invertebrates located at or near the surface could be struck or disturbed by vessels, and invertebrates throughout the water column could be similarly affected by in-water devices. There would be a higher likelihood of vessel and in-water device strikes over the continental shelf than in the open ocean portions of the Study Area because of the concentration of activities in those areas. However, direct strikes would generally be unlikely for most species, particularly for benthic invertebrates due to the absence of amphibious landings. Purposeful contact with the bottom would be avoided. Propeller wash and turbulent water flow could damage or kill zooplankton and invertebrate gametes, eggs, embryonic stages, or larvae. Zooplankton, larvae, and other invertebrate life stages are abundant in the water column and impacts would be biologically insignificant by comparison. Overall, the area exposed to vessel and in-water device disturbance is a very small portion of the surface and water column in the Study Area, and only a small number of individuals would be affected compared to overall abundance. The impact of vessels and in-water devices on marine invertebrates would be inconsequential. Activities are not expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Species that do not occur near the surface within the Study Area, including all ESA-listed coral species, would not be exposed to vessel or in-water device strikes. Although some activities would be conducted in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range, there would be no overlap of vessels or in-water devices with designated critical habitat for elkhorn and staghorn coral (Section 3.4.2.2.1.1, Status and Management) because the vessels and devices do not contact the bottom. Amphibious landings are not associated with testing activities. Pursuant to the ESA, the use of vessels and in-water devices during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

<u>Impacts from Vessels and In-Water Devices Under Alternative 2 for Training Activities</u>

Under Alternative 2, potential impacts to invertebrates resulting from vessels and in-water devices associated with training activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1) for a discussion of potential impacts.

As discussed in Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1), pursuant to the ESA, the use of vessels and in-water devices during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Vessels and In-Water Devices Under Alternative 2 for Testing Activities

Under Alternative 2, potential impacts to invertebrates resulting from vessels and in-water devices associated with testing activities would be similar to those discussed for activities under Alternative 1. There would be a very small increase in vessel and in-water device use in the Study Area. However, the difference would not result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.1.1 (Impacts from Vessels and In-Water Devices Under Alternative 1), pursuant to the ESA, the use of vessels and in-water devices during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Impacts from Vessels and In-Water Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., vessels and in-water devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.4.2 Impacts from Aircraft and Aerial Targets

Impacts from aircraft and aerial targets are not applicable to invertebrates because marine invertebrates do not occur in airborne environments and will not be analyzed further in this section. Refer to Section 3.4.3.4.3 (Impacts from Military Expended Materials) for potential disturbance from fragments of aircraft and aerial targets.

3.4.3.4.3 Impacts from Military Expended Materials

This section analyzes the strike potential to invertebrates from the following categories of military expended materials: (1) all sizes of non-explosive practice munitions, (2) fragments from high-explosive munitions, (3) expendable targets and target fragments, and (4) expended materials other than munitions, such as sonobuoys, expended bathythermographs, and torpedo accessories. For a discussion of the types of activities that use military expended materials, refer to Appendix B (Activity Stressor Matrices). For information on where they are used and how many exercises would occur under each alternative, see Appendix F (Military Expended Materials and Direct Strike Impact Analyses) and Section 3.0.3.3.4.2 (Military Expended Materials). Analysis of all potential impacts of military expended materials (disturbance, strike, shading, and abrasion) on invertebrates, including ESA-listed coral species and designated critical habitat (elkhorn and staghorn coral), is included in this section. Potential impacts of military expended materials resulting from entanglement and ingestion are discussed in Sections 3.4.3.5 (Entanglement Stressors) and Section 3.4.3.6 (Ingestion Stressors).

Military expended materials are deposited throughout the Study Area. However, the majority of military expended materials are deposited within established range complexes and testing ranges. These areas of higher military expended materials deposition are generally located away from the coastline on the continental shelf and slope and beyond (e.g., abyssal plain).

Physical disturbance or strikes by military expended materials on marine invertebrates is possible at the water's surface, through the water column, and at the bottom. However, disturbance or strike impacts on marine invertebrates by military expended materials falling through the water column are not very likely because military expended materials do not generally sink rapidly enough to cause strike injury. Exposed invertebrates would likely experience only temporary displacement as the object passes by. Therefore, the discussion of military expended materials disturbance and strikes will focus on items at the water's surface and on the bottom.

Potential impacts to invertebrates generally consist of physical trauma, stress or behavioral responses, abrasion, and shading. Military expended materials may injure or kill invertebrates by directly striking individuals, causing breakage (particularly for species with exoskeletons or that build structures), crushing, or other physical trauma. Direct strike may result from the initial impact, or may occur after items fall through the water column and settle onto invertebrates or are moved along the bottom by water currents or gravity. Expended items may also bury or smother organisms although, depending on the size of the expended item relative to the animal, some mobile invertebrates may be able to move or dig out from underneath an item. In addition to physical strike, military expended materials may disturb individuals and cause them to change locations, behaviors, or activities. Disturbance could therefore result in impacts such as briefly increased energy expenditure, decreased feeding, and increased susceptibility to predation. Expended items could also cause increased turbidity that could affect filter-feeding species, although such impacts are likely to be localized and temporary. Expended items that come to rest on or near corals could cause abrasion or shading (in the case of corals that host symbiotic algae) that reduces photosynthesis in the algae, although these effects are unlikely based on the mitigation measures in place for shallow water coral reefs where symbiotic algae are present. Abrasion refers to scraping or wearing down of a supporting structure or hard body part (e.g., coral skeleton, shell) through repeated impact to the same individual or structure. Abrasion would generally be associated with military expended materials such as flexible materials (e.g., wires or cords) that become fixed in a location for some time but that are moved repeatedly over sessile invertebrates by water currents.

Military expended materials that impact the water surface could directly strike zooplankton, the gametes, embryos, and larvae of various invertebrate species (including ESA-listed corals), and a small number of adult invertebrates (e.g., squid, jellyfish, swimming crabs). However, many zooplankton and squid are absent from the surface water column during the day when most training and testing activities occur. Inert military expended materials also have the potential to impact the water and produce a large impulse which could disturb nearby invertebrates. Potential impacts to invertebrates resulting from impulsive sound and shock waves are discussed in Section 3.4.3.1 (Acoustic Stressors) and Section 3.4.3.2 (Explosive Stressors). In addition to direct strike of invertebrates and production of impulsive sound, surface water impacts could affect water conditions. Physical disruption of the water column is a localized, temporary impact and would be limited to a small area (within a radius of tens of meter) around the impact point, persisting for a few minutes.

Compared to surface waters and offshore areas, a greater number of macroinvertebrates typically occurs on the bottom and closer to shore. Benthic species of numerous marine invertebrate taxa may occur in areas affected by military expended materials, including sponges, cnidarians, worms, bryozoans, molluscs, arthropods, and echinoderms. However, some of the most sensitive benthic species (e.g., corals) are more likely to occur on hard bottom, reefs, and other hard substrates. Shallow-water corals are protected by mitigation measures from most activities that generate military expended materials.

Military expended materials that impact the bottom may affect invertebrates by strike (including injury or mortality), disturbance, burial, abrasion, or shading within the footprint of the item (the area of substrate physically covered by the item). Military expended materials may also cause physiological or behavioral reactions to individual invertebrates outside the footprint of the items. After items come to rest on the bottom, continued impacts are possible if the items are mobilized by currents or waves and damage benthic invertebrates as they move. Turbidity may also occur as water flows around deposited items. However, these impacts would generally cease when the military expended materials are incorporated into the seafloor by natural encrustation or burial processes, or become otherwise immobilized.

Sessile marine invertebrates and infauna (organisms attached to the bottom or living in the sediments) are generally more susceptible to military expended material disturbance and strike than benthic species with the ability to move relatively quickly over the bottom. Some susceptible species have fragile structures and sensitive body parts that could be damaged or covered by military expended materials (e.g., hydroids, sponges, soft corals). Military expended materials could also break hard structures such as coral skeletons and mussel beds. Shallow- and deep-water corals that build complex or fragile structures could be particularly susceptible to breakage or abrasion. Such structures are resistant to physical forces typical of ambient conditions (e.g., water currents), but not as resilient to other types of physical disturbance involving greater force. Decelerators/parachutes would be unlikely to be carried by currents onto reef structures due to the typical offshore locations of use and the sink rate of the items. Expended items may provide new colonization sites for benthic invertebrates Researchers found that military expended materials in a bombing range became covered by sedentary reef invertebrates over time (Smith & Marx, 2016). However, invertebrate species composition on artificial substrates may differ from that of the surrounding natural community.

Potential impacts to shallow-water corals, invertebrates associated with hard bottom habitat, or deep-water corals present the greatest risk of long-term damage compared with other bottom communities because: (1) many corals and hard bottom invertebrates are sessile, fragile, and particularly vulnerable; (2) many of these organisms grow slowly and could require decades to recover; and (3) military expended materials are likely to remain exposed on hard bottom communities whereas shifting sediment patterns would tend to bury military expended materials in soft bottom communities. The probability of striking deep-water corals or invertebrates located on hard bottom habitat is low, given their low percent cover on suitable habitat (see Section 3.5.2.1.2, Bottom Habitats, for a discussion of hard bottom habitat). For example, deep-water coral was present on less than 5 percent of coral rubble mounds found beyond the shelf break in the Jacksonville Range Complex (U.S. Department of the Navy, 2010b).

A few investigations have been conducted to determine the presence and, in some cases, possible impacts of military expended materials on the bottom. The results of multi-year underwater surveys at a military bombing range in the Mariana Archipelago (Pacific Ocean) provide an example of potential impacts resulting from expended munitions. Water areas were not targeted at this range; bottom impacts occurred only when the target land mass was missed or the munition bounced off the land into the water. The surveys found no overall long-term adverse impacts to corals or other invertebrates due to expended items, despite several decades of use (Smith & Marx, 2016). Numerous intact bombs and fragments were observed on the bottom. Inert 500-lb. bombs were found to disturb a bottom area of 17 m^2 each, although specific damage to invertebrates, if any, was not described. It may be presumed that invertebrates within this footprint could have been killed, injured, damaged, or displaced.

Expended items, once settled in place, appeared to become encrusted with marine growth and pose no substantial long-term threat to invertebrates. The condition of corals indicated a healthy environment, with no apparent change in species composition, distribution, size, or stress indicators. However, the results of several other studies indicate that sessile invertebrate communities growing on artificial substrate such as the expended munitions are often different than those growing on natural substrate (Burt et al., 2009; Macreadie et al., 2011; Perkol-Finkel et al., 2006; Steimle & Zetlin, 2000). A remotely operated vehicle survey of deep portions of the Jacksonville Range Complex reported only two exposed items of military expended materials in about 37,800 m of survey line distance (U.S. Department of the Navy, 2010a, 2011). However, it is important to note that the survey was not designed to document MEM and these were only the items photographed using still frames. Another extensive remotely operated vehicle survey along the continental shelf break and canyons in the northeast and mid-Atlantic region found marine debris in 81 percent of individual dives, but the items did not include any visible military expended materials (Quattrini et al., 2015). Underwater surveys of bottom areas off the Gulf coast of Florida with a presumably high potential for military expended materials (based on reported obstructions by fishermen) found no items of military origin, suggesting that expended materials may be widely distributed or may become covered by sediments (U.S. Department of the Navy, 2013). In a deep-sea trawl survey of the northern Gulf of Mexico, items of military origin were found (artillery shells and a missile), but were among the least-frequently encountered types of debris (Wei et al., 2012).

Military Expended Materials - Munitions

Military expended materials that are munitions and that are associated with training activities include small-, medium-, and large-caliber projectiles, bombs, missiles, rockets, and grenades. Fragments of exploded munitions are also included because they can result in impacts on invertebrates that are similar to smaller intact munitions. Military expended materials associated with testing activities are the same except that there are no grenades. Navy training and testing activities in the Study Area include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including small-, medium-, and large-caliber projectiles. Large-caliber projectiles are primarily used in the open ocean beyond 20 NM from shore. Direct strike from bombs, missiles, and rockets would result in types of impacts similar to those of projectiles. However, they are larger than most projectiles and are likely to produce a greater number of fragments. Bombs, missiles, and rockets are designed to explode within about 3 ft. of the sea surface, where marine invertebrates larger than zooplankton are relatively infrequent.

Military Expended Materials Other Than Munitions

Military expended materials other than munitions associated with training and testing activities include a large number of items such as aerial countermeasures, targets (surface and aerial), mine shapes, ship hulk, decelerators/parachutes, acoustic countermeasures, sonobuoys, and other materials including torpedo accessories, concrete slugs, markers, bathythermographs, and endcaps and pistons. Some expended materials are recovered, including torpedoes, unmanned aerial systems, some targets, mine shapes, metal plates, and bottom placed instruments. Expended materials associated with training and testing activities are similar but include additional items such as flares, subsurface targets, and exploding sonobuoys and mines. Recovered items are also used during some training and testing activities.

Chaff, which consists of aluminum-coated glass fibers, may be transported great distances by the wind, beyond the areas where they are deployed before contacting the sea surface. These materials contact the sea surface and bottom with very little kinetic energy, and their low buoyant weight makes them an inconsequential strike and abrasion risk. Therefore, chaff is not considered to be a potential strike and disturbance stressor.

During a sinking exercise, aircraft, ship, and submarine crews deliver munitions on a surface target, which is a clean, deactivated ship that is deliberately sunk using multiple weapon systems. Sinking exercises occur in specific open ocean areas, outside of the coastal range complexes. Habitat-forming invertebrates are likely absent where sinking exercises are planned because the activity occurs in depths greater than the range for shallow-water and many deep-water coral species (approximately 3,000 m) and away from typical locations for hydrothermal vent or cold seep communities (e.g., seamounts, Mid-Atlantic Ridge) (Cairns, 2007). It is unlikely that deep-sea hard corals could be impacted by a sinking ship hulk or fragments of a hulk due to their lack of occurrence below depths of about 3,000 m (the depth of the aragonite saturation boundary; see Section 3.4.2.1.1, Habitat Use).

Decelerators/parachutes of varying sizes are used during training and testing activities and may be deployed from aircraft or vessels. Similar to other marine debris such as derelict fishing gear, decelerators/parachutes may kill or injure sessile benthic invertebrates due to covering/shading or abrasion. Activities that expend sonobuoy and air-launched torpedo decelerators/parachutes generally occur in relatively deep water away from the shore. Because they are in the air and water column for a time span of minutes, it is improbable that a decelerator/parachute deployed over deep water could travel far enough to affect shallow-water species (e.g., shallow-water corals). In addition, decelerators/parachutes expended over deep offshore areas may impact deep-water invertebrates (particularly sessile species) by disturbance, strikes, burial, smothering, or abrasion. For example, a decelerator/parachute could cover a sponge or deep-water coral and impair filter feeding.

3.4.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

Impacts from Military Expended Materials Under Alternative 1 for Training Activities

As indicated in Appendix F (Military Expended Materials and Direct Strike Impact Analyses), under Alternative 1, areas with the greatest amount of expended materials are expected to be the Northeast and Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems, and the Gulf Stream Open Ocean Area—specifically within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes, and in other AFTT areas. In addition, military expended materials would be deposited at five inland water locations. Offshore areas with the highest number of acres impacted by military expended materials would include the Virginia Capes and Jacksonville Range Complexes, and areas used for sinking exercises. Expended materials in inland waters would include items such as concrete slugs, flares, marine markers, mine shapes, and non-explosive small-caliber munitions. Most items expended in inland waters would occur in the James River and tributaries, Lower Chesapeake Bay, and Port Canaveral, Florida.

Military expended materials (munitions and items other than munitions) have the potential to impact invertebrates at the water surface and on the bottom throughout the Study Area. As described in detail in Section 3.4.3.4.3 (Impacts from Military Expended Materials), impacts may include injury or mortality due to direct strike or burial, disturbance, and indirect effects such as increased turbidity. The potential for direct strikes of pelagic zooplankton and squid at the surface would be minimized by their decreased occurrence in surface waters during the day when activities typically occur.

As described in the discussion of proportional analysis in Section 3.5.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1), the total bottom area affected by all military expended materials in all training areas would be about 82 acres annually. This represents only thousandths of

1 percent of available bottom habitat in any range complex. The area impacted by bottom type would be 7.5 acres (hard substrate), 6.0 acres (intermediate substrate), 63.0 acres (soft substrate), and 5.5 acres (unknown substrate).The substrate types and associated invertebrate assemblages within the estimated total of disturbed area are difficult to predict, as discussed in Appendix F (Military Expended Materials and Direct Strike Impact Analyses). Activities occurring at depths of less than about 3,000 m may impact deep-water corals, particularly in the Jacksonville Range Complex where ivory tree coral is apparently more abundant. However, activities conducted in relatively deep water throughout the Study Area have the potential to impact hard bottom communities, including deep-water corals, as well as invertebrates within all other habitat types. Consequences could include damage, injury, or mortality as a result of projectiles, munitions, or other items. Decelerators/parachutes, wires, and cables could also impact benthic communities if they are mobilized by water currents, although it is expected that most such materials would become buried, encrusted, or otherwise immobilized over time and would not continue to impact individual invertebrates or invertebrate assemblages. Impacts would be most pronounced if all the materials expended within the applicable depth range were deposited on areas of hard substrate supporting long-lived, sessile organisms such as deep-water corals, because it may be assumed that many of the benthic invertebrates present in the impact area footprint would be killed, injured, displaced, or disturbed by the expended materials. In addition, some previously undisturbed bottom area would be affected by activities in subsequent years. Conversely, impacts would be less if the materials were deposited on soft-bottom areas containing invertebrate communities that recover relatively quickly from disturbance. Although hard substrate potentially supporting deep-water corals and other invertebrate communities is present on the continental shelf break and slope in at least some areas in water depths less than 3,000 m, a scenario of all expended materials being deposited on such substrate is unrealistic. A low percentage of deep substrate on the continental shelf is suitable for hard bottom communities and, based on the results of limited investigation, a low percentage of this available hard substrate may be inhabited by deep-water corals or other invertebrate species (Harter et al., 2009; U.S. Department of the Navy, 2010a). It is expected that most of the bottom type affected would be soft substrate (Appendix F, Military Expended Materials and Direct Strike Impact Analyses). Therefore, although it is possible for a portion of expended items to impact hard substrate and associated sensitive invertebrate communities, the number of exposed individuals would not likely affect the overall viability of populations or species.

The impact of military expended materials on marine invertebrates is likely to cause injury or mortality to individuals of soft-bodied species that are smaller than the military expended materials. Zooplankton could therefore be impacted by most military expended materials. Impacts to populations would likely be inconsequential because the number of individuals affected would be small relative to known population sizes, the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized and would cease when the military expended material becomes part of the bottom (e.g., buried or encrusted with sessile organisms). However, as discussed previously, research has shown that sedentary/sessile invertebrate communities growing on artificial substrate are often different than those found on natural substrates. Activities involving military expended materials are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Potentially impacted invertebrates include ESA-listed corals and species associated with sensitive habitats such as shallow- and deep-water reefs and hard bottom. Most shallow-water corals in the Study Area occur within or adjacent to the Key West Range Complex, and all ESA-listed coral species occur within the Range Complex. Critical habitat for elkhorn coral and staghorn coral also occurs in the Key West Range Complex, although small areas around Naval Air Station Key West are excluded from designation (Section 3.4.2.2.1.1, Status and Management). Training activities involving military expended materials in the Key West Range Complex could therefore impact ESA-listed corals by direct strike and could expose substrate to disturbances that could degrade the quality, and potentially the quantity, of elkhorn and staghorn coral critical habitat. Important elements of critical habitat consist of hard substrates. Wires and cables could kill or injure corals due to abrasion.

Military expended materials used in the Key West Range Complex are mostly medium-caliber projectiles, decelerators/parachutes, chaff and flares, flare o-rings, endcaps, and pistons. Recovered items consist of aerial targets and drones. Chaff and flares have minimal to no potential to substantially affects corals. With the exception of mine neutralization and countermeasures training, materials are primarily expended far from shore. Most weapons firing takes place in offshore waters away from the source of coral eggs and larvae. Decelerator/parachute interactions are unlikely because they are generally expended in water deeper than 600 ft. and would most likely not travel far enough to impact shallow-water species. It is also noted that, in a ruling on potentially listing numerous coral species under the ESA, NMFS considered human-induced physical damage such as exposure to military expended material strikes to be a "negligible to low-importance" threat to coral species and was not cited as a factor when considering listing under the ESA (Endangered and Threatened Wildlife and Plants: Proposed Listing Determinations for 82 Reef-Building Coral Species; Proposed Reclassification of *Acropora palmata* and *Acropora cervicornis* from Threatened to Endangered, 77 *Federal Register* 73219–73262 [December 7, 2012]).

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including areas inhabited by shallow-water corals.

As discussed above, potential impacts to shallow-water corals would be minimized by the offshore location of many activities involving expended materials, and by mitigation that would result in avoidance of areas potentially supporting corals for many activities. Although the likelihood of impacts is correspondingly diminished, there is some potential for corals to be exposed. Pursuant to the ESA, the use of military expended materials during training activities as described under Alternative 1 may affect ESA-listed coral species and may affect designated critical habitat for elkhorn and staghorn coral. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

As indicated in Appendix F (Military Expended Materials and Direct Strike Impact Analyses), under Alternative 1, areas that involve the use of expended materials include the Northeast and Southeast U.S. Continental Shelf Large Marine Ecosystems and the Gulf Stream Open Ocean Area—specifically within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes, and three Testing Ranges (Naval Underwater Warfare Center, Newport, Naval Surface Warfare Center, Panama City Division, and South Florida Ocean Measurement Facility).

Military expended materials (munitions and items other than munitions) have the potential to impact invertebrates at the water surface and on the bottom throughout the Study Area. As described in detail in Section 3.4.3.4.3 (Impacts from Military Expended Materials), impacts may include injury or mortality due to direct strike or burial, disturbance, and indirect effects such as increased turbidity. The potential for direct strikes of pelagic zooplankton and squid at the surface would be minimized by their decreased occurrence in surface waters during the day.

As described in the discussion of proportional analysis in Section 3.5.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1), the total bottom area affected by all military expended materials in all testing areas would 70.5 acres annually. This represents only thousandths of 1 percent of available bottom habitat in any range complex. The area impacted by bottom type would be 6.5 acres (hard substrate), 6.5 acres (intermediate substrate), 57.0 acres (soft substrate), and 0.5 acre (unknown substrate). The substrate types and associated invertebrate assemblages within the estimated total of disturbed area is difficult to predict, as discussed in Appendix F (Military Expended Materials and Direct Strike Impact Analyses). Activities occurring at depths of less than about 3,000 m may impact deep-water corals, particularly in the Jacksonville Range Complex where ivory tree coral is apparently more abundant. However, activities conducted in relatively deep water throughout the Study Area have the potential to impact hard bottom communities, including deep-water corals, as well as invertebrates within all other habitat types. Consequences could include damage, injury, or mortality as a result of projectiles, munitions, or other items. Decelerators/parachutes, wires, and cables could also impact benthic communities if they are mobilized by water currents, although it is expected that most such materials would become buried, encrusted, or otherwise immobilized over time and would not continue to impact individual invertebrates or invertebrate assemblages. Impacts would be most pronounced if all the materials expended within the applicable depth range were deposited on areas of hard substrate supporting long-lived, sessile organisms such as deep-water corals, because it may be assumed that many of the benthic invertebrates present in the impact area footprint would be killed, injured, displaced, or disturbed by the expended materials. In addition, some previously undisturbed bottom area would be affected by activities in subsequent years. Conversely, impacts would be less if the materials were deposited on soft-bottom areas containing invertebrate communities that recover relatively quickly from disturbance. Although hard substrate potentially supporting deep-water corals and other invertebrate communities is present on the continental shelf break and slope in at least some areas in water depths less than 3,000 m, a scenario of all expended materials being deposited on such substrate is unrealistic. A low percentage of deep substrate on the continental shelf is suitable for hard bottom communities and, based on the results of limited investigation, a low percentage of this available hard substrate may be inhabited by deep-water corals or other invertebrate species (U.S. Department of the Navy, 2010a). It is expected that most of the bottom type affected would be soft substrate (Appendix F, Military Expended Materials and Direct Strike Impact Analyses). Therefore, although it is possible for a portion of expended items to impact hard substrate and associated sensitive invertebrate communities, the number of exposed individuals would not likely affect the overall viability of populations or species.

The impact of military expended materials on marine invertebrates is likely to cause injury or mortality to individuals, particularly soft-bodied organisms that are smaller than the military expended materials. Zooplankton could therefore be impacted by most military expended materials. Impacts to populations would likely be inconsequential because the number of individuals affected would be small relative to known population sizes, the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized and would cease when the military expended material becomes part of the bottom (e.g., buried or encrusted with sessile organisms). However, as discussed previously, research has shown that sedentary/sessile invertebrate communities growing on artificial substrate are often different than those found on natural substrates. Activities involving military expended materials are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

Military expended materials used for testing in the Key West Range Complex consist of various sizes of projectiles (including a small number of non-explosive missiles), chaff cartridges, targets (air, surface, and subsurface), bathythermographs, sabots, explosive sonobuoys, and decelerators/parachutes. Recovered items consist of torpedoes, unmanned aerial systems, and various types of targets. Military expended materials utilized within the South Florida Ocean Measurement Facility Testing Range include projectiles, acoustic countermeasures, anchors, bathythermographs, torpedo accessories, and sabots. Materials are primarily expended far from shore. Most weapons firing takes place in offshore waters away from the source of coral eggs and larvae. Decelerator/parachute interactions are unlikely because they are generally expended in water deeper than 600 ft. and would most likely not travel far enough to impact shallow-water species.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of mapped shallow-water coral reefs. The mitigation will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including areas inhabited by shallow-water corals.

As discussed above, potential impacts to shallow-water corals would be minimized by the offshore location of many activities involving expended materials, and by mitigation that would result in avoidance of areas potentially supporting corals for many activities. Although the likelihood of impacts is correspondingly diminished, there is some potential for corals to be exposed. Pursuant to the ESA, the use of military expended materials during testing activities as described under Alternative 1 may affect ESA-listed coral species activities and may affect designated elkhorn and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

Impacts from Military Expended Materials Under Alternative 2 for Training Activities

The locations of training activities using military expended materials would be the same under Alternatives 1 and 2. The total area affected for all training activities combined would increase by less than 1 acre under Alternative 2, and therefore the potential impacts would be similar between the two alternatives. Refer to Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1), pursuant to the ESA, the use of military expended materials during training activities as described under Alternative 2 may affect ESA-listed coral species and may affect designated elkhorn coral and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

The locations of testing activities using military expended materials would be the same under Alternatives 1 and 2. The total area affected for all testing activities combined would increase by less than 1 acre under Alternative 2, and therefore the potential impacts would be similar between the two alternatives. Refer to Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.3.1 (Impacts from Military Expended Materials Under Alternative 1), pursuant to the ESA, the use of military expended materials during testing activities as described under Alternative 2 may affect ESA-listed coral species and may affect designated elkhorn coral and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.4.3.3 Impacts from Military Expended Materials Under the No Action Alternative

Impacts from Military Expended Materials Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., military expended materials) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.4.4 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 Appendix B (Activity Stressor Matrices). Seafloor devices include items that are placed on, dropped on, or moved along the substrate for a specific purpose, and include mine shapes, anchor blocks, anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom placed targets that are recovered (not expended). Placement or deployment of seafloor devices would cause disturbance, injury, or mortality to marine invertebrates within the footprint of the device. However, the number of individuals affected would be small compared to overall population numbers. These items could potentially break hard substrate and associated biogenic habitats (e.g., hard coral skeletons). However, the number of individuals affected would be small compared to overall population numbers. Objects placed on the bottom may attract invertebrates, or provide temporary attachment points for invertebrates. Some invertebrates attached to the devices would be removed from the water when the devices are recovered. A shallow depression may remain for some time in the soft bottom sediment where an anchor was dropped, potentially altering the suitability of the affected substrate for benthic invertebrates temporarily (possibly months).

Seafloor devices may also disturb marine invertebrates outside the footprint of the device, and would cause temporary (possibly hours to days) local increases in turbidity and sedimentation near the bottom, along with some changes in scouring/deposition patterns in higher current areas with soft bottom. Sedimentation can smother sessile invertebrates, while turbidity may affect respiratory organs or impair the ability of filter-feeding invertebrates to obtain food (e.g., by clogging their feeding structures or diluting the amount of food in the surrounding volume of water). However, the brief episodes of minor turbidity associated with Navy seafloor devices would be very localized and the effects do not change the substrate type. Compared to overall populations, relatively few individuals would be affected.

Precision anchoring, and the associated potential impacts, is qualitatively different than other seafloor devices because the activity involves repeated disturbance of the same soft bottom areas. Precision anchoring may result in temporary and localized disturbances to water column and bottom habitats. Anchor impact on the bottom would likely crush a small number of benthic invertebrates. Bottom disturbance would result in localized sedimentation and turbidity, which could smother invertebrates or affect respiration or feeding. Turbidity would quickly dissipate (i.e., minutes to hours) following the exercise, and many soft bottom invertebrates are burrowing organisms that would be unaffected by shallow burial. Although precision anchoring occurs in soft-bottom areas, where invertebrate populations are generally resilient to disturbance, invertebrates in designated anchorage areas may be prevented from fully recovering due to frequent and long-term use, and benthic composition may be changed compared to historical conditions.

3.4.3.4.4.1 Impacts from Seafloor Devices Under Alternative 1

Impacts from Seafloor Devices Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, seafloor devices would occur in the Northeast and Southeast U.S. Continental Shelf Large Marine Ecosystems, as well as the Gulf Stream Open Ocean Area—specifically within the Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes. Most activities using seafloor devices are conducted in the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. In addition, seafloor devices would occur in all inland water locations, but primarily in the Lower Chesapeake Bay, James River and tributaries, and Narragansett Bay.

Seafloor devices are either stationary or move very slowly along the bottom and pose little threat to highly mobile organisms such as crabs and shrimp, with the exception of individuals that might be struck as an item settles on the bottom. Sessile or less mobile benthic organisms such as sponges, sea snails, and echinoderms would be more likely to be impacted. As discussed above in Section 3.4.3.4.4 (Impacts from Seafloor Devices), impacts may include injury or mortality due to direct strike, disturbance, smothering, and impairment of respiration or filter-feeding due to increased sedimentation and turbidity. Impacts to invertebrates resulting from movement of the devices through the water column before they contact the bottom would likely consist of only temporary displacement as the object passes by.

Although intentional placement of seafloor devices on bottom structure is avoided, activities occurring at depths less than about 3,000 m may inadvertently impact deep-water corals, other invertebrates associated with hard bottom, and other marine invertebrate assemblages. However, most activities involving seafloor devices (e.g., anchors for mine shapes, light salvage targets) are typically conducted in the nearshore ocean far from deep sea corals. Most seafloor devices are operated in the nearshore environment on bottom habitats suitable for deployment and retrieval (e.g., soft or intermediate bottom). Activities in all the affected range complexes, and particularly the Jacksonville Range Complex (where ivory tree coral is more abundant) have the potential to impact hard bottom and deep-water corals. Consequences of strikes could include damage, injury, or mortality for each device, mooring, or anchor. Hard substrate potentially supporting deep-water corals and other invertebrate communities is present on the continental shelf break and slope. A low percentage of deep substrate on the continental shelf is suitable for hard bottom communities. Based on the results of limited investigation, a low percentage of available hard substrate may be inhabited by deep-water corals or other invertebrate species (Harter et al., 2009; U.S. Department of the Navy, 2010a). The number of organisms affected would not result in impacts to the viability of invertebrate populations.

During precision anchoring, impact of the anchor on the bottom would likely crush a relatively small number of benthic invertebrates. Effects associated with turbidity and sedimentation would be temporary and localized. Precision anchoring would occur from 9 to 710 times per year in the same general location, depending on the specific range complex. Therefore, although invertebrates in soft bottom areas are generally resilient to disturbance, community composition may be chronically disturbed at anchoring sites that are used repeatedly. However, the impact is likely to be inconsequential and not detectable at the population level for species occurring in the region near the anchoring locations.

In summary, the impact of seafloor devices on mostly soft bottom invertebrates is likely to cause injury or mortality to some individuals, but impacts to populations would be inconsequential because the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, and the activities are generally dispersed such that few individuals would likely be exposed to more than one event (although seafloor device use is concentrated in some areas such as anchorages and mine ranges). In addition, exposures would be localized and temporary, and the organisms most frequently impacted would be burrowing soft bottom invertebrates that are relatively resilient to localized sediment disturbance. Activities involving seafloor devices are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates that inhabit these areas, including areas inhabited by shallow-water coral species.

A relatively small number of activities involving seafloor devices would be conducted in the Key West Range Complex, where all ESA-listed coral species, as well as designated elkhorn coral and staghorn coral critical habitat, occur. Bottom-disturbing activities have the potential to impact protected coral species and critical habitat. Recovered instruments would most likely be placed on soft substrates, where shallow-water corals do not occur. Impacts to shallow-water corals would be limited to instances where seafloor devices were inadvertently used in areas of unknown hard substrate that is colonized by corals. Although unlikely, there is some potential for corals to be exposed. Pursuant to the ESA, the use of seafloor devices during training activities as described under Alternative 1 may affect ESA-listed coral species and may affect designated elkhorn and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, the use of seafloor devices would occur in the Northeast and Southeast U.S. Continental Shelf Large Marine Ecosystems, the Gulf of Mexico Large Marine Ecosystems, and the Gulf Stream Open Ocean Area—specifically within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes; Naval Undersea Warfare Center Division, Newport Testing Range, Naval Surface Warfare Center, Panama City Division Testing Range, and the South Florida Ocean Measurement Facility Testing Range; and other AFTT areas. In addition, seafloor devices would be used in two inland water locations: Little Creek and Norfolk, Virginia.

Seafloor devices are either stationary or move very slowly along the bottom and pose little threat to highly mobile organisms such as crabs and shrimp, with the exception of individuals that might be struck as an item settles on the bottom. Sessile or less mobile benthic organisms such as sponges, sea snails, and echinoderms would be more likely to be impacted. As discussed in Section 3.4.3.4.4 (Impacts from Seafloor Devices), impacts may include injury or mortality due to direct strike, disturbance, smothering, and impairment of respiration or filter-feeding due to increased sedimentation and turbidity. Impacts to invertebrates resulting from movement of the devices through the water column before they contact the bottom would likely consist of only temporary displacement as the object passes by.

In testing areas where bottom-crawling unmanned underwater vehicles are used, benthic organisms would be exposed to strike and disturbance in the relatively small area transited by the vehicles. Potential consequences of a strike by bottom-crawling unmanned underwater vehicles would be dependent upon the type of benthic invertebrate encountered. Within the Naval Undersea Warfare Center Division, Newport Testing Range and the Naval Surface Warfare Center, Panama City Division Testing Range where primarily soft bottom habitats are present, impacts would consist primarily of disturbance; burrowing invertebrates are unlikely to be injured or killed due to the pressure exerted by bottom-crawling vehicles. The largest unmanned underwater vehicle weighs 92 lb. out of the water and has a footprint of 4.8 square feet. Assuming, worst case, that the unmanned underwater vehicle's buoyant weight is 92 lb., it exerts a pressure of only 0.133 lb. per square inch. Few benthic marine invertebrates would be injured by this pressure level, particularly over soft sediments, which would compress under the invertebrate and relieve some of the pressure being exerted by the crawler.

Although intentional placement of seafloor devices on bottom structure is avoided, activities occurring at depths less than about 3,000 m may inadvertently impact deep-water corals, other invertebrates associated with hard bottom, and other marine invertebrate assemblages. Activities in the Northeast, Virginia Capes, and Gulf of Mexico Range Complex, and particularly the Jacksonville Range Complex, have the potential to impact hard bottom and deep-water corals. However, most activities involving seafloor devices (e.g., anchors for mine shapes, bottom crawlers) are typically conducted in the nearshore ocean far from deep sea corals. Most seafloor devices are operated in the nearshore environment, away from shallow-water corals and on bottom habitats suitable for deployment and retrieval (e.g., soft or intermediate bottom). Consequences of a strike could include damage, injury, or mortality for each device, mooring, or anchor. Hard substrate potentially supporting deep-water corals and other invertebrate communities is present on the continental shelf break and slope. A low percentage of deep substrate on the continental shelf is suitable for hard bottom communities. Based on the results of limited investigations, a low percentage of available hard substrate may be inhabited by deep-water corals or other invertebrate species (U.S. Department of the Navy, 2010a). Individual organisms would not likely be affected directly or indirectly to the extent that the viability of populations or species would be impacted.

The impact of seafloor devices on mostly soft bottom invertebrates is likely to cause injury or mortality to some individuals, but impacts to populations would be inconsequential because the area exposed to the stressor is extremely small relative to the area of both suitable and occupied habitats, and the activities are generally dispersed such that few individuals would likely be exposed to more than one event (although seafloor device use is concentrated in some areas such as anchorages and mine ranges). In addition, exposures would be localized and temporary, and the organisms most frequently impacted would be burrowing soft bottom invertebrates that are relatively resilient to localized sediment disturbance. Activities involving seafloor devices are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at the population level.

All ESA-listed coral species occur in the Key West Range Complex and the South Florida Ocean Measurement Facility Testing Range and would have the potential to be exposed to seafloor devices. While critical habitat for staghorn and elkhorn coral has been designated in the Key West Range Complex and within part of the shallow (less than 30 m) nearshore portion of the South Florida Ocean Measurement Facility Testing Range, testing activities that involve the use of seafloor devices mainly occur offshore in deeper water. Furthermore, the use of seafloor devices is not likely to intersect with hard substrate.

The Navy will implement mitigation to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas within the South Florida Ocean Measurement Facility, as discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources). For example, the Navy will use real-time geographic information system and global positioning system (along with remote sensing verification) during deployment, installation, and recovery of anchors and mine-like objects to avoid impacts on shallow-water coral reefs and live hard bottom. This mitigation will consequently help avoid potential impacts on invertebrates that occur in these areas.

Based on the preceding discussion, impacts to shallow-water corals would be limited to instances where seafloor devices were inadvertently used in areas of unknown hard substrate that is colonized by corals. Although unlikely, there is some potential for corals to be exposed. Pursuant to the ESA, the use of seafloor devices during testing activities as described under Alternative 1 may affect ESA-listed coral species and may affect designated elkhorn and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.4.4.2 Impacts from Seafloor Devices Under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

The locations, number and type of training activities, and potential effects associated with seafloor devices would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1), pursuant to the ESA, the use of seafloor devices during training activities as described under Alternative 2 may affect ESA-listed coral species and may affect designated elkhorn and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

The locations and type of testing activities using seafloor devices would be the same under Alternatives 1 and 2. There would be a very small increase in the number of testing activities using seafloor devices. However, the increase would not result in substantive changes to the potential for or the types of impacts on invertebrates. Refer to Section 3.4.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.4.4.1 (Impacts from Seafloor Devices Under Alternative 1), pursuant to the ESA, the use of seafloor devices during testing activities as described under Alternative 2 may affect ESA-listed coral species and may affect designated elkhorn and staghorn coral critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Impacts from Seafloor Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., seafloor devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.4.5 Impacts from Pile Driving

In this section, impacts to invertebrates resulting from pile driving and vibratory pile extraction are considered in the context of injury, mortality, or displacement that may occur due to physical strikes and disturbance. Pile driving produces impulsive sound that may also affect invertebrates. Impacts associated with impulsive sound are discussed with other acoustic stressors in Section 3.4.3.1.4 (Impacts from Pile Driving).

Installation and removal of piles could crush or injure invertebrates due to direct physical impact. Direct impacts would be most likely for sessile or slow-moving species such as bivalve molluscs, worms, and echinoderms. Individuals located near the activities but not directly impacted could be disturbed and show behavioral reactions (e.g., fleeing from the area, valve closure, changes in activity). Behavioral reactions require energy expenditure and may result in additional effects such as feeding disruption or increased exposure to predators.

Bottom disturbance resulting from pile installation and removal would result in sediment displacement and turbidity. Suspended sediment particles may affect respiratory organs or impair the ability of filter-feeding invertebrates to obtain food (e.g., by clogging their feeding structures or diluting the amount of food in the surrounding volume of water).

3.4.3.4.5.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Under Alternative 1, one event involving pile driving and removal would occur annually in the nearshore and surf zone at one of the following locations: Virginia Capes Range Complex (Joint Expeditionary Base Little Creek, Virginia or Joint Expeditionary Base Fort Story, Virginia) or Navy Cherry Point Range Complex (Marine Corps Base Camp Lejeune, North Carolina) (Section 3.0.3.3.1.3, Pile Driving). Each annual event would consist of intermittent disturbance over an estimated 20 days during installation and 10 days during removal. Invertebrates could be exposed to impact noise for a total of 60 minutes per 24-hour period during installation, and could be exposed to noise and substrate vibration for a total of 36 minutes per day during pile removal.

Invertebrates could be crushed, injured, displaced, or react behaviorally as a result of pile installation and removal. In addition, turbidity could affect respiration and feeding in some individuals. However, this activity occurs along high energy beaches where organisms are resilient to frequent sediment disturbance. During the relatively short duration that piles are in the water (less than 2 weeks per year), limited colonization of the piles by fast-growing, sedentary invertebrates would likely occur. For example, the planktonic young of sedentary invertebrates such as mussels, hydroids, bryozoans, sea squirts, and sponges could use the piles for attachment. Adults of mobile species such as crabs could use the piles for foraging or refuge. Removal of the piles would result in mortality to limited-mobility and attached sessile species, and displacement and possibly injury to more mobile species. Compared to overall population size, only a very small number of individuals would be affected. In addition, pile driving events would occur infrequently (once per year), and impacts to the sandy substrate would be recoverable. Effects to overall invertebrate populations would not be discernable.

ESA-listed coral species and critical habitat do not occur in areas proposed for pile driving. Pursuant to the ESA, the use of pile driving during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

There would be no pile driving or vibratory pile extraction associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.4.5.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

The locations, number of training events, and potential effects associated with pile driving and vibratory pile extraction would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.4.5.1 (Impacts from Pile Driving Under Alternative 1) for a discussion of impacts on invertebrates.

ESA-listed coral species and critical habitat do not occur in areas proposed for pile driving. Pursuant to the ESA, the use of pile driving during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

There would be no pile driving or vibratory pile extraction associated with testing activities. Therefore, pile driving is not analyzed in this subsection.

3.4.3.4.5.3 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.5 Entanglement Stressors

This section analyzes the potential entanglement impacts of the various types of expended materials used by the Navy during training and testing activities within the Study Area. Included are potential impacts from wires and cables, decelerators/parachutes, and biodegradable polymer. Aspects of entanglement stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.4 (Conceptual Framework for Assessing Effects from Entanglement). In this section, only potential impacts of these items as entanglement stressors are discussed. Abrasion and covering/shading impacts on sessile benthic invertebrates are discussed with physical impacts in Section 3.4.3.4.3 (Impacts from Military Expended Materials).

Marine invertebrates are likely less susceptible than vertebrates to entanglement, as illustrated by the fact that fishing nets which are designed to take pelagic marine invertebrates operate by enclosing or entrapping rather than entangling (Chuenpagdee et al., 2003). However, entanglement may be possible for some species and some expended items. A survey of marine debris entanglements found that marine invertebrates accounted for 16 percent of all animal entanglements (Ocean Conservancy, 2010). The same survey cites potential entanglement in military items only in the context of waste-handling aboard ships, and not for military expended materials. The potential for a marine invertebrate to become entangled in wires, cables, decelerators/parachutes, or biodegradable polymer is considered remote. The materials generally do not have the characteristics required to entangle marine species. Wires and cables are essentially rigid lines. Sonobuoy components may include plastic mesh and a float unit. Although mesh items have increased potential for entangling marine animals in general, and invertebrates can become entangled in nets (Ocean Conservancy, 2010), invertebrates are not particularly susceptible to entanglement in these items. Decelerators/parachutes have large openings between the cords separating the decelerator/parachute fabric from the release mechanism. There is no plausible scenario in which decelerator/parachute cords would tighten around and hold a mobile invertebrate. Decelerators/parachutes sink slowly through the water column, although many have weights attached to their lines to speed their sinking. Invertebrates in the water column with limited mobility (e.g., jellyfish, zooplankton) could be trapped in decelerator/parachute fabric as it sinks. The potential effects of decelerators/parachutes covering sessile invertebrate species on the bottom is discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials).

3.4.3.5.1 Impacts from Wires and Cables

Fiber optic cables, torpedo guidance wires, sonobuoy wires, and expendable bathythermograph wires would be expended during training and testing activities. For a discussion of the types of activities that use wires and cables, see Appendix B (Activity Stressor Matrices).

A marine invertebrate could become temporarily entangled and escape unharmed, be held tightly enough that it could be injured during its struggle to escape, be preyed upon while entangled, or starve while entangled. The probability of these outcomes cannot be predicted because interactions between invertebrate species and entanglement hazards are not well known. However, it is unlikely that an invertebrate would become entangled in wires or cables. The items would be essentially linear after deployment, as they sink through the water column. Once the items reach the bottom, they could be moved into different shapes by water currents, but the items are resistant to coiling, and the possibility of an invertebrate being ensnared is remote. The wires and cables would eventually become buried in sediment or encrusted by marine growth, which would eliminate or further reduce the entanglement potential. The small number of most items that would be expended across the Study Area would result in an extremely low rate of potential encounter for marine invertebrates. However, a comparatively large number of sonobuoy wires would be expended.

3.4.3.5.1.1 Impacts from Wires and Cables Under Alternative 1

Impacts from Wires and Cables Under Alternative 1 for Training Activities

Under Alternative 1, fiber optic cables, guidance wires, sonobuoy wires, and bathythermograph wires would be expended during sinking exercises, anti-submarine warfare activities, torpedo exercises, and various mine warfare and countermeasures exercises in the Northeast and Southeast U.S. Continental Shelf Large Marine Ecosystems as well as the Gulf Stream and North Atlantic Gyre Open Ocean Areas – specifically within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes, and within the Sink Exercise Area. The majority of expended items would be sonobuoy wires, and most of the sonobuoy wires would be expended in the Jacksonville Range Complex. The number of wires and cables expended in other areas is substantially lower.

All locations of wire and cable use potentially coincide with deep-water corals and other invertebrates associated with hard bottom areas in water depths less than 3,000 m. Items used in the Jacksonville Range Complex in particular could potentially coincide with deep-water corals and hard bottom habitat, although the portion of suitable substrate occupied by living coral is very low and coincidence with such low densities of linear materials is unlikely.

Given the number of wires and cables used compared to invertebrate population numbers, most marine invertebrates would not be exposed to a wire or cable. The impact of wires and cables on marine invertebrates is not likely to cause injury or mortality to individuals because of the rigid, linear nature of the material. Impacts to individuals and populations would be inconsequential because the area exposed to the stressor is extremely small relative to most marine invertebrates' ranges, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. Activities involving wires and cables are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

No activities using fiber optic cables, guidance wires, sonobuoy wires, or bathythermograph wires would occur in the Key West Range Complex. Therefore, there would therefore be no overlap of wires and cables with ESA-listed corals or critical habitat. Pursuant to the ESA, the use of wires and cables during training activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Wires and Cables Under Alternative 1 for Testing Activities

Under Alternative 1, activities that expend fiber optic cables, guidance wires, sonobuoy wires, and bathythermograph wires would occur in the Northeast and Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems, as well as the Gulf Stream Open Ocean Area—specifically within the Virginia Capes, Jacksonville, Key West, and Gulf of Mexico Range Complexes, and the Naval Surface Warfare Center, Panama City Testing Range, the Naval Undersea Warfare Center Division, Newport Testing Range, and the South Florida Ocean Measurement Facility Testing Range. The majority of expended items would be sonobuoy wires. Sonobuoy wires would be expended in all the range complexes but would be concentrated in the Northeast, Virginia Capes, and Jacksonville Range Complexes.

All locations of fiber optic cable, guidance wire, and sonobuoy wire use potentially coincide with deep-water corals and other invertebrates associated with hard bottom areas in water depths less than 3,000 m. Items used in the Jacksonville Range Complex in particular could potentially coincide with deep-water corals and hard bottom habitat, although the portion of suitable substrate occupied by living coral is very low and coincidence with such low densities of linear materials is unlikely.

Given the number of wires and cables used compared to invertebrate population numbers, most marine invertebrates would not be exposed to a wire or cable. The impact of wires and cables on marine invertebrates is not likely to cause injury or mortality to individuals because of the rigid, linear nature of the material. Impacts to individuals and populations would be inconsequential because the area exposed to the stressor is extremely small relative to most marine invertebrates' ranges, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. Activities involving wires and cables are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

All ESA-listed coral species, as well as designated critical habitat for elkhorn and staghorn coral, occur within the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range. A total of over 4,000 combined types of wires and cables would be expended annually in the Key West Range Complex, and a total of 70 would be expended in the South Florida Ocean Measurement Testing Range. Whereas some of these materials are associated with anti-submarine warfare and torpedo testing in deeper water seaward of typical shallow-water coral occurrence, many sonobuoy wires are associated with sonobuoy lot testing in Key West. However, it is not expected that corals would be affected by entanglement in wires or cables because there is no likely scenario in which an individual coral (adult polyp, egg, or larva) would be ensnared by a wire or cable and suffer adverse effects such as restricted movement. Potential impacts to corals, including ESA-listed species, would primarily be associated with covering, shading, breakage, and abrasion. These impacts are discussed in the context of physical disturbance and strike in Section 3.4.3.4.3 (Impacts from Military Expended Materials). Elkhorn and staghorn coral critical habitat consists of exposed hard substrate or dead coral skeleton. There is no mechanism for entanglement stressors to affect these characteristics. Therefore, entanglement stressors would not degrade the quality of elkhorn or staghorn coral critical habitat. Pursuant to the ESA, the use of wires and cables during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.5.1.2 Impacts from Wires and Cables Under Alternative 2

Impacts from Wires and Cables Under Alternative 2 for Training Activities

Under Alternative 2, the locations and types of potentially entangling expended items used would be the same as Alternative 1. There would be a small increase in the number of sonobuoy wires and bathythermograph wires expended. Most of the increase would be due to the addition of sonobuoy wire expenditures in the Gulf of Mexico Range Complex. The additional items would represent an overall increase of less than 3 percent in the total number of items expended. The difference is not expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under Alternative 1) for a discussion of potential entanglement impacts resulting from wires and cables associated with training activities.

As discussed in Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under Alternative 1), pursuant to the ESA, the use of wires and cables during training activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

Impacts from Wires and Cables Under Alternative 2 for Testing Activities

Under Alternative 2, the locations and types of potentially entangling expended items used would be the same as Alternative 1. There would be a small increase in the number of fiber optic cables and sonobuoy wires expended. Use of fiber optic cables would increase in the Virginia Capes Range Complex and Naval Surface Warfare Center, Panama City Division Testing Range; sonobuoy wire use would increase in the Northeast, Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. The additional items would represent an overall increase of less than 2 percent of the total amount of materials expended. The difference is not expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under

Alternative 1) for a discussion of potential entanglement impacts resulting from wires and cables associated with testing activities.

As discussed in Section 3.4.3.5.1.1 (Impacts from Wires and Cables Under Alternative 1), pursuant to the ESA, the use of wires and cables during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.5.1.3 Impacts from Wires and Cables Under the No Action Alternative

Impacts from Wires and Cables Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various entanglement stressors (e.g., wires and cables) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.5.2 Impacts from Decelerators/Parachutes

Decelerators/parachutes of varying sizes are used during training and testing activities. For a discussion of the types of activities that use decelerators/parachutes and the physical characteristics of these expended materials, see Section 3.0.3.3.5.2 (Decelerators/Parachutes). Aircraft-launched sonobuoys, lightweight torpedoes, submarine warfare training targets, and other devices deployed from aircraft or vessels use decelerators/parachutes that are made of cloth and nylon, and many have weights attached to the lines for rapid sinking. At water impact, the decelerator/parachute assembly is expended, and it sinks away from the unit. The decelerator/parachute assembly may remain at the surface for 5 to 15 seconds before the decelerator/parachute and its housing sink to the bottom, where it becomes flattened. Because they are in the air and water column for a time span of minutes, it is unlikely that a decelerator/parachute deployed in areas greater than 3 NM from the shore could travel far enough to affect shallow-water corals, including ESA-listed coral species. Movement of the decelerator/parachute in the water or along the bottom may break more fragile invertebrates such as deep-water corals which would also reduce suitable hard substrate for encrusting invertebrates. Deep-water coral species potentially occur everywhere that decelerator/parachute use occurs. Corals (shallow-water and deep-water) are susceptible to entanglement in decelerators/parachutes, but the principal mechanisms of damage are shading, abrasion, and breakage (refer to Section 3.4.3.4.3, Impacts from Military Expended Materials, for a discussion of these impacts). On a large enough spatial and temporal scale, these impacts could affect a sufficient number of individuals to reduce the extent of coral coverage. However, available studies suggest a very low percentage of suitable habitat is occupied by deep sea corals, making coincidence with entangling parachutes very unlikely. Refer to the affected environment section for details on the study results. In addition to corals, other sessile benthic invertebrates such as sponges, anemones, and hydrozoans could be affected by damage, burial, smothering, or abrasion.

A decelerator/parachute or attached lines sinking through the water column is unlikely to affect pelagic invertebrates. The lines would result in only temporary displacement of individuals. Most pelagic invertebrates would be too small to be ensnared, and the lines would be relatively straight as the decelerator/parachute descends, making entanglement of larger invertebrates such as jellyfish or squid highly unlikely. In addition, there are large openings between the cords. The decelerator/parachute mesh is solid, permitting only microscopic animals to pass through it. Some individuals of relatively slow-moving species (e.g., jellyfish, swimming crabs) could therefore be caught in a billowed decelerator/parachute as it sinks. However, although they are often weighted, decelerators/parachutes float relatively slowly through the water column (potential time span of minutes), and would likely impact few individuals larger than zooplankton. Any individuals trapped within the decelerator/parachute as it sinks may escape, or may remain enclosed for some time and experience potential effects similar to those described for cables and wires (e.g., injury, starvation).

3.4.3.5.2.1 Impacts from Decelerators/Parachutes Under Alternative 1

Impacts from Decelerators/Parachutes Under Alternative 1 for Training Activities

Under Alternative 1, activities involving decelerator/parachute use would occur in the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, and Key West Range Complexes, and in other AFTT areas. The vast majority of expended items would be small decelerators/parachutes; only a small number of medium and large decelerators/parachutes would be used. Most large decelerators/parachutes would be expended in the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes, but a small number would also be expended in the Key West Range Complex.

Decelerator/parachute lines could temporarily displace invertebrates in the water column but would be unlikely to ensnare individuals. Decelerator/parachute mesh could envelop invertebrates as the item sinks through the water column. Envelopment would primarily be associated with zooplankton, although other relatively slow-moving invertebrates such as jellyfish and swimming crabs could be caught in a billowed decelerator/parachute. Ensnared individuals may be injured or killed, or may eventually escape. Decelerators/parachutes on the bottom could cover benthic invertebrates, but some would likely be able to move away from the item. It is highly unlikely that an individual invertebrate would be ensnared by a decelerator/parachute on the bottom and suffer adverse effects. Decelerators/parachutes could break or abrade deep-water corals. These impacts are discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials) in the context of physical disturbance and strike.

The vast majority of marine invertebrates would not encounter a decelerator/parachute. The impact of decelerators/parachutes on marine invertebrates is not likely to cause injury or mortality to individuals, and impacts would be inconsequential because the area exposed to the stressor is extremely small relative to most marine invertebrates' ranges, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. The surface area of decelerators/parachutes expended across the Study Area is extremely small compared to the relatively low percentage of suitable substrate inhabited by deep-sea coral species, resulting in a low risk of coincidence. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. The number of individuals affected would be inconsequential compared to overall invertebrate population numbers. Activities involving decelerators/parachutes are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

A very low number of decelerators/parachutes (eight large decelerators/parachutes) would be expended in the Key West Range Complex, where all ESA-listed coral species and elkhorn and staghorn critical habitat occurs. In addition, ESA-listed coral species and elkhorn and staghorn coral critical habitat occurs in other AFTT areas (Caribbean Sea Large Marine Ecosystem). Decelerators/parachutes are typically expended in deep, offshore waters, where shallow-water corals are unlikely to occur. Impacts to ESA-listed corals could potentially occur if decelerators/parachutes were expended in areas of unmapped reef or hard bottom habitat. Decelerators/parachutes would not be expected to drift into nearshore areas due to the sink rate of the assembly. Coral eggs or larvae could be caught in a decelerator/parachute as it strikes the water surface and sinks, although microscopic organisms may be able to pass through the mesh. Individual coral polyps that are attached to hard structure would not likely be entangled in the context of being ensnared and experiencing subsequent effects such as restricted movement. Impacts would be associated with covering, shading, and abrasion that could occur to individuals or groups of individuals if a decelerator/parachute became entangled on hard structure. These impacts are discussed in the context of physical disturbance and strike in Section 3.4.3.4.3 (Impacts from Military Expended Materials). Elkhorn and staghorn coral critical habitat consists of exposed hard substrate or dead coral skeleton. There is no mechanism for entanglement stressors to affect these characteristics. Therefore, entanglement stressors would not degrade the quality of elkhorn or staghorn coral critical habitat.

Based on the discussion above, pursuant to the ESA, the use of decelerators/parachutes during training activities as described under Alternative 1 may affect ESA-listed coral species. The use of decelerators/parachutes would have no effect on designated critical habitat for elkhorn coral or staghorn coral. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Decelerators/Parachutes Under Alternative 1 for Testing Activities

Under Alternative 1, activities involving decelerators/parachute use would occur in the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes, and in the Naval Underwater Warfare Center, Newport, Naval Surface Warfare Center, Panama City, and South Florida Ocean Measurement Facility Testing Ranges. The vast majority of expended items would be small decelerators/parachutes. Only a low number of medium decelerators/parachutes would be used, and no large parachutes would be expended. Most decelerators/parachutes would be expended in the Northeast, Virginia Capes, and Jacksonville Range Complexes.

Decelerator/parachute lines could temporarily displace invertebrates in the water column but would be unlikely to ensnare individuals. Decelerator/parachute mesh could envelop invertebrates as the item sinks through the water column. Envelopment would primarily be associated with zooplankton, although other relatively slow-moving invertebrates such as jellyfish and swimming crabs could be caught in a billowed decelerator/parachute. Ensnared individuals may be injured or killed, or may eventually escape. Decelerators/parachutes on the bottom could cover benthic invertebrates, but some would likely be able to move away from the item. It is highly unlikely that an individual invertebrate would be ensnared by a decelerator/parachute on the bottom and suffer adverse effects. Decelerators/parachutes could break or abrade deep-water corals. These impacts are discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials) in the context of physical disturbance and strike.

The vast majority of marine invertebrates would not encounter a decelerator/parachute. The impact of decelerators/parachutes on marine invertebrates is not likely to cause injury or mortality to individuals, and impacts would be inconsequential because the area exposed to the stressor is extremely small relative to most marine invertebrates' ranges, the activities are dispersed such that few individuals would likely be exposed to more than one event, and exposures would be localized. The surface area of decelerators/parachutes expended across the Study Area is extremely small compared to the relatively low percentage of suitable substrate inhabited by deep-sea coral species, resulting in a low risk of coincidence. In addition, marine invertebrates are not particularly susceptible to entanglement stressors, as most would avoid entanglement and simply be temporarily disturbed. The number of individuals affected would be inconsequential compared to overall invertebrate population numbers. Activities involving decelerators/parachutes are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

A total of approximately 4,000 decelerators/parachutes (almost all of which would be small) would be expended in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range, where all ESA-listed coral species and elkhorn and staghorn critical habitat occur. Decelerators/parachutes are typically expended in deep, offshore waters, where shallow-water corals are unlikely to occur. Impacts to shallow-water corals could potentially occur if decelerators/parachutes were expended in areas of unmapped reef or hard bottom habitat. Decelerators/parachutes would not be expected to drift into nearshore areas potentially supporting corals due to the sink rate. Coral eggs or larvae could be caught in a decelerator/parachute as it strikes the water surface and sinks, although microscopic organisms may be able to pass through the mesh. Individual coral polyps that are attached to hard structure would not likely be entangled in the context of being ensnared and experiencing subsequent effects such as restricted movement. However, individuals or groups of individuals could be impacted by covering, shading, and abrasion if a decelerator/parachute became entangled on the reef structure. These impacts are discussed in the context of physical disturbance and strike in Section 3.4.3.4.3 (Impacts from Military Expended Materials). Elkhorn and staghorn coral critical habitat consists of exposed hard substrate or dead coral skeleton. There is no mechanism for entanglement stressors to affect these characteristics; impacts due to breakage of hard structures are discussed in Section 3.4.3.4.3 (Impacts from Military Expended Materials). Therefore, entanglement stressors would not degrade the quality of elkhorn or staghorn coral critical habitat.

Based on the discussion above, pursuant to the ESA, the use of decelerators/parachutes during testing activities as described under Alternative 1 may affect ESA-listed coral species. The use of decelerators/parachutes would have no effect on designated critical habitat for elkhorn coral or staghorn coral. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.5.2.2 Impacts from Decelerators/Parachutes Under Alternative 2

Impacts from Decelerators/Parachutes Under Alternative 2 for Training Activities

Under Alternative 2, the locations and number of decelerators/parachutes expended would be the same as Alternative 1, with one exception. Under Alternative 2, small decelerators/parachutes would be expended in the Gulf of Mexico Range Complex. This would result in 785 additional decelerators/parachutes expended, which represents an increase of less than 2 percent compared to Alternative 1. The difference is not expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1) for a discussion of potential entanglement impacts resulting from decelerators/parachutes associated with training activities.

As discussed in Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1), pursuant to the ESA, the use of decelerators/parachutes during training activities as described under Alternative 2 may affect ESA-listed coral species. The use of decelerators/parachutes would have no effect on designated critical habitat for elkhorn coral or staghorn coral. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Decelerators/Parachutes Under Alternative 2 for Testing Activities

Under Alternative 2, the locations of activities using decelerators/parachutes would be the same as Alternative 1. Under Alternative 2, there would be a small increase in the number of small decelerators/parachutes used. An additional 780 small decelerators/parachutes would be expended throughout the Northeast, Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. The difference represents an increase of about 2 percent and would not be expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.5.2 (Impacts from Decelerators/Parachutes) for a discussion of potential entanglement impacts resulting from decelerators/parachutes associated with testing activities.

As discussed in Section 3.4.3.5.2.1 (Impacts from Decelerators/Parachutes Under Alternative 1), pursuant to the ESA, the use of decelerators/parachutes during testing activities as described under Alternative 2 may affect ESA-listed coral species. The use of decelerators/parachutes would have no effect on designated critical habitat for elkhorn coral or staghorn coral. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.5.2.3 Impacts from Decelerators/Parachutes Under the No Action Alternative

Impacts from Decelerators/Parachutes Under the No Action Alternative for Training and Training Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various entanglement stressors (e.g., decelerators/parachutes) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.5.3 Impacts from Biodegradable Polymer

Biodegradable polymer is an expended item constructed of high molecular weight polymers. For a discussion of the types of activities that use biodegradable polymer material and the physical characteristics of these expended materials, see Section 3.0.3.3.5.3 (Biodegradable Polymer). Although it is unlikely that most invertebrates would become entangled in the biodegradable polymer material, entanglement risk would be conceivable for relatively large invertebrates that occur in the water column (e.g., jellyfish and squid). The material would degrade into small pieces within a few days to a few weeks, after which time the entanglement potential would cease. Impacts to pelagic invertebrates would most likely be limited to temporary displacement as the biodegradable polymer material floats past an animal. Entanglement impacts to benthic species are not expected due to the relatively rapid degradation of the items.

3.4.3.5.3.1 Impacts from Biodegradable Polymer Under Alternative 1

Impacts from Biodegradable Polymer Under Alternative 1 for Training Activities

There would be no use of biodegradable polymer associated with training activities. Therefore, biodegradable polymer is not analyzed in this subsection.

Impacts from Biodegradable Polymer Under Alternative 1 for Testing Activities

Under Alternative 1, a small number of activities would involve the use of biodegradable polymer in the Northeast, Virginia Capes, Jacksonville, Key West, and Gulf of Mexico Range Complexes, and in the Naval Undersea Warfare Center Division, Newport Testing Range. It is conceivable that relatively large pelagic invertebrates such as jellyfish would be temporarily entangled, although the probability is low due to the polymer design. The most likely effect would be temporary displacement as the material floats past an animal. Impacts to benthic species would not be expected. Activities involving biodegradable polymer would not yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction of invertebrate species at individual or population levels.

Biodegradable polymer would be used in the Key West Range Complex and could therefore potentially be transported by water currents to areas occupied by ESA-listed corals or into elkhorn and staghorn coral critical habitat. However, the polymer material would be expected to remain buoyant until substantial degradation occurs and would have little potential for entanglement of sessile corals. Coral larvae in the water column would not be entangled due to their small size relative to the polymer material. Degraded polymer material would not damage or decrease the value of critical habitat. Pursuant to the ESA, the use of biodegradable polymer during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.5.3.2 Impacts from Biodegradable Polymer Under Alternative 2

Impacts from Biodegradable Polymer Under Alternative 2 for Training Activities

There would be no use of biodegradable polymer associated with training activities. Therefore, biodegradable polymer is not analyzed in this subsection.

Impacts from Biodegradable Polymer Under Alternative 2 for Testing Activities

The locations, number of events, and potential effects associated with biodegradable polymer use would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.5.3.1 (Impacts from Biodegradable Polymer Under Alternative 1) for a discussion of the potential impacts of biodegradable polymer on invertebrates.

Biodegradable polymer would be used in the Key West Range Complex and could therefore potentially be transported by water currents to areas occupied by ESA-listed corals or into elkhorn and staghorn coral critical habitat. However, the polymer material would be expected to remain buoyant until substantial degradation occurs and would have little potential for entanglement of sessile corals. Coral larvae in the water column would not be entangled due to their small size relative to the polymer material. Degraded polymer material would not damage or decrease the value of critical habitat. Pursuant to the ESA, the use of biodegradable polymer during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species or critical habitat.

3.4.3.5.3.3 Impacts from Biodegradable Polymer Under the No Action Alternative

Impacts from Biodegradable Polymer Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed testing activities in the AFTT Study Area. Biodegradable polymer is not a part of ongoing Navy activities in the Study Area and this entanglement stressor would not be introduced into the marine environment under the No Action Alternative. Therefore, no change in baseline conditions of the existing environment would occur.

3.4.3.6 Ingestion Stressors

This section analyzes the potential ingestion impacts of the various types of military expended materials used by the Navy during training and testing activities within the Study Area, which may be broadly categorized as munitions and materials other than munitions. Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.5 (Conceptual Framework for Assessing Effects from Ingestion). The Navy expends the following types of materials that could become ingestion stressors during training and testing in the Study Area: non-explosive practice munitions (small- and medium-caliber), fragments from high-explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), and small decelerators/parachutes. Very few invertebrates are large enough to ingest intact small- and medium-caliber munitions; potential impact resulting from these items would be limited to a few taxa such as squid and octopus. Other military expended materials such as targets, large-caliber projectiles, intact training and testing bombs, guidance wires, sonobuoy tubes, and marine markers are too large for any marine invertebrate to consume and are eliminated from further discussion.

Expended materials could be ingested by marine invertebrates in all large marine ecosystems and open ocean areas. Ingestion could occur at the surface, in the water column, or at the bottom, depending on the size and buoyancy of the expended object and the feeding behavior of the animal. Floating material is more likely to be eaten by animals that may feed at or near the water surface (e.g., jellyfish, squid), while materials that sink to the bottom present a higher risk to both filter-feeding sessile (e.g., sponges) and bottom-feeding animals (e.g., crabs). Marine invertebrates are universally present in the water column, on the bottom, and within bottom sediments, but the majority of individuals (based on species richness and abundance) are smaller than a few millimeters (e.g., zooplankton, most roundworms, and most arthropods). Most military expended materials and fragments of military expended materials are too large to be ingested by marine invertebrates, and relatively large predatory or scavenging individuals are unlikely to consume an item that does not visually or chemically resemble food (Koehl et al., 2001; Polese et al., 2015). Many arthropods such as blue crab (*Callinectes sapidus*) and spiny lobster are known to discriminate between palatable and unpalatable food items inside the mouth, so in a strict sense, only items that are passed into the interior digestive tract should be considered to be ingested (Aggio et al., 2012). If expended material is ingested by marine invertebrates, the primary risk is blockage in the digestive tract. Most military expended materials are relatively inert in the marine environment, and are not likely to cause injury or mortality via chemical effects (see Section 3.4.3.7, Secondary Stressors, for more information on the chemical properties of these materials). However, pollutants (e.g., heavy metals and volatile organic compounds) may accumulate on the plastic components of some military expended materials. Plastic debris pieces collected at various locations in the North Pacific Ocean had polycyclic aromatic hydrocarbons and pesticides associated with them (Rios et al., 2007). Relatively large plastic pieces could be ingested by some species. However, filter- or deposit-feeding invertebrates have the greatest potential to ingest small plastic items, and any associated pollutants could harm the individual animal or subsequently be incorporated into the food chain.

The potential for marine invertebrates to encounter fragments of ingestible size increases as the military expended materials degrade into smaller fragments over months to decades. Intact munitions, fragments of munitions, and other items could degrade into metal and plastic pieces small enough to be consumed by indiscriminate feeders, such as some marine worms. Deposit-feeding, detritus-feeding, and filter-feeding invertebrates such as amphipods, polychaete worms, zooplankton, and mussels have been found to consume microscale plastic particles (microplastics) that form from the breakdown of larger plastic items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014; Wright et al., 2013a). Ingestion by these types of organisms is the most likely pathway for degraded military expended materials to enter the marine food web. Transfer of microplastic particles to higher trophic levels was demonstrated in one experiment (Setala et al., 2014). Ingestion of microplastics may result in physical effects such as internal abrasion and gut blockage, toxicity due to leaching of chemicals, and exposure to attached pollutants. Potentially harmful bacteria may also grow on microplastic particles (Kirstein et al., 2016). In addition, consumption of microplastics may result in decreased consumption of natural foods such as algae (Cole et al., 2013). Microplastic ingestion by marine worms was shown in one study to result in lower energy reserves (Wright et al., 2013a). Microplastic ingestion has been documented in numerous marine invertebrates (e.g., mussels, worms, mysid shrimp, bivalve molluscs, zooplankton, and scleractinian corals (Cole et al., 2013; Hall et al., 2015; Setala et al., 2016; Wright et al., 2013b). In an experiment involving pelagic and benthic marine invertebrates with different feeding methods, all species exposed to microplastic particles ingested some of the items (Setala et al., 2016). Deposit-feeding worms and an amphipod species ingested the fewest particles, while bivalves and free-swimming crustaceans ingested higher amounts. Ingestion of plastic particles may result in negative physical and chemical effects to invertebrates, although invertebrates are generally able to discharge these particles from the body. Overall population-level effects across a broad range of species are currently uncertain (Kaposi et al., 2014; Wright et al., 2013b).

Biodegradable polymer materials used during marine vessel stopping activities degrade relatively quickly as a result of microbial actions or enzymes. The material breaks down into small pieces within days to weeks, and degrades into particles small enough to dissolve in the water within weeks to months. Molecules formed during degradation can range from complex to simple products, depending on whether the polymers are natural or synthetic (Karlsson & Albertsson, 1998). Items of ingestible size would therefore be produced throughout the breakdown process. However, the products are considered environmentally benign and would be dispersed quickly to undetectable concentrations.

The most abundant military expended material of ingestible size is chaff. The materials in chaff are generally nontoxic in the marine environment except in quantities substantially larger than those any marine invertebrate would likely encounter as a result of Navy training and testing activities. Chaff fibers are composed of an aluminum alloy coating on glass fibers of silicon dioxide (Section 3.0.3.3.6.3, Military Expended Materials Other Than Munitions). Chaff is similar in form to fine human hair, and is somewhat analogous to the spicules of sponges or the siliceous cases of diatoms (Spargo et al., 1999). Many invertebrates ingest sponges, including the spicules, without suffering harm (Spargo et al., 1999). Marine invertebrates may occasionally encounter chaff fibers in the marine environment and may incidentally ingest chaff when they ingest prey or water. Literature reviews and controlled experiments suggest that chaff poses little environmental risk to marine organisms at concentrations that could reasonably occur from military training and testing (Arfsten et al., 2002; Spargo et al., 1999). Studies were conducted to determine the effects of chaff ingestion on various estuarine invertebrates occurring near a site of frequent chaff testing in Chesapeake Bay (Schiff, 1977). American oysters (various life stages), blue crabs (*Callinectes sapidus*), blue mussels (*Mytilus edulis*), and the polychaete worm *Nereis succinea* were force fed a chaff-and-food mixture daily for a few weeks at concentrations 10 to 100 times the predicted exposure level in the Bay. Although some mortality occurred in embryonic oyster larvae from 0 to 48 hours, the authors suggest confounding factors other than chaff (e.g., contaminated experimental water) as the cause. The authors reported no statistically significant mortality or effects on growth rate for any species. Because many invertebrates (e.g., crabs, shrimp) actively distinguish between food and non-food particles, the experimental design represents an unrealistic scenario with respect to the amount of chaff consumed. An investigation of sediments in portions of Chesapeake Bay exposed to aluminized chaff release for approximately 25 years found no significant increase in concentration compared to samples collected 3.7 km from the release area (Wilson et al., 2002).

As described in Section 3.4.2 (Affected Environment), many thousands of marine invertebrate species inhabit the Study Area. Most available literature regarding the effects of debris ingestion on marine invertebrates pertains to microplastics (Goldstein & Goodwin, 2013; National Oceanic and Atmospheric Administration Marine Debris Program, 2014; Wright et al., 2013a). Discussion of potential consumption of larger items is typically focused on fishes, reptiles, mammals, and birds. Consequently, it is not feasible to speculate in detail on which invertebrates in which locations might ingest all types of military expended materials. Despite the potential impacts, it is reasonable to conclude that relatively large military expended materials would not be intentionally consumed by actively foraging invertebrates unless they are attracted by other cues (e.g., visual cues such as flashing metal bits that squid might attack). Passively-feeding invertebrates (e.g., shellfish, jellyfish) may accidently ingest small particles by filtration or incidental adhesion to sticky mucus. The potential impact on invertebrates is decreased somewhat by the typical locations of high invertebrate population densities and Navy training and testing activities. Increased invertebrate densities are associated with the highest densities of microscopic plant food, which are typically located in nearshore waters in closer proximity to nutrient sources or in areas where upwelling tends to occur. Conversely, activities that generate military expended materials occur mostly seaward of nearshore water. Small deposit-feeding, detritus-feeding, and filter-feeding invertebrates would be most likely to ingest small items such as degraded plastic particles, although lobsters reportedly may also ingest microplastics (National Oceanic and Atmospheric Administration Marine Debris Program, 2014). Though ingestion is possible in some circumstances, due to the overall size and composition of military expended materials, impacts on populations would likely not be detectable.

Important physical and biological characteristics of ESA-listed coral species are defined in Section 3.4.2.2.1.2 (Habitat and Geographic Range), and generally include any hard substrate suitable for settlement. There is no established mechanism for ingestion stressors to affect important characteristics of this critical habitat and the discussion of potential consequences to critical habitat will not be carried forward. Potential impacts of military expended material on corals and critical habitat are discussed and analyzed as a physical impact in Section 3.4.3.4.3 (Impacts from Military Expended Materials).

3.4.3.6.1 Impacts from Military Expended Materials - Munitions

Ingestion of intact military expended materials that are munitions is not likely for most types of expended items because they are too large to be ingested by most marine invertebrates. Though ingestion of intact munitions or large fragments is conceivable in some circumstances (e.g., a relatively large invertebrate such as an octopus or lobster ingesting a small-caliber projectile), such a scenario is unlikely due to the animal’s ability to discriminate between food and non-food items. Indiscriminate deposit- and detritus-feeding invertebrates such as some marine worms could potentially ingest munitions fragments that have degraded to sediment size. In addition, metal particles in the water column may be taken up by suspension feeders (e.g., copepods, mussels) (Chiarelli & Roccheri, 2014; Griscom & Fisher, 2004). Although most metals do not technically dissolve in water, many react with water to form a soluble compound, and researchers often discuss these compounds in terms of dissolved metals. Investigations of silver ingestion by marine invertebrates found that the metal is less toxic when dissolved in water (Brix et al., 2012), and an investigation of metals in a nearshore area heavily influenced by industrial activities found that concentrations were substantially greater in the sediment than in the water column (Bazzi, 2014). The results of these studies suggest that suspension-feeding invertebrates could be less susceptible to impacts than invertebrates that might consume metal particles directly from the sediment.

3.4.3.6.1.1 Impacts from Military Expended Materials - Munitions Under Alternative 1

Impacts from Military Expended Materials - Munitions Under Alternative 1 for Training Activities

Under Alternative 1, military expended materials from munitions associated with training activities that could potentially be ingested include non-explosive practice munitions (small-caliber) and fragments from high-explosives. These items could be expended throughout most of the Study Area but would be concentrated in the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. Small caliber casings would also be expended in some inland waters locations, primarily in the James River and tributaries and Lower Chesapeake Bay. The number and locations of activities that expend potentially ingestible materials are provided in Appendix F (Military Expended Materials and Direct Strike Impact Analyses). A general discussion of the characteristics of ingestible materials is provided in Section 3.0.3.3.6 (Ingestion Stressors).

It is possible but unlikely that invertebrates would ingest intact munitions. Deposit- and detritus-feeding invertebrates could potentially ingest munitions fragments that have degraded to sediment size, and dissolved metals may be taken up by suspension feeders. Impacts on individuals are unlikely, and impacts on populations would probably not be detectable.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates that feed on shallow-water coral reefs.

All ESA-listed coral species occur in the Key West Range Complex. Military expended materials used in the Key West Range Complex consist of small- and medium-caliber non-explosive projectiles and a small number of missiles. The only potential impact to ESA-listed corals would be associated with ingestion of metal particles that are suspended in the water column or that may have been consumed by zooplankton on which the corals feed. With the exception of mine neutralization and countermeasures training, materials are primarily expended far from shore. Most weapons firing takes place in offshore waters away from shallow-water corals. The potential for corals to ingest degraded metal particles is considered remote. Pursuant to the ESA, the use of military expended materials that are munitions during training activities as described under Alternative 1 would have no effect on ESA-listed coral species.

Impacts from Military Expended Materials - Munitions Under Alternative 1 for Testing Activities

Under Alternative 1, military expended materials from munitions associated with testing activities that could potentially be ingested include non-explosive practice munitions (small-caliber) and fragments from high-explosives. These items could be expended throughout most of the Study Area but would be concentrated in the Virginia Capes and Jacksonville Range Complexes. The number and locations of activities that expend potentially ingestible materials are provided in Appendix F (Military Expended

Materials and Direct Strike Impact Analyses). A general discussion of the characteristic of ingestible materials in provided in Section 3.0.3.3.6 (Ingestion Stressors).

It is possible but unlikely that invertebrates would ingest intact munitions. Deposit- and detritus-feeding invertebrates could potentially ingest munitions fragments that have degraded to sediment size, and dissolved metals may be taken up by suspension feeders. Impacts on individuals are unlikely, and impacts on populations would probably not be detectable.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on invertebrates that feed on shallow-water coral reefs.

All ESA-listed coral species occur in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range. Military expended materials used in the Key West Range Complex would consist of small- and medium-caliber non-explosive projectiles, in addition to high-explosive items (torpedoes, explosive sonobuoys, large-caliber projectiles). A very small number of explosive projectiles would be used in the South Florida Ocean Measurement Facility Testing Range. As discussed for training activities, the only potential ingestion impact to ESA-listed corals would be associated with ingestion of metal particles that are suspended in the water column or that may have been consumed by zooplankton on which the corals feed. Materials are primarily expended far from shore. Most weapons firing takes place in offshore waters away from shallow-water corals. The potential for corals to ingest degraded metal particles is considered remote. Pursuant to the ESA, the use of military expended materials that are munitions during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species.

3.4.3.6.1.2 Impacts from Military Expended Materials - Munitions Under Alternative 2

Impacts from Military Expended Materials - Munitions Under Alternative 2 for Training Activities

The types and locations of expended military munitions used would be the same under Alternatives 1 and 2. Refer to Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from expended military munitions associated with training activities.

As discussed in Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials that are munitions during training activities as described under Alternative 2 would have no effect on ESA-listed coral species.

Impacts from Military Expended Materials - Munitions Under Alternative 2 for Testing Activities

The locations and types of expended military munitions would be the same under Alternatives 1 and 2. There would be an increase in the number of fragments resulting from high explosives under Alternative 2, primarily associated with about 6,000 additional large projectiles expended in the Virginia Capes Range Complex. However, this increase would not be expected to result in substantive changes to the potential for or types of impacts on invertebrates. Refer to Section 3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from expended military munitions associated with testing activities.

As discussed in Section3.4.3.6.1.1 (Impacts from Military Expended Materials - Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials that are munitions during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species.

3.4.3.6.1.3 Impacts from Military Expended Materials - Munitions Under the No Action Alternative

Impacts from Military Expended Materials - Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various ingestion stressors (e.g., military expended materials - munitions) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.6.2 Impacts from Military Expended Materials Other Than Munitions

Military expended materials other than munitions include a large number of items such as aerial countermeasures, targets (surface and aerial), mine shapes, ship hulk, small decelerators/parachutes, acoustic countermeasures, sonobuoys, and other various materials including torpedo accessories, concrete slugs, markers, bathythermographs, and endcaps and pistons. Some expended materials are recovered, including torpedoes, unmanned aerial systems, some targets, mine shapes, metal plates, and bottom placed instruments. Most expendable items, such as targets and target fragments, would sink to the bottom, while materials such as Styrofoam or degraded plastic particles could persist at the surface or in the water column for some time. Ingestion is not likely for most military expended materials because they are too large to be consumed by most marine invertebrates. Though ingestion of intact items on the bottom is conceivable in some circumstances (e.g., a relatively large invertebrate such as an octopus or lobster ingesting a small target fragment), such a scenario is unlikely due to the animal's ability to discriminate between food and non-food items. Similarly, it is unlikely that an invertebrate at the surface or in the water column would ingest a relatively large expended item as it floats or sinks through the water column.

Degradation of plastic materials could result in microplastic particles being released into the marine environment over time. Eventually, deposit-feeding, detritus-feeding, and filter-feeding invertebrates could ingest these particles, and there is potential for some of the particles to be transferred up trophic levels. Ingestion of plastic particles may result in negative physical and chemical effects to invertebrates. Invertebrates outside the Study Area could encounter microplastic particles if plastic items drift with ocean currents. Currently, overall population-level effects across a broad range of invertebrate species are uncertain (Kaposi et al., 2014). Navy training and testing activities would result in a small amount of plastic particles introduced to the marine environment compared to other sources, as many military expended materials are not composed of plastic. Non-military items are associated with the vast majority of marine debris by volume and ingestion potential (Kershaw et al., 2011).

Marine invertebrates may occasionally encounter chaff fibers in the marine environment and incidentally ingest chaff when they ingest prey or water. Literature reviews and controlled experiments suggest that chaff poses little environmental risk to marine organisms at concentrations that could reasonably occur from military training and testing (Arfsten et al., 2002; Spargo et al., 1999).

3.4.3.6.2.1 Impacts from Military Expended Materials Other Than Munitions Under Alternative 1

Impacts from Military Expended Materials Other Than Munitions Under Alternative 1 for Training Activities

Under Alternative 1, a variety of potentially ingestible military expended materials would be released to the marine environment by Navy training activities, including target fragments, chaff, canisters, and flare casings. These items could be expended throughout the Study Area, including all range complexes, other AFTT areas, and inland waters. A comparatively low number of items would be expended in most inland waters, although a relatively large quantity of items (primarily flares, o-rings, and compression pads) would occur in the James River and tributaries. The number and locations of activities that expend potentially ingestible materials are provided in Appendix F (Military Expended Materials and Direct Strike Impact Analyses). A general discussion of the characteristics of ingestible materials is provided in Section 3.0.3.3.6 (Ingestion Stressors).

Most invertebrates would not be able to ingest most intact expended items. Ingestion would be limited to small items such as chaff, and fragments of larger items such as targets. Deposit- and detritus-feeding invertebrates could potentially ingest small items that have degraded to sediment size, and suspended metals may be taken up by suspension feeders. In addition, small plastic pieces may be consumed by a wide variety of invertebrates with diverse feeding methods in the water column or on the bottom (detritivores, planktivores, deposit-feeders, filter-feeders, and suspension-feeders). Adverse effects due to metal pieces on the bottom or in the water column are unlikely. Microplastic particles could affect individuals. Although the potential effects on invertebrate populations due to microplastic ingestion are currently uncertain, Navy activities would result in a small amount of plastic particles introduced to the marine environment compared to other sources. Overall, impacts on invertebrate populations due to military expended materials other than munitions would probably not be detectable.

All ESA-listed coral species occur in the Key West Range Complex. Military expended materials used in the Key West Range Complex consist of chaff, flares, endcaps, pistons, targets, and large decelerators/parachutes. Whereas sinking materials would become unavailable to corals, floating materials (e.g., flare compression pads) would degrade over time and release suspended particles in the water column. Materials are primarily expended far from shore where shallow-water corals are not encountered, and it is unlikely that coral polyps or larvae would be impacted by ingestion of small fragments of expended items in the water column. There is potential for corals to ingest very small particles of degraded plastic items suspended in the water column. However, no information is currently available that indicates adverse effects to coral health resulting from plastic ingestion. The vast majority of plastic waste in the ocean originates from non-military sources. Pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 1 would have no effect on ESA-listed coral species.

Impacts from Military Expended Materials Other Than Munitions Under Alternative 1 for Testing Activities

Under Alternative 1, a variety of potentially ingestible military expended materials would be released to the marine environment by Navy testing activities, including target fragments, chaff, concrete slugs, sabots, and various other items. These items could be expended throughout most of the Study Area. However, expended materials other than munitions would not occur in inland waters during testing activities. The number and locations of activities that expend potentially ingestible materials are provided in Appendix F (Military Expended Materials and Direct Strike Impact Analyses). A general discussion of the characteristics of ingestible materials is provided in Section 3.0.3.3.6 (Ingestion Stressors).

Most invertebrates would not be able to ingest most intact expended items. Ingestion would be limited to small items such as chaff, and fragments of larger items. Deposit- and detritus-feeding invertebrates could potentially ingest small items that have degraded to sediment size, and suspended metals may be taken up by suspension feeders. Small plastic pieces may be consumed by invertebrates with a wide diversity of feeding methods in the water column or on the bottom. In addition, products resulting from the breakdown of biodegradable polymer would be introduced to the water column. The types of invertebrates that could ingest these particles would vary as the material degrades into smaller particles with increasing amount of time in the water. Adverse effects due to metal pieces on the bottom or in the water column are unlikely. Microplastic particles could affect individuals. Although the potential effects on invertebrate populations due to microplastic ingestion are currently uncertain, Navy activities would result in a small amount of plastic particles introduced to the marine environment compared to other sources. Overall, impacts on invertebrate populations due to military expended materials other than munitions would probably not be detectable.

All ESA-listed coral species occur in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range. Chaff, targets, mine shapes, and other items would be expended in these areas. Whereas sinking materials would become unavailable to corals, floating materials would degrade over time and release suspended particles in the water column. Materials are primarily expended far from shore where shallow-water corals are not encountered, and it is unlikely that coral polyps or larvae would be impacted by ingestion of small fragments of expended items in the water column. There is potential for corals to ingest very small particles of degraded plastic items suspended in the water column. However, no information is currently available that indicates adverse effects to coral health resulting from plastic ingestion. The vast majority of plastic waste in the ocean originates from non-military sources. Pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 1 would have no effect on ESA-listed coral species.

3.4.3.6.2.2 Impacts from Military Expended Materials Other Than Munitions Under Alternative 2

Impacts from Military Expended Materials Other Than Munitions Under Alternative 2 for Training Activities

Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. Under Alternative 2, there would be an increase in the number of some items expended, such as targets, sonobuoys, bathythermograph equipment, and small decelerators or parachutes. This relatively small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts to invertebrates. Refer to Section 3.4.3.6.2.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1) for a discussion of potential ingestion impacts resulting from military expended materials other than munitions associated with training activities.

As discussed in Section 3.4.3.6.2.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 2 would have no effect on ESA-listed coral species.

Impacts from Military Expended Materials Other Than Munitions Under Alternative 2 for Testing Activities

Under Alternative 2, the locations and types of military expended materials used would be the same as those of Alternative 1. Under Alternative 2, there would be a slight increase in the number of some items expended, such as sonobuoys, mines, and small decelerators/parachutes. This small increase in the total number of items expended would not be expected to result in substantive changes to the type or degree of impacts to invertebrates. Refer to Section 3.4.3.6.2.1 for a discussion of potential ingestion impacts resulting from military expended materials other than munitions associated with testing activities.

As discussed in Section 3.4.3.6.1.1 (Impacts from Military Expended Materials Other Than Munitions Under Alternative 1), pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 2 would have no effect on ESA-listed coral species.

3.4.3.6.2.3 Impacts from Military Expended Materials Other Than Munitions Under the No Action Alternative

Impacts from Military Expended Materials Other Than Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various ingestion stressors (e.g., military expended materials other than munitions) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.3.7 Secondary Stressors

This section analyzes potential impacts on marine invertebrates exposed to stressors indirectly through impacts on their habitat (sediment or water quality) or prey. Sediments and water are also primary constituents of marine invertebrate habitat, and clear distinctions between direct habitat impacts and indirect impacts to individual invertebrates are difficult to maintain. The assessment of potential water and sediment quality stressors refers to previous sections (Section 3.2, Sediments and Water Quality), and addresses specific activities in local environments that may affect invertebrate habitats. 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 Navy training and testing activities that could pose indirect impacts to marine invertebrates via habitat or prey include: (1) explosives, (2) explosives byproducts and unexploded munitions, (3) metals, and (4) chemicals.

Secondary or indirect stressors may impact benthic and pelagic invertebrates, gametes, eggs, and larvae by changes to sediment and water quality. Physical and biological features of ESA-listed elkhorn and staghorn coral critical habitat are defined in Section 3.4.2.2.1.2 (Habitat and Geographic Range). These characteristics can be summarized as any hard substrate of suitable quality and availability to support settlement, recruitment, and attachment at depths from mean low water to 30 m. Physical or biological features were not formally defined for these species. Exemptions from critical habitat designations include a small zone around Naval Air Station Key West, and a small area within the South Florida Ocean Measurement Facility Testing Range (Section 3.4.2.2.1.1, Status and Management). However, exemption does not preclude analysis of ESA-listed coral species. Impacts to hard substrate would not result from the introduction of metal, plastic, or chemical substances into the water column. Potential impacts are associated with physical effects such as breakage or covering of hard surfaces.

Explosives

Secondary impacts to invertebrates resulting from explosions at the surface, in the water column, or on the bottom would be associated with changes to habitat structure and effects to prey species. Most explosions on the bottom would occur in soft bottom habitat and would displace some amount of sediment, potentially resulting in cratering. However, water movement would redistribute the affected sediment over time. A small amount of sediment would be suspended in the water column temporarily (turbidity), but would resettle to the bottom. There would be no overall reduction in the surface area or volume of sediment available to benthic species that occur on the bottom or within the substrate. Activities that inadvertently result in explosions on or near hard bottom habitat or reefs could break hard structures and reduce the amount of colonizing surface available to encrusting organisms (e.g., corals, sponges).

Explosions in the water column or on the bottom could impact invertebrate prey species. At least some species of most invertebrate taxa prey upon other invertebrate species, with prey items ranging in size from zooplankton to relatively large shrimps and crabs. Therefore, in a strict sense, mortality to most invertebrate species resulting from an explosion may represent a reduction in prey to other invertebrate species. A few invertebrates such as squid and some jellyfish prey upon fish, although jellyfish capture fish passively rather than through active pursuit. Therefore, fish mortality resulting from an explosion would reduce the number of potential prey items for invertebrates that consume fish. In addition to mortality, fish located near a detonation would likely be startled and leave the area, temporarily reducing prey availability until the affected area is repopulated.

Many types of invertebrates (e.g., worms, crustaceans, sea stars) are scavengers that would feed on any vertebrate or invertebrate animal that is killed or significantly impaired by an explosion. Therefore, scavenging invertebrates that are not killed or injured themselves could benefit from physical impacts to other animals resulting from explosions in the water column or on the bottom.

Explosives Byproducts and Unexploded Munitions

High-order explosions consume most of the explosive material, leaving only small or residual amounts of explosives and combustion products. Many combustion products are common seawater constituents. All combustion products are rapidly diluted by ocean currents and circulation (see Section 3.2.3.1, Explosives and Explosives Byproducts). Explosives byproducts from high-order detonations present no indirect stressors to marine invertebrates through sediment or water. Low-order detonations and unexploded munitions present an elevated potential for effects on marine invertebrates. Deposition of undetonated explosive materials into the marine environment can be reasonably estimated by the known failure and low-order detonation rates of high-explosives (Section 3.2.3.1, Explosives and Explosives Byproducts). Explosive materials not completely consumed during a detonation from munitions disposal and mine clearing training are collected after the activities are completed; therefore, potential impacts are likely inconsequential and not detectable for these activities.

Exposure to various explosive materials in sediments and in the water column water may result in lethal and sub-lethal effects to invertebrates at relatively high concentrations. The type and magnitude of effects appear to be different among various invertebrate species and are also influenced by the type of explosive material and physical characteristics of the affected water and sediment. For example, lethal toxicity has been reported in some invertebrate species (e.g., the amphipod *Eohaustorius estuarius*), while mortality has not been found in other species, even when exposed to very high concentrations (e.g., the polychaete worm *Neanthes arenaceodentata*) (Rosen & Lotufo, 2005). Exposure to water-borne explosive materials has been found to affect reproduction or larval development in bivalve, sea urchin, and polychaete worm species (Lotufo et al., 2013). Invertebrates on the bottom may be exposed to explosive materials by ingesting contaminated sediment particles, in addition to being exposed to materials in the overlying water column or in voids in the sediment (for burrowing invertebrates). However, toxicity and other sub-lethal effects have often been associated with exposure levels (explosive material concentrations) that are unlikely to occur in marine or estuarine waters of the Study Area.

Indirect impacts of explosives and unexploded munitions on marine invertebrates via sediment are possible near the munitions. Rosen and Lotufo (2010) exposed mussels and deposit-feeding amphipods and polychaete worms to levels of trinitrotoluene (i.e., TNT) and royal demolition explosive potentially associated with a breached munition or low-order detonation. The authors found concentrations in the sediment above toxicity levels within about an inch of the materials, although no statistical increase in mortality was observed for any species. No toxicity occurred in the water column. Explosive material in the marine environment is readily degraded via several biotic and abiotic pathways, as discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts). The results of studies of explosive material deposition at munitions disposal sites and active military water ranges suggest that explosives and explosives residues pose little risk to fauna living in direct contact with munitions, and that sediment is not a significant sink for these materials (Kelley et al., 2016; Koide et al., 2016; Smith & Marx, 2016). Munitions constituents and degradation products would likely only be detectable only within a few feet of a degrading munition, and the range of toxicity could be less (inches). It has been suggested that toxicity risk to invertebrates in realistic exposure scenarios is negligible (Lotufo et al., 2013). Indirect impacts of explosives and unexploded munitions on marine invertebrates via water are likely to be inconsequential and not detectable. Most explosives and explosive degradation products have relatively low solubility in seawater. This means that dissolution occurs extremely slowly, and harmful concentrations of explosives and degradation products are not likely to accumulate except within confined spaces. Also, the low concentration of materials delivered slowly into the water column is readily diluted by ocean currents and would be unlikely to concentrate in toxic levels. Filter feeders such as sponges or some marine worms in the immediate vicinity of degrading explosives may be more susceptible to chemical byproducts. While marine invertebrates may be adversely impacted by the indirect effects of degrading explosives via water, this is unlikely in realistic scenarios.

Impacts on marine invertebrates, including zooplankton, eggs, and larvae, are likely only within a very small radius of the munition (potentially inches). These impacts may continue as the munition degrades over decades (Section 3.2.3.1, Explosives and Explosives Byproducts). Because most munitions are deployed as projectiles, multiple unexploded or low-order detonations would not likely accumulate on spatial scales as small as feet to inches; therefore, potential impacts are likely to remain local and widely separated. Explosives, explosives byproducts, and unexploded munitions would therefore generally not be present in these habitats.

Metals

Certain metals and metal-containing compounds are harmful to marine invertebrates at various concentrations above background levels (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) (Chan et al., 2012; Negri et al., 2002; Wang & Rainbow, 2008). For example, physiological effects in crabs, limpets, and mussels due to copper exposure were reported

(Brown et al., 2004), although the effects were found at concentrations substantially higher than those likely to be encountered due to Navy expended materials. Metals are introduced into seawater and sediments as a result of training and testing activities involving vessel hulks, targets, munitions, and other military expended materials (see Section 3.2.3.3, Metals). Some effects due to metals result from the concentrating effects of bioaccumulation, which is not discussed in this section. Bioaccumulation issues are discussed in the *Ecosystem Technical Report for the Atlantic Fleet Training and Testing (AFTT) Environmental Impact Statement* (U.S. Department of the Navy, 2012). Secondary effects may occur when marine invertebrates are exposed by contact with the metal, contact with trace amounts in the sediment or water (e.g., from leached metals), and ingestion of contaminated sediments. Ingested metals are toxic at substantially lower effective concentrations than metals dissolved or suspended in the water (Brix et al., 2012).

Because metals tend to precipitate out of seawater and often concentrate in sediments, potential adverse indirect impacts are much more likely via sediment than water (Zhao et al., 2012). Despite the acute toxicity of some metals (e.g., hexavalent chromium or tributyltin), concentrations above sediment levels generally considered to correlate with biological effects are rarely encountered even in previous Navy training areas such as Vieques, Puerto Rico, where deposition of metals from Navy activities is very high (Section 3.2.3.3, Metals). Researchers sampled areas associated with Vieques in which live ammunition and weapons were used and found generally low concentrations of metals in the sediment (Pait et al., 2010). Comparison with guidelines suggested by the National Oceanic and Atmospheric Administration's National Status and Trends Program showed that average metal concentrations were below threshold effects levels for all constituents except copper, and were below probable effects levels for all constituents. The concentration of munitions at Vieques is substantially greater than would occur in the AFTT Study Area. Evidence from a number of studies indicates metal contamination is very localized (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016). Impacts to invertebrates, eggs, or larvae would likely be limited to exposure in the sediment within a few inches of the object.

Concentrations of metals in sea water are orders of magnitude lower than concentrations in marine sediments. Marine invertebrates probably would not be indirectly impacted by Navy-derived toxic metals via the water, or via sediment near the object (e.g., within a few inches) because such impacts would be local and widely separated. Concentrations of metals in water are not likely to be high enough to cause injury or mortality to marine invertebrates. Metals may accumulate in marine vegetation and phytoplankton (Bilgrami & Kumar, 1997; Karthick et al., 2012). High concentrations could affect the health of these organisms and result in decreased availability as an invertebrate food source. However, due to the low concentration of metals likely to occur in the water column or in sediments resulting from Navy activities, effects would likely be undetectable.

Chemicals

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, primarily propellants and combustion products, other fuels, polychlorinated biphenyls, other chemicals associated with munitions, and simulants (Section 3.2.3.2, Chemicals Other Than Explosives). Ammonium perchlorate (a rocket and missile propellant) is the most common chemical used. Perchlorate is known to occur naturally in nitrate salts, such as from Chile, and it may be formed by atmospheric processes such as lightning and reactions between ozone and sodium chloride in the air (associated with evaporated seawater) (Dasgupta et al., 2005; Sijimol & Mohan, 2014; U.S. Environmental Protection Agency, 2014). Perchlorate may impact metabolic processes in plants and animals. Effects have been found in earthworms and aquatic (freshwater) insects (Smith, 2002;

Srinivasan & Viraraghavan, 2009), although effects specific to marine invertebrates are unknown. Other chemicals with potential for adverse effects to invertebrates include some propellant combustion products such as hydrogen cyanide and ammonia.

Potential impacts to sediments and seawater resulting from use of chemicals are discussed in Section 3.2.3.2 (Chemicals Other Than Explosives). Rockets and missiles are highly efficient at consuming perchlorate and other propellants (over 99.9 percent of perchlorate is typically consumed). Additionally, perchlorate does not readily absorb into sediments, potentially reducing the risk to deposit- and detritus-feeding invertebrates. Overall, analysis concludes that impacts to sediments and water quality would be minimal for several reasons. The size of the area affected is large, and chemicals would therefore not be concentrated. Most propellant combustion byproducts are benign, and those of concern (e.g., hydrogen cyanide) would be quickly diluted. Most propellants are consumed during normal operations, and the failure rate of munitions using propellants and other combustible materials is low. Most byproducts of torpedo fuel occur naturally in seawater, and most torpedoes are recovered after use. In addition, most constituents are readily degraded by biotic and abiotic processes. Concentrations of chemicals in sediment and water are not likely to cause injury or mortality to marine invertebrates, gametes, eggs, or larvae.

3.4.3.7.1 Impacts on Habitat

As discussed in Section 3.4.3.7 (Secondary Stressors), impacts on invertebrate habitat resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would be minor overall and the possibility of population-level impacts on marine invertebrates is remote. Explosions would temporarily disturb soft bottom sediments and could potentially damage hard structures, but the effects would likely be undetectable at the population or subpopulation level. Individuals could be killed, injured, or experience physiological effects due to exposure to metals and chemical materials (including explosives materials) in the water column or on the bottom, but these effects would be very localized. The number of individuals affected would be small compared to overall population numbers.

Deposition of metal materials would provide new hard substrate that could be colonized by encrusting invertebrates (e.g., sponges, barnacles, hydrozoans, corals). The increased area of artificial hard habitat could therefore provide a benefit to some invertebrate species. However, invertebrate communities on artificial substrate may be different than those found in adjacent natural substrate.

Explosions would not occur on known hard bottom areas. Therefore, impacts to habitat potentially supporting ESA-listed corals would be limited to activities that are inadvertently conducted on or near unknown habitat areas. Any impacts to hard structure could reduce the amount of adequate substrate available to ESA-listed corals. Hard substrate is considered an essential physical feature of elkhorn coral and staghorn coral critical habitat. Due to the possibility of inadvertent impacts to hard structure, explosions may affect ESA-listed coral species and critical habitat. The Navy will consult with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.7.2 Impacts on Prey Availability

As discussed in Section 3.4.3.7 (Secondary Stressors), impacts on invertebrate prey availability resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would likely be negligible overall and population-level impacts on marine invertebrates are not expected. Because individuals of many invertebrate taxa prey on other invertebrates, mortality resulting from explosions or exposure to metals or chemical materials would reduce the number of invertebrate prey items available. A few species prey upon fish, and explosions and exposure to metals and chemical materials could result in a minor reduction in the number of fish available. However, as discussed in Section 3.6.3.7 (Secondary Stressors), explosive materials, metals, and chemicals would have a negligible effect on fishes. Therefore, secondary effects to invertebrates due to reduced fish prey availability are unlikely. Any vertebrate or invertebrate animal killed or significantly impaired by Navy activities could potentially represent an increase in food availability for scavenging invertebrates. None of the effects described above would likely be detectable at the population or subpopulation level.

Pursuant to the ESA, potential effects to prey availability would have no effect on ESA-listed coral species.

3.4.4 Summary of Potential Impacts on Invertebrates

3.4.4.1 Combined Impacts of All Stressors Under Alternative 1

As described in Section 3.0.3.5 (Resource-Specific Impacts Analysis for Multiple Stressors), this section evaluates the potential for combined impacts of all stressors from the proposed action. The analysis and conclusions for the potential impacts from each of the individual stressors are discussed in the sections above. Stressors associated with Navy training and testing activities do not typically occur in isolation but rather occur in some combination. For example, mine neutralization activities include elements of acoustic, physical disturbance and strike, entanglement, ingestion, and secondary stressors that are all coincident in space and time. An analysis of the combined impacts of all stressors considers the potential consequences of additive stressors and synergistic stressors, as described below. This analysis makes the assumption that the majority of exposures to stressors are non-lethal, and instead focuses on consequences potentially impacting the organism's fitness (e.g., physiology, behavior, reproductive potential).

There are generally two ways that a marine invertebrate could be exposed to multiple additive stressors. The first would be if an invertebrate were exposed to multiple sources of stress from a single event or activity within a single testing or training event (e.g., a mine warfare event 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 to effects of each of the stressors and the response or lack of response to that stressor. Most of the activities proposed under Alternative 1 generally involve the use of moving platforms (e.g., ships, torpedoes) that may produce one or more stressors; therefore, if an invertebrate were within the potential impact range of those activities, it may be impacted by multiple stressors simultaneously. Individual stressors that would otherwise have minimal to no impact, may combine to have a measurable response. However, due to the wide dispersion of stressors, speed of the platforms, and general dynamic movement of many training and testing activities, it is unlikely that a pelagic or mobile marine invertebrate would occur in the potential impact range of multiple sources or sequential exercises. Impacts would be more likely to occur to sessile and slow-moving species, and in areas where training and testing activities are concentrated (e.g., in the vicinity of Naval Stations Norfolk and Mayport, the gunnery box in the Jacksonville Range Complex, the Undersea Warfare Training Range, and the Naval Surface Warfare Center, Panama City Division and Naval Undersea Warfare Center Division, Newport Testing Ranges).

Secondly, an invertebrate could be exposed to multiple training and testing activities over the course of its life. It is unlikely that mobile or migratory marine invertebrates that occur within the water column would be exposed to multiple activities during their lifespan because they are relatively short-lived, and most Navy training and testing activities impact small, widely-dispersed areas, often during the day when many pelagic invertebrates have migrated away from the surface. It is much more likely that stationary organisms or those that only move over a small range (e.g., corals, sponges, worms, and sea urchins) would be exposed to multiple stressors for a prolonged duration. A few activities occur at a fixed point (e.g., port security training, pierside sonar testing), and could potentially affect the same sessile or sedentary individual invertebrates. However, due to invertebrate distribution and lifespan, few individuals compared to overall population size would likely be affected repeatedly by the same stressor, and the impacts would be mostly non-lethal. Other Navy activities may occur in the same general area (e.g., gunnery activities), but do not occur at the same specific point each time and would therefore be unlikely to affect the same individual invertebrates.

Multiple stressors may also have synergistic effects. For example, although it has been suggested that military activities contribute substantially to coral decline, global impacts are driven primarily by synergistic impacts of pollution, overfishing, climate change, sedimentation, and naturally occurring stressors such as predator outbreaks and storms, among other factors (Ban et al., 2014; Muthukrishnan & Fong, 2014). As discussed in the analyses above, marine invertebrates are not particularly susceptible to energy, entanglement, or ingestion stressors resulting from Navy activities; therefore, the potential for Navy stressors to result in additive or synergistic consequences is most likely limited to acoustic, physical strike and disturbance, and secondary stressors. The potential synergistic interactions of multiple stressors resulting from Navy activities are largely speculative, and without data on the specific combination of multiple stressors, impacts are difficult to predict in any meaningful way. Even for shallow-water corals, an exceptionally well-studied resource, predictions of the consequences of multiple stressors are semi-quantitative and generalized predictions remain qualitative (Hughes & Connell, 1999; Norström et al., 2009).

Although potential impacts on marine invertebrate species from training and testing activities under Alternative 1 may include injury and mortality, in addition to other effects such as physiological stress, masking, and behavioral effects, the impacts are not expected to lead to long-term consequences for invertebrate populations or subpopulations. The number of invertebrates impacted is expected to be small relative to overall population sizes, and would not be expected to yield any lasting effects on the survival, growth, recruitment, or reproduction of any invertebrate species. The potential impacts anticipated on ESA-listed species from Alternative 1 are summarized in Section 3.4.5 (Endangered Species Act Determinations). For a discussion of cumulative impacts, see Chapter 4 (Cumulative Impacts). For a discussion of mitigation, see Chapter 5 (Mitigation).

3.4.4.2 Combined Impacts of All Stressors Under Alternative 2

Training and testing activities proposed under Alternative 2 would represent an increase over what is proposed for Alternative 1. However, this increase is not expected to substantially increase the potential for impacts over what is analyzed for Alternative 1. The analysis presented in Section 3.4.4.1 (Combined Impacts of All Stressors Under Alternative 1) would similarly apply to Alternative 2. The combined impacts of all stressors for training and testing activities under Alternative 2 are not expected to have deleterious impacts on the fitness of any individuals or long-term consequences to populations of marine invertebrates.

3.4.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training or testing activities in the AFTT Study Area. All stressors associated with Navy training and testing activities would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.4.5 Endangered Species Act Determinations

As described in the subsections above, some Navy training and testing activities may affect ESA-listed coral species and may affect designated elkhorn coral and staghorn coral critical habitat. The Navy will consult with NMFS as required by section 7(a)(2) of the ESA in that regard. The outcome of those consultations pursuant to ESA will be described in the Final AFTT EIS/OEIS.

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3.5 Habitats

HABITATS SYNOPSIS

The United States Department of the Navy considered all potential stressors that abiotic substrate as a habitat for marine life could potentially be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: Acoustic stressors are not applicable to habitats, due to the fact that habitats do not have hearing capabilities, and are not analyzed further in this section.
- Explosives: Most of the high-explosive military expended materials would detonate at or near the water surface. The surface area of bottom substrate affected would be a tiny fraction of the total training and testing area available in the Study Area.
- Energy: Energy stressors are not applicable to habitats because of the lack of sensitivity of habitats and are not analyzed further in this section.
- Physical Disturbance and Strike: Most seafloor devices would be placed in areas that would result in minor and temporary bottom substrate impacts. Once on the seafloor and over time, military expended material would be buried by sediment, corroded from exposure to the marine environment, or colonized by benthic organisms. The surface area of bottom substrate affected over the short-term would be a tiny fraction of the total training and testing area available in the Study Area.
- Entanglement: Entanglement stressors are not applicable because habitats do not have the ability to become “entangled” by materials. The potential for expended material to cover a substrate is discussed under the physical disturbance and strike stressor.
- Ingestion: Ingestion stressors are not applicable because habitats lack the ability to ingest; therefore, ingestion stressors are not analyzed for habitats.
- Secondary stressors: Secondary stressors are not applicable to habitats, as they are not susceptible to impacts from secondary stressors, and are not analyzed further in this section.

3.5.1 Introduction

This chapter provides the analysis of potential impacts on marine and estuarine nonliving (abiotic) substrates found in the Atlantic Fleet Training and Testing (AFTT) Study Area (Study Area). This section provides an introduction to the abiotic habitats that occur in the Study Area. The following sections describe the abiotic habitats in greater detail (Section 3.5.2, Affected Environment) and evaluate the potential impacts of testing and training activities on abiotic habitats (Section 3.5.3, Environmental Consequences). A summary of the potential impacts on abiotic habitats for each alternative is provided in Section 3.5.4 (Summary of Potential Impacts on Habitats).

The Study Area covers a range of marine and estuarine habitats, each supporting communities of organisms that may vary by season and location. The intent of this section is to cover abiotic habitat features and impacts that are not addressed in the individual living resources chapters. The water column and bottom substrate provide the necessary habitats for living resources, including those that form biotic habitats such as aquatic plant beds and coral reefs, which are discussed in other sections (e.g., Section 3.3, Vegetation; Section 3.4, Invertebrates). The potential for training or testing to impact the chemical quality of abiotic habitat is addressed in a separate chapter (Section 3.2, Sediments and Water Quality). Potential impacts to organisms and biotic habitats are covered in their respective resource sections. Potential impacts to the water column are not addressed in this section, because the effects would not be associated with a change in habitat type but rather would be limited to changes in water quality, which are addressed in Section 3.2 (Sediments and Water Quality). Therefore this section only addresses impacts to habitat substrate.

Table 3.5-1 presents the types of habitats discussed in this section in relation to the open ocean areas; large marine ecosystems; and bays, estuaries, and rivers in which they occur. Habitat types are derived from *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979), which includes a basic classification of intertidal shores, subtidal bottoms, and associated substrates. Whereas there are many classification systems spanning a range of spatial dimensions and granularity (Allee et al., 2000; Cowardin et al., 1979; Howell et al., 2010; Kendall et al., 2001; United Nations Educational Scientific and Cultural Organization, 2009; Valentine et al., 2005), there are basically three types of abiotic substrates based on the grain size of unconsolidated material: "soft bottom" (e.g., sand, mud), "intermediate" (e.g., cobble, gravel), and "hard bottom" (e.g., bedrock, boulders).

Spatial and temporal variation in abiotic substrate is created by the interplay of underlying geology, currents, and water quality at a location. The modified classification system provided in Table 3.5-1 starts at the subsystem level (e.g., intertidal shores/subtidal bottoms) and focuses analysis on a modified class level (e.g., soft shores/bottoms, intermediate shores/bottoms, hard shores/bottom) differentiating non-living substrates from the living structures on the substrate. Living structures on the substrate are termed biotic habitats, and include wetland shores, aquatic plant beds (i.e., attached macroalgae, rooted vascular plants), sedentary invertebrate beds, and reefs (e.g., corals, oysters).

Table 3.5-1: Habitat Types Within the Large Marine Ecosystems and Open Ocean of the Atlantic Fleet Training and Testing Study Area

Substrate Type	*Subtypes (Examples)*	*Open Ocean*	*Large Marine Ecosystems*	*Bays, Estuaries, and Rivers*
Intertidal Shores				
Soft Shores	Beach, Tidal Delta/Flat	–	All	All
Intermediate Shores	Cobble/Gravel, Mixed	–	Northeast U.S. Continental Shelf	All
Hard Shores	Rocky Intertidal	–	Northeast U.S. Continental Shelf, Caribbean Sea	Bath, ME; Portsmouth Naval Shipyard; Kittery, ME; coastal southern New England waters; Naval Submarine Base New London; Groton, CT
Subtidal Bottoms				
Soft bottoms	Channel, Flat, Shoal	All	All	All
Intermediate Bottom	Cobble/Gravel, Mixed	All	All	All
Hard bottom	Rocky Subtidal	All	All	All
Intertidal Shore or Subtidal Bottom				
Artificial Structures	Artificial reefs, ship wrecks, oil/gas platforms, bulkheads, and piers	All	All	All

The physical characteristics of substrates, whether they are unconsolidated and soft or hard and rocky, are key factors in structuring sedentary biological communities (Nybakken, 1993). The difference between substrates represents a viable target for the best available mapping technology (i.e., multibeam sonar) and is useful for characterizations of Navy impacts (e.g., explosive charges on soft bottom).

Differences among the physical and chemical environments of various abiotic habitats dictate both the variety and abundance of sessile marine organisms supported. The assessment in this section focuses on the potential for testing or training activities to change or modify the physical properties of abiotic substrates and their ecological functions as habitat for organisms. A physical impact on abiotic marine habitats is anticipated where training or testing activities have the potential to displace sediment, convert one substrate type into another (e.g., bedrock to unconsolidated soft bottom), alter vertical relief, or modify structural complexity.

3.5.2 Affected Environment

3.5.2.1 General Background

Abiotic marine habitats vary according to geographic location, underlying geology, hydrodynamics, atmospheric conditions, and suspended particles and associated biogenic features. Sediments may be derived from material eroded from land sources associated with coastal bluff erosion and sediment flows from creeks and rivers, which may create channels, tidal deltas, intertidal and subtidal flats, and shoals of unconsolidated material along the shorelines and estuaries.

The influence of land-based nutrients on habitat type and sediment increases with proximity to streams, bays and harbors, and nearshore waters. In the open ocean, gyres, eddies, and oceanic currents influence the distribution of organisms. Major bottom features in the offshore areas of large marine ecosystems include shelves, banks, breaks, slopes, canyons, plains, and seamounts. Geologic features such as these affect the hydrodynamics of the ocean water column (i.e., currents, gyres, upwellings) as well as living resources present. Bathymetric features of the Study Area are described in Section 3.0.2.2 (Bathymetry). The distribution of abiotic marine habitats among the large marine ecosystems and open ocean areas is described in their respective sections.

The majority of the Study Area lies outside of state waters. State waters extend from shore to 3 nautical miles (NM) throughout the Study Area, with the exception of the Gulf coast of Florida, Texas, and Puerto Rico, where state waters extend 9 NM offshore. Therefore, relatively little of the Study Area includes intertidal and shallow subtidal areas in state waters where numerous habitats are exclusively present (e.g., salt/brackish marsh, mangrove, seagrass beds, kelp forests, oyster reefs). Intertidal abiotic habitats (i.e., beaches, tidal deltas, mudflats, rocky shores) represent only a small portion of the Study Area; however, they are addressed the same as all other habitats (where those habitats overlap with naval training or testing activities).

3.5.2.1.1 Shore Habitats

3.5.2.1.1.1 Description

<u>Soft Shores</u>

Soft shores include all aquatic habitats that have three characteristics: (1) unconsolidated substrates with less than 25 percent areal cover of stones, boulders, or bedrock; (2) unconsolidated sediment composed of predominantly sand or mud; and (3) primarily intertidal water regimes (Cowardin et al., 1979). Note that a shoreline covered in vegetation (e.g., marsh) could still have a soft substrate foundation. Soft shores include beaches, tidal flats/deltas, and streambeds of the tidal riverine and estuarine systems.

Intermittent or intertidal channels of the riverine system and intertidal channels of the estuarine system are classified as streambed. Intertidal flats, also known as tidal flats or mudflats, consist of loose mud, silt, and fine sand, with organic-mineral mixtures, and are regularly exposed and flooded by the tides (Karleskint et al., 2006). Muddy and fine sediment tends to be deposited where wave energy is low, such as in sheltered bays and estuaries (Holland & Elmore, 2008). Mudflats are typically unvegetated, but may be covered with encrusting microscopic algae (e.g., diatoms) or sparsely vegetated with low-growing aquatic plants (e.g., macroalgae/seaweed, seagrass). Muddy intertidal habitat occurs most often as part of a patchwork of intertidal habitats that may include rocky shores, tidal creeks, sandy beaches, salt marshes, and mangroves. A flat area of unconsolidated sediment that is covered in aquatic plants could be considered an aquatic bed growing on soft shore habitat.

Beaches form through the interaction of waves and tides, as particles are sorted by size and are deposited along the shoreline (Karleskint et al., 2006). Wide flat beaches with fine-grained sands occur where wave energy is limited. Narrow steep beaches of coarser sand form where energy and tidal ranges are high (Speybroeck et al., 2008). Three zones characterize beach habitats: (1) dry areas above mean high water, (2) wrack lines (the area where seaweed and debris is deposited at high tide), and (3) a high-energy intertidal zone (area between high and low tide).

Intermediate Shores

Intermediate shores include all aquatic habitats with the following three characteristics: (1) substrates with at least 25 percent cover in particles smaller than stones, (2) unconsolidated substrate is predominantly gravel or cobble-sized, and (3) primarily intertidal water regimes. These areas may or may not be stable enough for attached vegetation or invertebrates, depending on overlying hydrology and water quality. Note that a shoreline covered in vegetation (e.g., macroalgae/seagrass) could still have an intermediate substrate foundation.

Hard Shores

Rocky shores include intertidal aquatic habitats characterized by bedrock, stones, and/or boulders that cover 75 percent or more of an area (Cowardin et al., 1979). Note that a shoreline covered in vegetation could still have a hard substrate foundation. Rocky intertidal shores are areas of bedrock occupying the area between high and low tide lines (Menge & Branch, 2001). Extensive rocky shorelines can be interspersed with sandy areas, estuaries, or river mouths.

Environmental gradients between hard shorelines and subtidal habitats are determined by wave action, depth, frequency of tidal inundation, and stability of substrate (Cowardin et al., 1979). Where wave energy is extreme, only rock outcrops may persist. In lower energy areas, a mixture of rock sizes will form the intertidal zone. Boulders scattered in the intertidal provide substrate for attached macroalgae and sessile invertebrates.

3.5.2.1.1.2 Distribution

Soft Shores

Mudflats occur to some extent in virtually every large marine ecosystem within the Study Area. Muddy deposits accumulate in many wave-protected pockets on the Gulf of Maine coast along the northern part of the Northeast United States (U.S.) Continental Shelf Large Marine Ecosystem, especially at the heads of bays. Extensive mudflats occur in the upper reaches of the Bay of Fundy. In the Southeast

U.S. Continental Shelf Large Marine Ecosystem, mudflats are most often associated with tidal creeks and estuaries. In the Northeast and Southeast U.S. Continental Shelf Large Marine Ecosystems, salt marshes and tidal creeks occur along the coastal margins behind barrier islands. Mudflats associated with mangroves occur on the east coast of Florida, roughly from St. Augustine to the Florida Keys, and north to Cedar Key on the west coast in the southern part of the Southeast U.S Continental Shelf Large Marine Ecosystem. Tidal deltas and intertidal flats are present along the coast of Puerto Rico and Vieques (National Ocean Service, 2011).

Sandy beaches are less abundant but do occur in the northern part of the Northeast U.S. Continental Shelf Large Marine Ecosystem, which are otherwise dominated by rocky coasts. Small pocket beaches occur within the northern Gulf of Maine, and sandy beaches are abundant on Cape Cod in the southern Gulf of Maine. Some sandy intertidal habitats occur in all the states and provinces on the Gulf of Maine coast.

The Mid- and South Atlantic coast region is protected by an almost continuous string of barrier islands, which provide sandy intertidal shores (National Ocean Service, 2011). Sandy coasts and barrier islands are common from Long Island, New York to as far south as Florida. A long arc of barrier islands known as the Outer Banks protects the shore stretching from southeastern Virginia almost to South Carolina.

Sandy intertidal habitat predominates in the Southeast U.S. Continental Shelf Large Marine Ecosystem. The east and west coasts of Florida have long stretches of sandy beaches. The West Central Barrier Chain, a series of sandy barrier islands, stretches from Anclote Key (north of Tampa Bay) south to Cape Romano and protects the west coast of Florida. Sandy beaches are present along the shoreline of Puerto Rico and Vieques.

The eastern portion of the Gulf of Mexico Large Marine Ecosystem is fringed by sandy intertidal habitat, including barrier islands off the coast of the Florida panhandle. Shorelines of the western portion of the Gulf of Mexico Large Marine Ecosystem are dominated by sand that forms broad straight beaches and barrier islands (Britton & Morton, 1998). The longest undeveloped barrier island in the world is Padre Island National Seashore in Texas, which has 70 miles of sand beaches that provide nesting ground for sea turtles, foraging ground for shorebirds, and sandy intertidal habitat for numerous other species (National Park Service, 2010). Other barrier islands continue in an arc, trending up the Texas coast (Mustang, San Jose, Matagorda, Follets, and Galveston Islands) (Britton & Morton, 1998).

Intermediate Shores

Most of the intermediate coastline of the U.S. Atlantic coast occurs in the transitional area of the Northeast U.S. Continental Shelf Large Marine Ecosystem where the mostly consolidated rocky shores primarily off of Maine give way to the sandy shores in the south (Roman et al., 2000). On the U.S. Atlantic shore, intermediate rocky and gravelly areas do not typically occur south of New York (National Ocean Service, 2011).

Hard Shores

Most of the rocky coastline of the U.S. Atlantic coast occurs from Massachusetts northward into the Gulf of Maine, in the northern part of the Northeast U.S. Continental Shelf Large Marine Ecosystem (Roman et al., 2000). Glacial terrain made of bedrock, gravel, and sediment typical of the New England coast is unique on the east coast of the United States. Rocky shorelines border training or testing activities originating from the shipyard in Bath, Maine; Portsmouth Naval Shipyard (Kittery, Maine); coastal southern New England waters; and the shipyard and Naval Submarine Base New London (Groton, Connecticut). On the U.S. Atlantic shore, rocky and gravelly areas do not typically occur south of New

York (National Ocean Service, 2011). Rocky coasts in the northern areas give way to intermediate or mixed shores and sandy shores toward the south. In the Southeast U.S. Continental Shelf Large Marine Ecosystem, sandy beaches predominate. In the Caribbean Sea, rocky bedrock shorelines are mapped along the coast of Puerto Rico and Vieques (National Ocean Service, 2011). Very little hard shores occur anywhere in the northern Gulf of Mexico.

3.5.2.1.2 Bottom Habitats

3.5.2.1.2.1 Description

Soft Bottom

Soft bottoms include all aquatic habitats with the following three characteristics: (1) at least 25 percent cover of particles smaller than stones, (2) unconsolidated sediment is predominantly mud or sand, and (3) primarily subtidal water regimes (Cowardin et al., 1979). Soft bottom forms the substrate of channels, shoals, subtidal flats, and other features of the bottom. Sandy channels emerge where strong currents connect estuarine and ocean water columns. Shoals or capes form where sand is deposited by interacting, sediment-laden currents. Subtidal flats occur between the soft shores and the channels or shoals. The continental shelf extends seaward of the shoals and inlet channels and includes relatively coarse-grained, softbottom habitats. Relatively finer-grained sediments collect off the shelf break, continental slope, and abyssal plain. Organisms characteristic of soft bottom environments, such as worms and clams, may be found at all depths where there is sufficient oxygen and sediment accumulation (Nybakken, 1993).

Intermediate Bottom

Intermediate bottom includes all aquatic habitats with the following three characteristics: (1) substrates with at least 25 percent cover in particles smaller than stones, (2) unconsolidated substrate is predominantly gravel or cobble-sized, and (3) primarily subtidal water regimes. These areas may or may not be stable enough for attached vegetation or sedentary invertebrates, depending on overlying hydrology and water quality.

Hard Bottom

Hard bottom includes all aquatic habitats with substrates having a surface of stones, boulders, or bedrock (75 percent or greater coverage) (Cowardin et al., 1979). Subtidal rocky habitat occurs as extensions of intertidal rocky shores and as isolated offshore outcrops. The shapes and textures of the larger rock assemblages and the fine details of cracks and crevices are determined by the type of rock, the wave energy, and other local variables (Davis, 2009). Maintenance of mostly low-relief hard bottom (e.g., bedrock) requires wave energy sufficient to sweep sediment away (Lalli & Parsons, 1993) or offshore areas lacking a significant sediment supply; therefore, rocky reefs are rare on broad coastal plains near sediment-laden rivers and are more common on high-energy shores and beneath strong bottom currents, where sediments cannot accumulate.

In the deep waters of the Gulf of Mexico and Atlantic Ocean, there are also a number of cold seeps and thermal vents, which tend to support unique biotic communities. A cold seep, or cold vent, is an area of the ocean floor where chemical fluid seepage occurs. Cold seeps develop unique topography over time, where reactions between methane and seawater create carbonate rock formations and reefs. A thermal, or hydrothermal, vent is a fissure in the seafloor where geothermally heated water is released. Hard substrate in the abyssal zone and some locations landward of the deep ocean are virtually devoid of encrusting or attached organisms due to the scarcity of drifting food particles in the deep ocean

(Nybakken, 1993). Exceptions are areas on seamounts and along the Mid-Atlantic Ridge where chemosynthetic communities occur (see Section 3.4, Invertebrates, for additional information).

3.5.2.1.2.2 Distribution

Soft, intermediate, and hard bottom occur in all large marine ecosystems and the open ocean. However, the bottom types vary across the Study Area (Figure 3.5-1 through Figure 3.5-4) and are depicted by over 25 datasets. These datasets were ranked by quality and assembled into the non-overlapping mosaic as described in *Building and Maintaining a Comprehensive Database and Prioritization Scheme for Overlapping Habitat Data* (U.S. Department of the Navy, 2016). The datasets employ a variety of data collection techniques and data analysis to characterize the seafloor; results are summarized below. Thousands of acres of lower quality data were superseded by high quality data in the process of creating the non-overlapping abiotic substrate maps for the AFTT study area. However, some data sources were excluded due to the quality of the data, availability at the time of database assembly, or for other reasons.

Most of the bottom within the Study Area (approximately 80 percent) has not been mapped. However the majority of the unmapped portion is seaward of the U.S. continental shelf in the Atlantic Basin/Abyssal Zone (Table 3.5-2). Available mapping for abiotic substrate indicates a benthic surface composed of mostly soft bottom (less than 88 percent) with a little over 5 percent hardbottom, adjusted qualitatively for over- or under-estimation. The intermediate category of substrate (7 percent) could add to either the soft bottom or hard bottom type, depending on other environmental variables affecting stability and the supply of colonizing sedentary organisms and nutrition sources, which also affect hard substrate as a habitat for hard bottom organisms (to a lesser degree). It should be noted that percent of bottom area does not account for the vertical relief of some hard bottom areas, which contribute disproportionately to hard bottom community biomass. The data also does not account for the typically smaller dimensions of hard bottom features present in predominantly soft bottom areas; the Southeast Area Monitoring and Assessment Program – South Atlantic (Southeast Area Monitoring and Assessment Program—South Atlantic, 2001) line data is based primarily on trawl samples that indicate hard bottom with the collection of species associated with hard bottom, suggesting there were numerous hard bottom features too small to be resolved by even the highest quality data in the Study Area. U.S. Department of the Navy (2011) data and classification came the closest to finding these smaller areas of hardbottom attracting associated species.

Table 3.5-2: Percent Coverage of Abiotic Substrate Types in Large Marine Ecosystems and the Atlantic Basin/Abyssal Zone of the AFTT Study Area

Large Marine Ecosystem	*Percent of Large Marine Ecosystem*				*Total Acres*
	Hard	*Intermediate*	*Soft*	*Unknown*	
Atlantic Basin / Abyssal Zone	0.04 %	0.04%	7.13%	92.79%	1,907,486,932
Canadian Eastern Arctic - West Greenland	0.00%	0.00%	0.00%	100.00%	64,745,140
Caribbean Sea	4.91%	1.60%	20.76%	72.73%	31,139,231
Gulf of Mexico	2.73%	4.10%	62.97%	30.21%	360,245,296
Labrador - Newfoundland	0.00%	0.00%	0.00%	100.00%	151,841,856
Northeast U.S. Continental Shelf	1.54%	28.75%	69.58%	0.14%	69,321,609
Scotian Shelf	0.03%	1.69%	6.11%	92.16%	39,949,769
Southeast U.S. Continental Shelf	19.19%	5.3%	75.5%	0.01%	67,064,801
Grand Total	0.97%	1.49%	17.48%	80.06%	2,691,794,634

Soft Bottom

Softbottom occupies the largest habitat area within mapped portions of the Study Area and occur in all large marine ecosystems and the open ocean, and are depicted in Figure 3.5-1 through Figure 3.5-4 based on over 25 datasets (U.S. Department of the Navy, 2016).

Intermediate Bottom

Intermediate bottoms occur in all large marine ecosystems and the open ocean, and are depicted in Figure 3.5-1 through Figure 3.5-4 by at least eight datasets (U.S. Department of the Navy, 2016).

Hard Bottom

Hard bottoms occur in all large marine ecosystems and the open ocean, and are depicted in Figure 3.5-1 through Figure 3.5-4 based on at least eight datasets (U.S. Department of the Navy, 2016).

3.5.2.1.3 Artificial Structures

3.5.2.1.3.1 Description

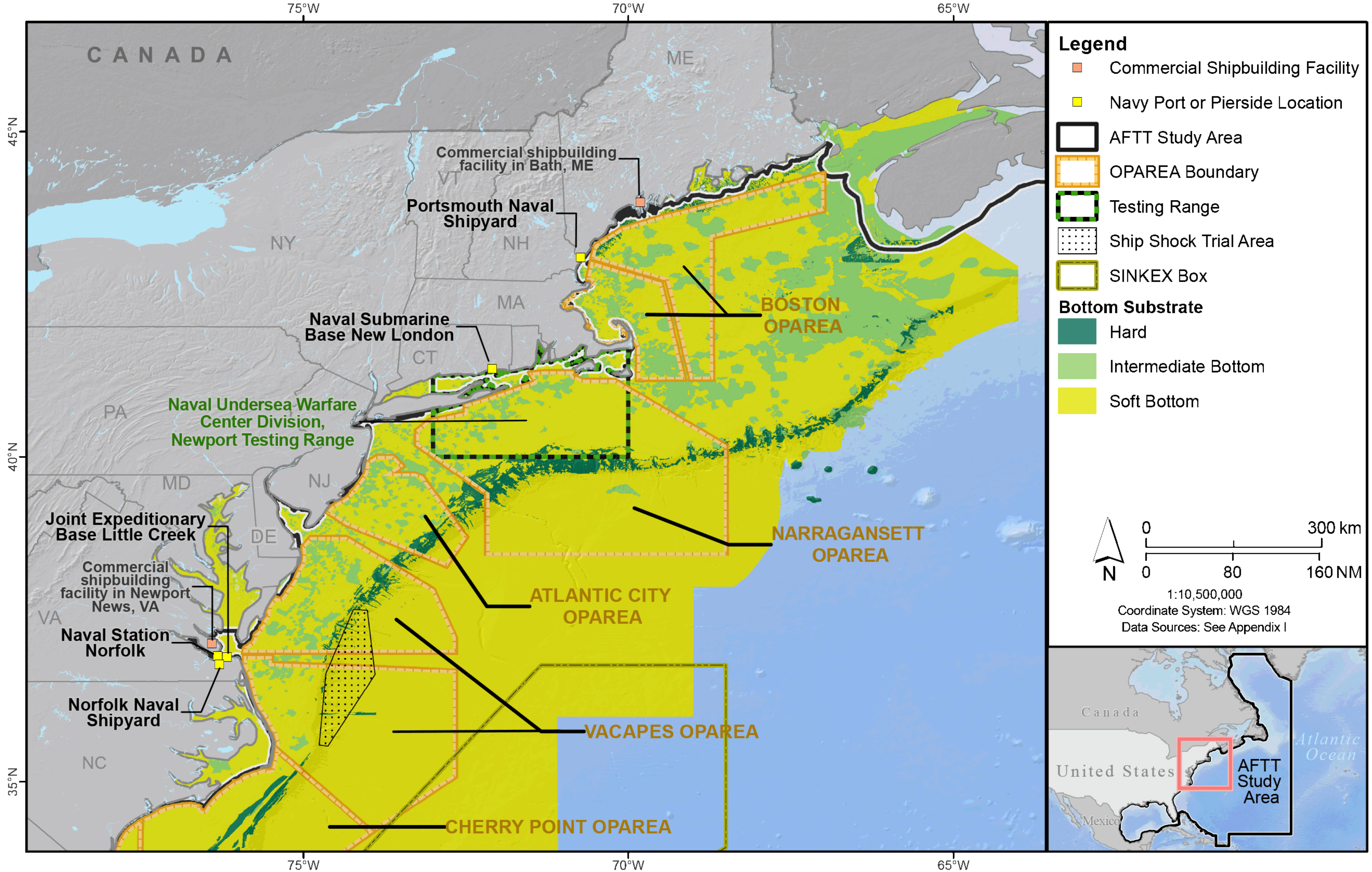
Man-made structures that are either deliberately or unintentionally submerged underwater create artificial habitats that mimic some characteristics of natural habitats, such as providing hard substrate and vertical relief (Broughton, 2012). Artificial reef habitats have been intentionally created with material from sunken ships, rock and stone, concrete and rubble, car bodies, tires, and scrap metal, etc. Artificial habitats also have been created as a result of structures built for other purposes (e.g., breakwaters, jetties, piers, wharves, bridges, oil and gas platforms, fish aggregating devices) or unintentional sinking of vessels (i.e., shipwrecks).

Some artificial structures provide similar ecological functions as natural hardbottom habitats, such as providing attachment substrate for algae and sessile invertebrates, which in turn supports a community of mobile organisms that may forage, shelter, and reproduce there (National Oceanic and Atmospheric Administration, 2007). Other structures may or may not support sessile organisms and only temporarily attract mobile organisms. Factors such as the materials, structural features, and surface area of the artificial substrate, as well as local environmental conditions, influence the variety and abundance of sessile organisms that may become established and the relative success of attracting or enhancing local fish populations (Ajemian et al., 2015; Broughton, 2012; Macreadie et al., 2011; Powers et al., 2003; Ross et al., 2016).

Artificial habitats in the Study Area include artificial reefs, shipwrecks, oil and gas platforms, man-made shoreline structures (e.g., piers, wharfs, docks, pilings), and obsolete military towers used for aircraft training (Macfadyen et al., 2009; Seaman, 2007; U.S. Department of the Navy, 2016). Artificial reefs are designed and deployed to supplement the ecological services provided by coral or rocky reefs. Artificial reefs range from simple concrete blocks to highly engineered structures. Vessels that are unintentionally sunk in the Study Area may be colonized by encrusting and attached marine organisms if there is a larval source and enough nutrition (e.g., detritus) drifting through the water column. Wrecks in the abyssal zone and some locations landward of the deep ocean are virtually devoid of encrusting or attached organisms due to the scarcity of drifting food particles in the deep ocean (Nybakken, 1993).

3.5.2.1.3.2 Distribution

Artificial shoreline structures (e.g., piers, wharfs, docks, pilings) in the Study Area occur at or along pierside locations (Section 2.1.10.1, Pierside Locations), including facilities associated with Navy ports and naval shipyards, and channels and routes to and from Navy ports.



Notes: AFTT: Atlantic Fleet Training and Testing; OPAREA: Operating Area; SINKEX: Sinking Exercise

Figure 3.5-1: Bottom Types Within the Northeast U.S. Continental Shelf Large Marine Ecosystem and Open Ocean Areas

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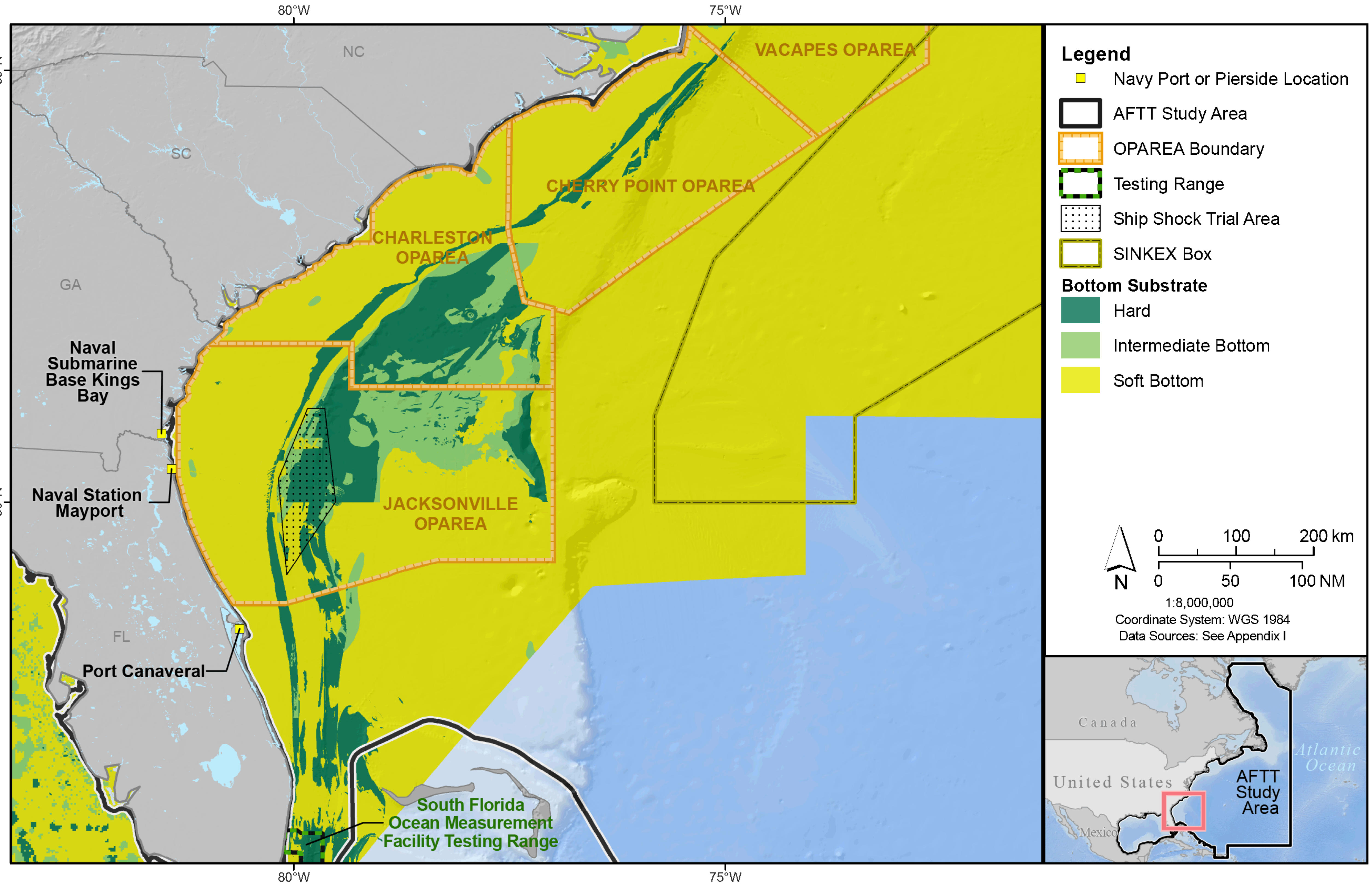

Notes: AFTT: Atlantic Fleet Training and Testing; OPAREA: Operating Area; SINKEX: Sinking Exercise

Figure 3.5-2: Bottom Types Within the Southeast U.S. Continental Shelf Large Marine Ecosystem and Open Ocean Areas

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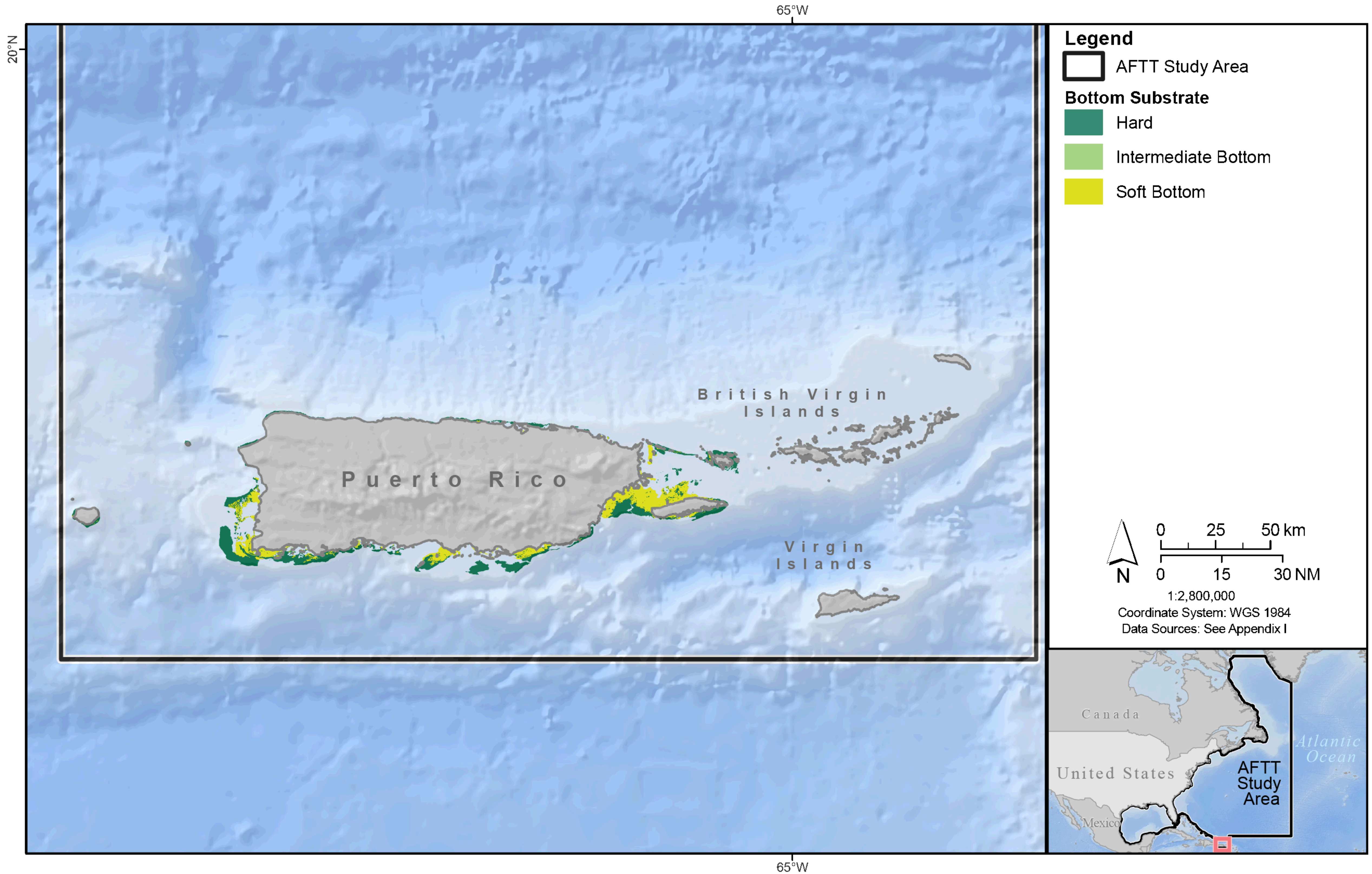

Notes: AFTT: Atlantic Fleet Training and Testing

Figure 3.5-3: Bottom Types Within the Caribbean Sea Large Marine Ecosystem

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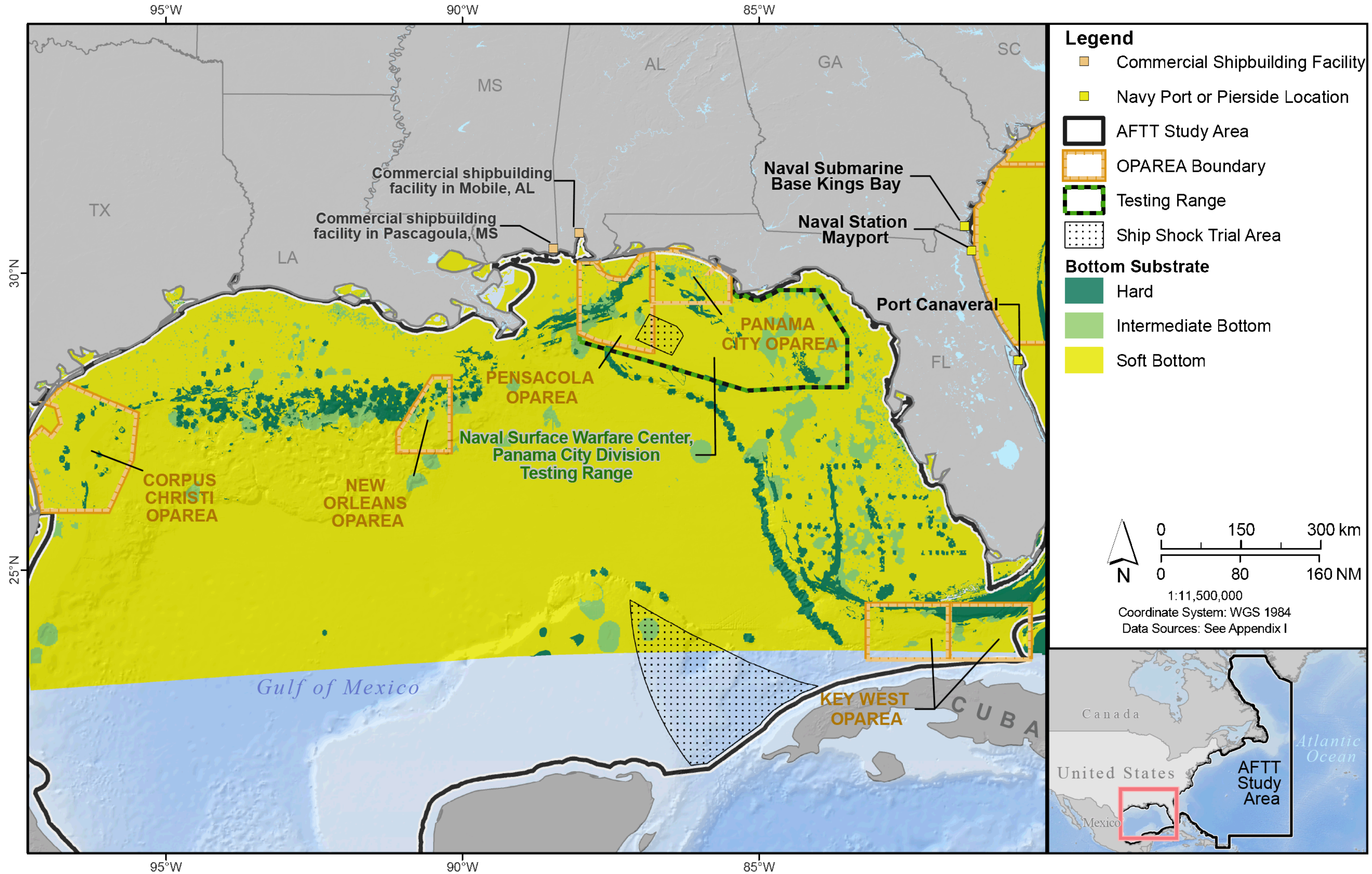

Notes: AFTT: Atlantic Fleet Training and Testing; OPAREA: Operating Area

Figure 3.5-4: Bottom Types Within the Gulf of Mexico Large Marine Ecosystem

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The centroid points of mapped artificial structures in waters of the Study Area are depicted on Figure 3.5-5 through Figure 3.5-8. These include more than 15,000 mapped points, including mostly shipwrecks (over 11,000), oil/gas platforms (2,400), artificial reefs (1,400), and military towers (18) (Table 3.5-3). Artificial reefs may occur at individual permit sites or within large General Permit areas. Very large individual permit areas and General Permit areas range from nearly 100 to several hundred square miles (shown as polygons on the artificial structure figures); whereas, typical artificial reef permit areas range from less than 0.5 square mile to a few square miles (U.S. Department of the Navy, 2016). Not shown on Figure 3.5-5 through Figure 3.5-8 are shipwrecks that are "address restricted" due to status on the National Register of Historic Places (e.g., Gen. C.B. Comstock located in Texas state waters) and ship hulks sunk during Naval sinking exercises.

Table 3.5-3: Number of Artificial Structures Documented in Large Marine Ecosystems of the AFTT Study Area

Large Marine Ecosystem	*Air Force Towers*	*Artificial Reef*	*Navy Towers*	*Oil/Gas Platform*	*Shipwreck*	*Grand Total*
Atlantic Basin / Abyssal Zone	0	0	0	0	106	106
Caribbean Sea	0	9	0	0	350	359
Gulf of Mexico	6	1,166	0	2,400	6,174	9,746
Northeast U.S. Continental Shelf	0	62	4	0	3,845	3,911
Scotian Shelf	0	0	0	0	18	18
Southeast U.S. Continental Shelf	0	163	8	0	1,284	1,455
Grand Total	6	1,400	12	2,400	11,777	15,595

3.5.2.1.4 General Threats

Estuarine and ocean environments worldwide are under pressure from a variety of human activities, such as coastal development, shoreline stabilization, dredging, flood control, and water diversion; destructive fishing practices; offshore energy and resource development and extraction; and global climate change (Boehlert & Gill, 2010; Clark et al., 2016; Clarke et al., 2014; Crain et al., 2009; National Oceanic and Atmospheric Administration Marine Debris Program, 2016). These activities produce a range of physical and chemical stressors on habitats. Primary threats to marine habitats include habitat loss, degradation, or modification. Although stressors may be similar or wide-spread geographically, their effects on marine habitats are not random or equal. Human activities vary in their spatial distribution and intensity of impact (Halpern et al., 2008). Accordingly, their effects on habitats will vary depending on local differences in the duration, frequency, and intensity of stress; scale of effect; and environmental conditions. Areas where heavy concentrations of human activity co-occur with naval training and testing activities have the greatest potential for cumulative stress on the marine ecosystem (see Chapter 4, Cumulative Impacts, for more information).

3.5.2.1.4.1 Urbanization

Habitat loss and degradation are the primary threats of urbanization. Coastal development has resulted in loss of coastal dune and wetland habitats, modification of shorelines and estuaries, and degradation of water quality (Crain et al., 2009; Lotze et al., 2006). In addition, development has resulted in a proliferation of artificial structure habitats, such as breakwaters, jetties, rock groins, seawalls, oil and gas platforms, docks, piers, wharves, and underwater cables and pipelines, as well as artificial reefs.

Maintenance of coastal infrastructure, ports, and harbors disturbs or modifies intertidal and subtidal habitats, the extent of which varies depending on the type, scale, or frequency of the activity. For example, maintenance has increased the use of shoreline stabilization measures (engineered structures, beach nourishment) to reduce storm-related damages to coastal infrastructure. Flood control or shoreline stabilization measures may have temporary or long-term impacts on beach habitats and may also affect adjacent intertidal and subtidal habitats due to suspended sediment and sedimentation, altered sediment supply and transport dynamics, or creation of artificial substrates (Bacchiocchi & Airoldi, 2003). Periodic dredging and excavation of sediment is undertaken to maintain navigable channels, tidal exchange, and/or flood control capacity in bays and estuaries. Sediment removal directly disturbs subtidal softbottom habitat and may indirectly disturb or modify adjacent habitats (Newell et al., 1998). A number of factors may influence maintenance frequency, including sediment characteristics, shoreline and watershed characteristics, oceanographic conditions, and climate.

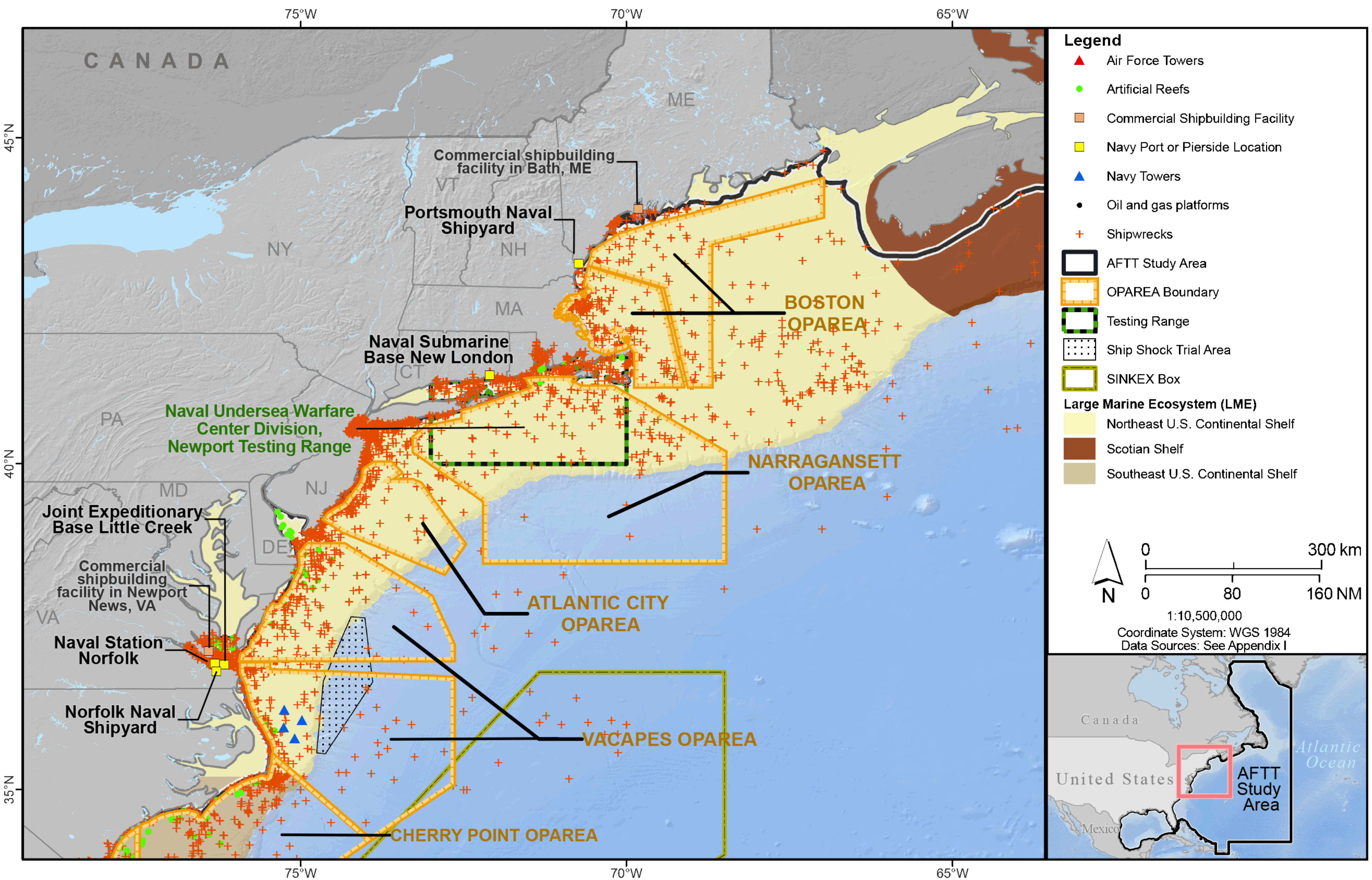
3.5.2.1.4.2 Water Quality

Pollution of marine waters and the accumulation of contaminants in marine sediments pose threats to marine ecosystems, public health, and local economies of coastal regions (Crain et al., 2009).Marine and estuarine water and sediment quality may be influenced by industrial and wastewater discharges, soil erosion, stormwater runoff, vessel discharges, marine construction, and accidental spills. Activities that disturb or remove marine sediments also impact water quality and may alter physical and chemical properties of sediments at and adjacent to the disturbance due to sediment resuspension and sedimentation. Generally, threats to water and sediment quality are greater in waterbodies adjacent to watersheds with substantial urban or agriculture land uses. For more detailed discussion of water quality and potential impacts, see Section 3.2 (Sediments and Water Quality).

Large areas of bottom waters lacking dissolved oxygen, or “dead zones,” are documented in the Study Area off the Mississippi River outlet (Rabalais et al., 2002) and other large rivers flowing into coastal ocean waters (Diaz & Rosenberg, 2008). Whereas the physical structure of abiotic substrate is unaffected by dead zones, associated organisms are adversely impacted there. Refer to individual resource sections for specific stressors and impacts on living resources associated with marine substrates.

3.5.2.1.4.3 Commercial Industries

A variety of commercial development, operations, and activities impact marine habitats and associated organisms (e.g., oil/gas development, telecommunications infrastructure, steam and nuclear power plants, desalinization plants, alternative energy development, shipping and cruise vessels, commercial fishing, aquaculture, and tourism operations) (Crain et al., 2009). Commercial activities are conducted under permits and regulations that require companies to avoid and minimize impacts to marine habitats, especially sensitive hardbottom and biogenic habitats (e.g., coral reefs, shellfish beds, and vegetated habitats).



Notes: AFTT: Atlantic Fleet Training and Testing; OPAREA: Operating Area; SINKEX: Sinking Exercise

Figure 3.5-5: Artificial Structures Within the Northeast U.S. Continental Shelf Large Marine Ecosystem and Open Ocean Areas

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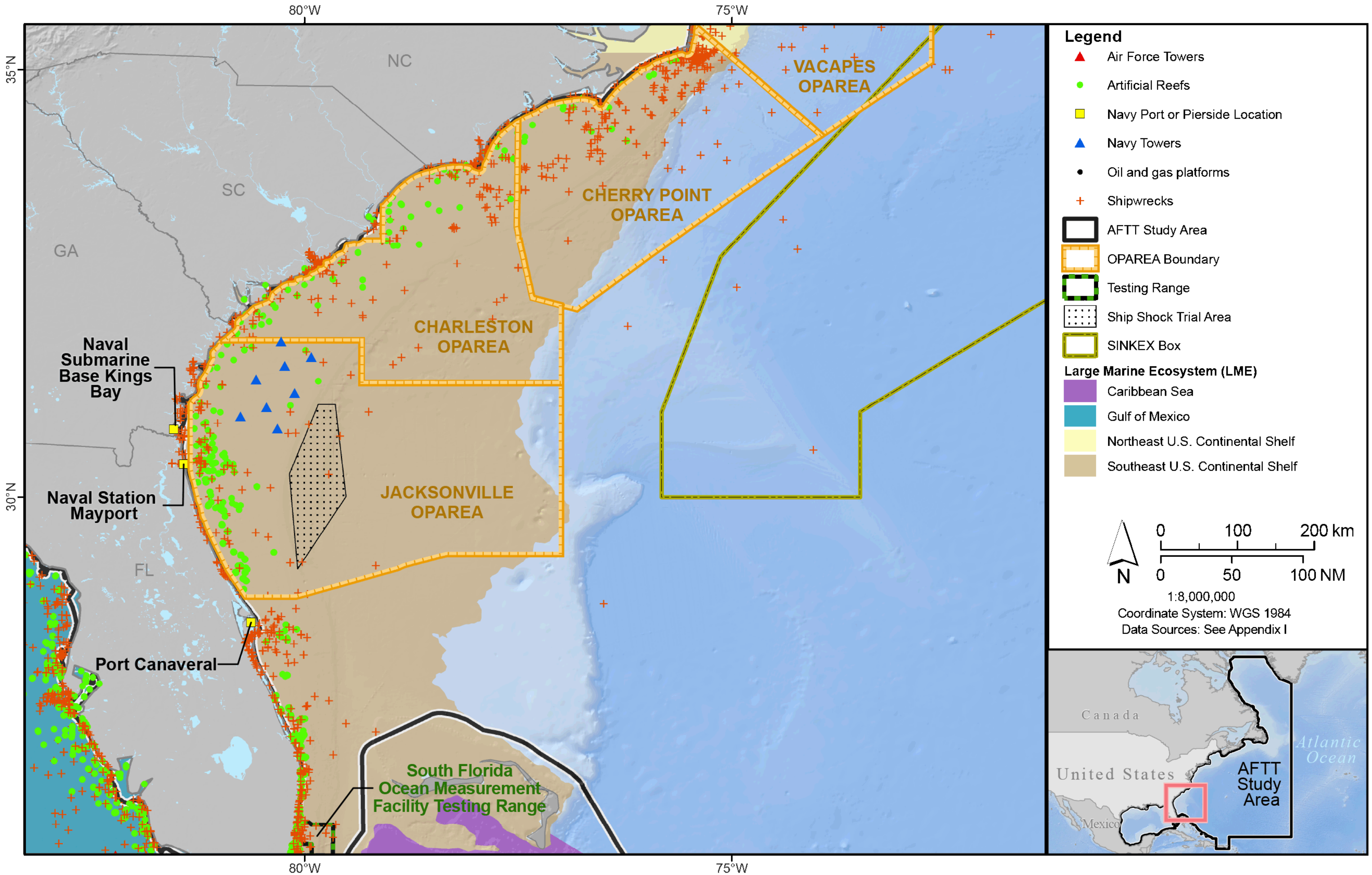

Notes: AFTT: Atlantic Fleet Training and Testing; OPAREA: Operating Area; SINKEX: Sinking Exercise

Figure 3.5-6: Artificial Structures Within the Southeast U.S. Continental Shelf Large Marine Ecosystem and Open Ocean Areas

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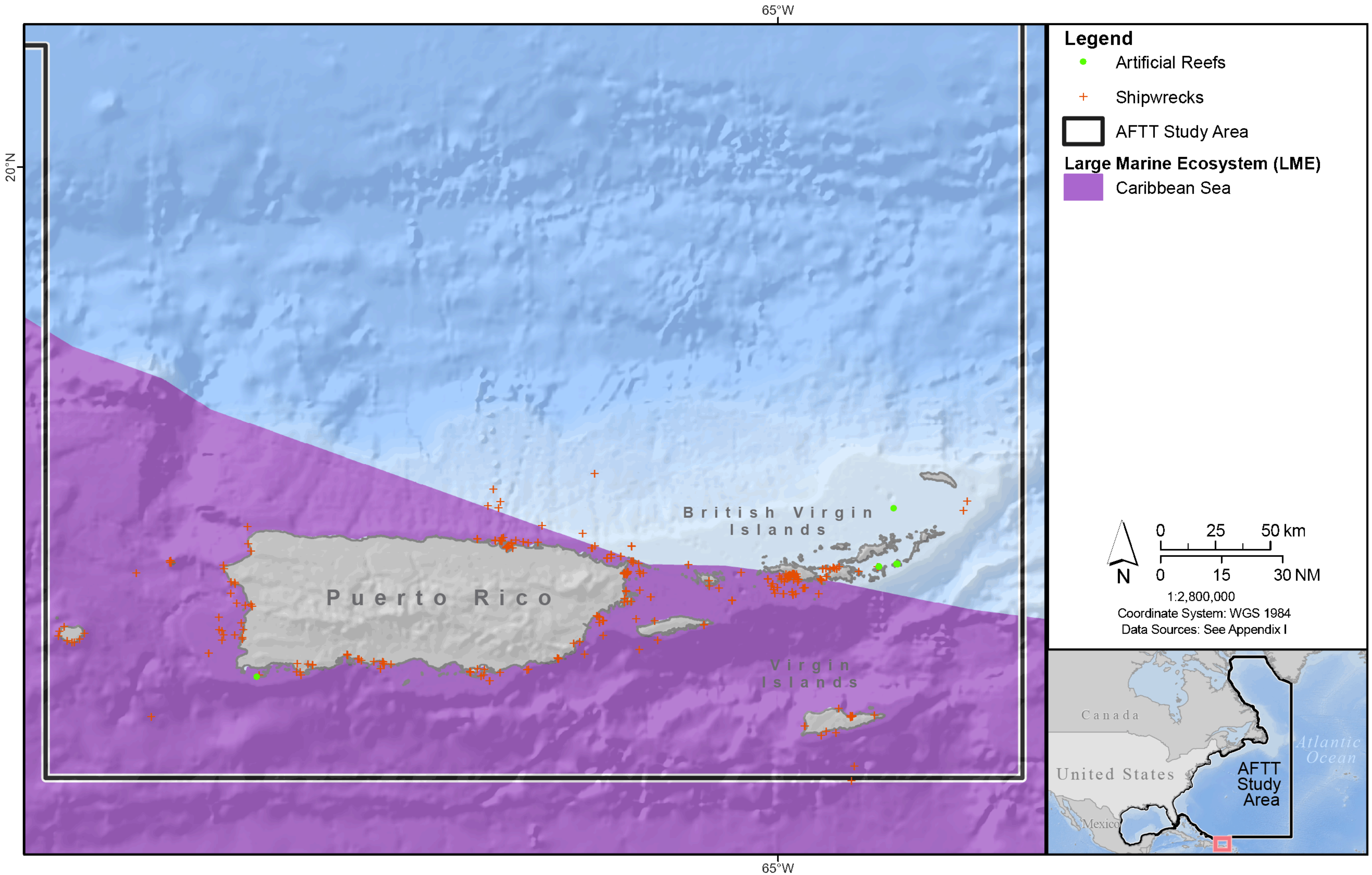

Notes: AFTT: Atlantic Fleet Training and Testing

Figure 3.5-7: Artificial Structures Within the Caribbean Sea Large Marine Ecosystem

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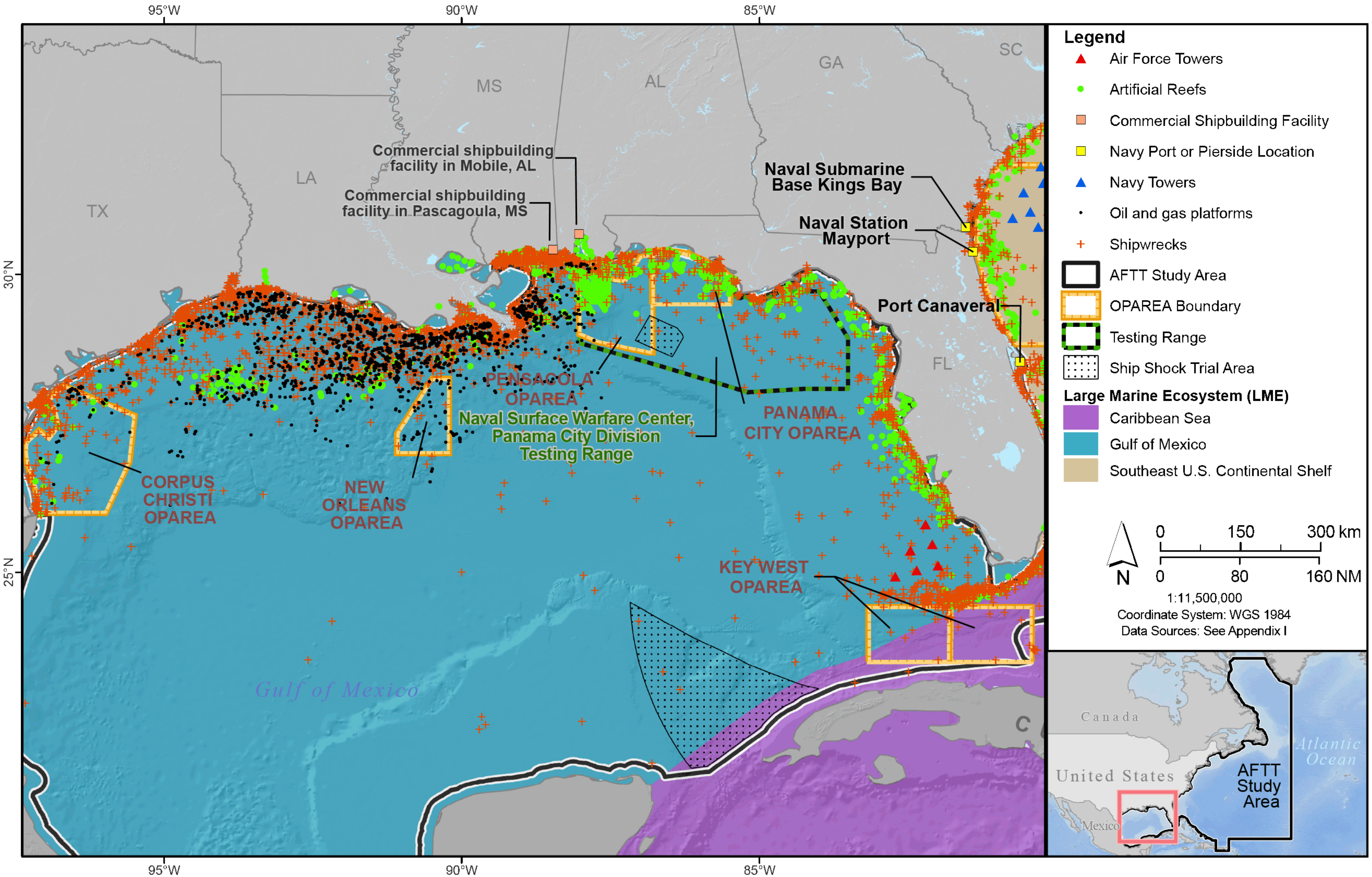

Notes: AFTT: Atlantic Fleet Training and Testing; OPAREA: Operating Area

Figure 3.5-8: Artificial Structures Within Western Portion of the Gulf of Mexico Large Marine Ecosystem

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Marine habitats may be directly impacted during marine construction (e.g., cable laying and burial, dredging, pipeline installation, pile driving, work boat anchoring), and commercial bottom fishing and by commercial vessel anchoring. Generally, disturbance impacts to softbottom habitats are temporary; however, there is the potential to degrade the quality of softbottom habitat for biological resources depending on the extent and frequency of disturbance (Newell et al., 1998). Hardbottom and biogenic habitats are most vulnerable to damage or degradation by commercial industry development and operations. For example, anchors, anchor chains, or cables may damage habitats and abrade and remove organisms from hardbottom surfaces. Commercial fishing use of dredges and bottom trawls impacts bottom topography and sediments and may degrade habitat quality and associated biological communities (Clark et al., 2016). Abandoned or lost fishing gear may alter the structure of abiotic habitats and result in abrasion or entanglement of organisms.

Indirect impacts to habitats may occur from commercial development, discharges, or accidental spills that degrade water or sediment quality. Threats associated with impacts to water and sediment quality are further described in Section 3.5.2 (Affected Environment). Accidental spills have the potential to contaminate and degrade marine habitats by coating hard bottom or biogenic substrates as well as mixing into bottom sediments (Hanson et al., 2003). Many factors determine the degree of environmental damage from oil spills, including the type of oil, size and duration of the spill, geographic location, season, and types of habitats and resources present. Effects of oil on the bottom habitat have the potential to have long-term impacts on fish and wildlife populations.

3.5.2.1.4.4 Climate Change

All marine ecosystems are vulnerable to the widespread effects of climate change, which include increased ocean temperatures, sea level rise, ocean acidification, and changes in precipitation patterns (Hoegh-Guldberg & Bruno, 2010; Scavia et al., 2002). Rising ocean temperatures will cause waters to expand and ice caps to melt, driving sea levels to rise at various rates depending on geographic location and local environmental conditions. Sea level rise will have the greatest impacts on intertidal and coastal ecosystems that have narrow windows of tolerance to flooding frequency or depth (Crain et al., 2009). Changes in ocean temperatures also are projected to alter ocean circulation, upwelling, and nutrient distribution patterns. It is projected that wet tropical areas and mid-latitude land will experience more frequent and extreme precipitation, which will increase erosion-related sedimentation and runoff to coastal habitats (Keener et al., 2012). The climatic effects will be superimposed upon, and interact with, a wide array of current stresses, including excess nutrient loads, overfishing, invasive species, habitat destruction, and chemical contamination (Scavia et al., 2002).

3.5.2.1.4.5 Marine Debris

In the past decade, marine debris has been increasingly recognized as a key threat to marine ecosystems throughout the world. The Marine Debris Act (33 United States Code 1951 et seq.) defines marine debris as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment. Artificial substrate that provides hard bottom habitat for marine organisms is discussed in Section 3.4 (Invertebrates). This section focuses on the aspects of marine debris that pose a threat to marine habitats. The accumulation of marine debris can alter and degrade marine habitats through physical damage (e.g., abrasion, shearing); changes to the physical and chemical composition of sediments; and reductions in oxygen and underwater light levels (National Oceanic and Atmospheric Administration Marine Debris Program, 2016). Accumulation or concentration also can degrade the aesthetic appeal of coastal habitats for recreational use, decrease visitation and tourism, require costly cleanups, and impact local economies (Leggett et al., 2014).

3.5.3 Environmental Consequences

The Navy considered all potential stressors and the following have been analyzed for habitats: explosives and physical disturbance and strikes. This section evaluates how and to what degree the activities described in Chapter 2 (Description of Proposed Action and Alternatives) and Section 3.0.3.3 (Identifying Stressors for Analysis) could impact marine habitats as defined in this section in the Study Area. Table 2.6-1 (Proposed Training Activities per Alternative) through Table 2.6-4 (Office of Naval Research Proposed Testing Activities per Alternative) present the proposed training and testing activities (including number of events and locations). General characteristics of all Navy stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors analyzed for habitats are:

- **Explosives** (explosives detonated on or near the bottom);
- **Physical Disturbance and Strikes** (vessels and in-water devices; military expended materials; seafloor devices; pile driving)

Impacts of explosives and military expended material were assessed based on three types of analyses: (1) a worst-case scenario assuming all the impacts occur on a single habitat type in an affected area (1-year totals), (2) a more realistic situation in which the impacts are spread proportionally among the habitat types in an affected area, and (3) a 5-year cumulative analysis. The most accurate projection would be somewhere between the worst-case and proportional distribution because there are locations that specific training or testing occurs most frequently within range complexes. However, training and testing in those areas are not limited by a percentage as a proposed action in this document. The remaining stressors (vessels and in-water devices, seafloor devices, and pile driving) were analyzed based on the number of annual events estimated to occur annually within each Range Complex. The analysis includes consideration of the mitigation that the Navy will implement to avoid potential impacts on habitats from explosives and physical disturbance and strike stressors. Mitigation for habitats will be coordinated with NMFS through the consultation processes.

3.5.3.1 Acoustic Stressors

Acoustic stressors are not applicable to habitats due to the lack of hearing capabilities of abiotic habitats and will not be analyzed further in this section.

3.5.3.2 Explosive Stressors

Background

This section analyzes the potential impacts of in-water explosions on or near the bottom resulting from training and testing activities within the Study Area, because those are the only explosives that are expected to potentially impact abiotic substrate.

In-water detonations are used during various mine warfare training and testing activities, surface-to-surface gunnery exercises, air-to-surface gunnery, missile, and bombing exercises, as well as sinking exercises, underwater demolition, and other training activities. Likewise, air-to-surface gunnery, missile, and bombing tests, anti-submarine warfare tracking tests, mine warfare, detection, neutralization tests, and other testing activities also employ underwater explosives. The potential impacts of in-water detonations on marine habitats are assessed according to size of charge (net explosive weight), charge radius, height above the bottom, substrate types in the area, and equations linking all these factors.

Most explosive detonations during training and testing involving the use of high-explosive munitions, including bombs, missiles, and projectile casings, would occur in the air or near the water's surface. Explosives associated with torpedoes, explosive sonobuoys, and explosive mines would occur in the water column; demolition charges could occur near the surface, in the water column, or the ocean bottom. Most surface and water column detonations would occur in waters greater than 3 NM from shore in water depth greater than 100 feet (ft.), although mine warfare and demolition detonations could occur in shallow water, and typically in a few specific locations within the Study Area. This section only evaluates the impact of explosives placed on the bottom, because the physical structure of the water column is not affected by explosions.

An explosive charge would produce percussive energy that would be absorbed and reflected by the bottom. Hard bottom would mostly reflect the charge (Berglind et al., 2009), whereas a crater would be formed in soft bottom (Gorodilov & Sukhotin, 1996). For a specific size of explosive charge, crater depths and widths would vary depending on depth of the charge and substrate type. There is a nonlinear relationship between crater size and depth of water, with relatively small crater sizes in the shallowest water, followed by a spike in size at some intermediate depth, and a decline to an average flat line at greater depth (Gorodilov & Sukhotin, 1996; O'Keeffe & Young, 1984). Radii of the craters reportedly vary little among unconsolidated substrate types (O'Keeffe & Young, 1984). On substrate types with nonadhesive particles (everything except clay), the effects should be temporary, whereas craters in clay may persist for years (O'Keeffe & Young, 1984). Soft substrate moves around with the tides and currents and depressions are only short-lived (days – weeks) unless they are maintained.

3.5.3.2.1 Impacts from Explosives

3.5.3.2.1.1 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

Relevant training activities under Alternative 1 include explosives used during mine countermeasures, mine neutralization using remotely operated vehicles, mine neutralization explosive ordnance disposal, and other activities (see Table 2.6-1, Proposed Training Activities per Alternative, and Appendix B, Activity Stressor Matrices). The number and locations for these stressors under Alternative 1 are provided in Section 3.0.3.3.4.2, Military Expended Materials. The Navy testing and training areas listed by range complex, and acreages of abiotic habitat by type are shown in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

The analysis assumes that half the charges that could be detonated on the bottom during training activities are actually detonated on the bottom. The determination of impact is based on this scenario: 0.5, 5, 10, 20, and 60 pounds (lb.) net explosive weight explosions on the bottom. Note that mitigation measures that may prevent impacts are not included in the quantitative assessment (Chapter 5, Mitigation). Only the acreage in the large marine ecosystem areas was included in percentages shown in Table 3.5-2. The areas within the Atlantic Basin/Abyssal Zone were not included in order to focus on bottom areas likely to have a combination of suitable habitat, supply of sedentary invertebrate larvae, and sufficient food particles for filtration or deposit-feeding. Artificial substrate was not included, because it was inconsistently included for mapping and it likely represented a miniscule percentage of habitat types in the large marine ecosystems.

The mine neutralization and other training activities involving explosives could occur over a larger area, to support the added flexibility of conducting activities anywhere within the specified range complexes. Based on the number of charges and impact areas per year, the worst-case scenarios for hard bottom impacts are 8.0, less than 0.5, less than 0.5, and 0.5 acres in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Caribbean and Gulf of Mexico, and Gulf of Mexico Large Marine Ecosystems, respectively. This represents less than 0.01 percent of the available hard bottom in each of the large marine ecosystems.

Analysis was conducted in order to determine the proportional impact of explosives training on marine habitats in each of the training areas within the Study Area (Figure 3.5-9). Based on the proportional analysis, total explosive impacts to hard substrate from explosives training activities would be less than 0.5 acre. Impacts to other substrate types would be approximately 0.5, 8.0, and less than 0.5 acres for intermediate, soft, and unknown substrates, respectively. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from training activities in each Training Area.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, some habitat would recover over time as soft substrates are dynamic systems and craters could refill. Areas of hard bottom and other sensitive habitats could be avoided using the Protective Measures Assessment Protocol. The total footprint for impacts from high explosives over the 5-year period would be approximately 44.2 acres. Of this, less than 0.6 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted, and less than 0.01 percent of hard bottom. Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Under Alternative 1, the areas of bottom habitat in the AFTT Study Area affected annually or over a 5-year period by in-water detonations for training activities would be a negligible portion of available bottom habitat. Training events that include seafloor detonations would be infrequent, the percentage of the Study Area affected would be small, and the disturbed areas are likely soft bottom areas that recover relatively quickly from disturbance. Therefore, underwater explosions under Alternative 1 would be limited to local and short-term impacts on habitat structure in the Study Area.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigations to avoid impacts from explosives on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct explosive mine countermeasure and neutralization activities within a specified distance of shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from certain explosive activities.

Impacts from Explosives Under Alternative 1 for Testing Activities

Various types of explosives are used during testing activities. The type, number, and location of activities that use explosives are described in Section 3.0.3.3.2 (Explosive Stressors), and the resulting footprints on bottom habitats are quantified in Appendix F (Military Expended Materials and Direct Strike Impact Analyses). The general locations for Alternative 1 activities are listed in Appendix A (Navy Activity Descriptions) and shown on Figure 3.5-1 through Figure 3.5-4.

Based on the number of charges and impact areas per year, the worst-case scenarios for hardbottom area impacted are 3.0, 1.5, and 10.0 acres in the Northeast U.S. Continental Shelf, Southeast

U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems, respectively (Figure 3.5-17).This represents less than 0.01 percent of hardbottom habitat for each of the large marine ecosystems.

Additional analysis was conducted in order to determine the proportional impact of explosives testing on marine habitats in each of the range complexes and testing ranges within the Study Area (Figure 3.5-9). Based on the proportional analysis of impacts, total explosive impacts to hard substrate from testing activities would be approximately 0.9 acre. Impacts to other substrate types would be approximately 1.5 and 12.0 acres for intermediate and soft substrates, respectively. Impacts to unknown substrate would be less than 0.5 acre. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from testing activities in each range complex and testing range.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would be cumulative. In reality, some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. Areas of hard bottom and other sensitive habitats could be avoided using the Protective Measures Assessment Protocol. The total footprint for impacts from high explosives over the 5-year period would be approximately 70.5 acres. Of this, less than 0.01 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Under Alternative 1, the areas of bottom habitat in the AFTT Study Area affected annually by in-water detonations for testing activities would be a negligible portion of available bottom habitat (less than 0.01 percent for each substrate type). Testing events that include seafloor detonations would be infrequent, the percentage of testing area affected would be small, and the disturbed areas are likely soft bottom areas that recover relatively quickly from disturbance. Therefore, in-water explosions under Alternative 1 would be limited to local and short-term impacts on habitat structure in the Study Area.

3.5.3.2.1.2 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

Relevant training activities included in Alternative 2 include explosives used during mine countermeasures, mine neutralization using remotely operated vehicles, mine neutralization explosive ordnance disposal, and other training activities (see Table 2.6-1, Proposed Training Activities per Alternative). Explosive activities would be the same under Alternative 2 as those analyzed under Alternative 1, as only the frequency and duration of sonar activities would differ. The general locations for these activities under Alternative 2 are listed in Appendix A (Navy Activity Descriptions) and are shown on Figure 3.5-1 through Figure 3.5-4. The Navy testing and training areas, listed by large marine ecosystem and acreages of abiotic habitat by type, are shown in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Testing events that include seafloor detonations would be infrequent, the percentage of testing area affected would be small, and the disturbed areas are likely soft bottom areas that recover relatively quickly from disturbance. Therefore, in-water explosions under Alternative 2 would be limited to local and short-term impacts on habitat structure in the Study Area.

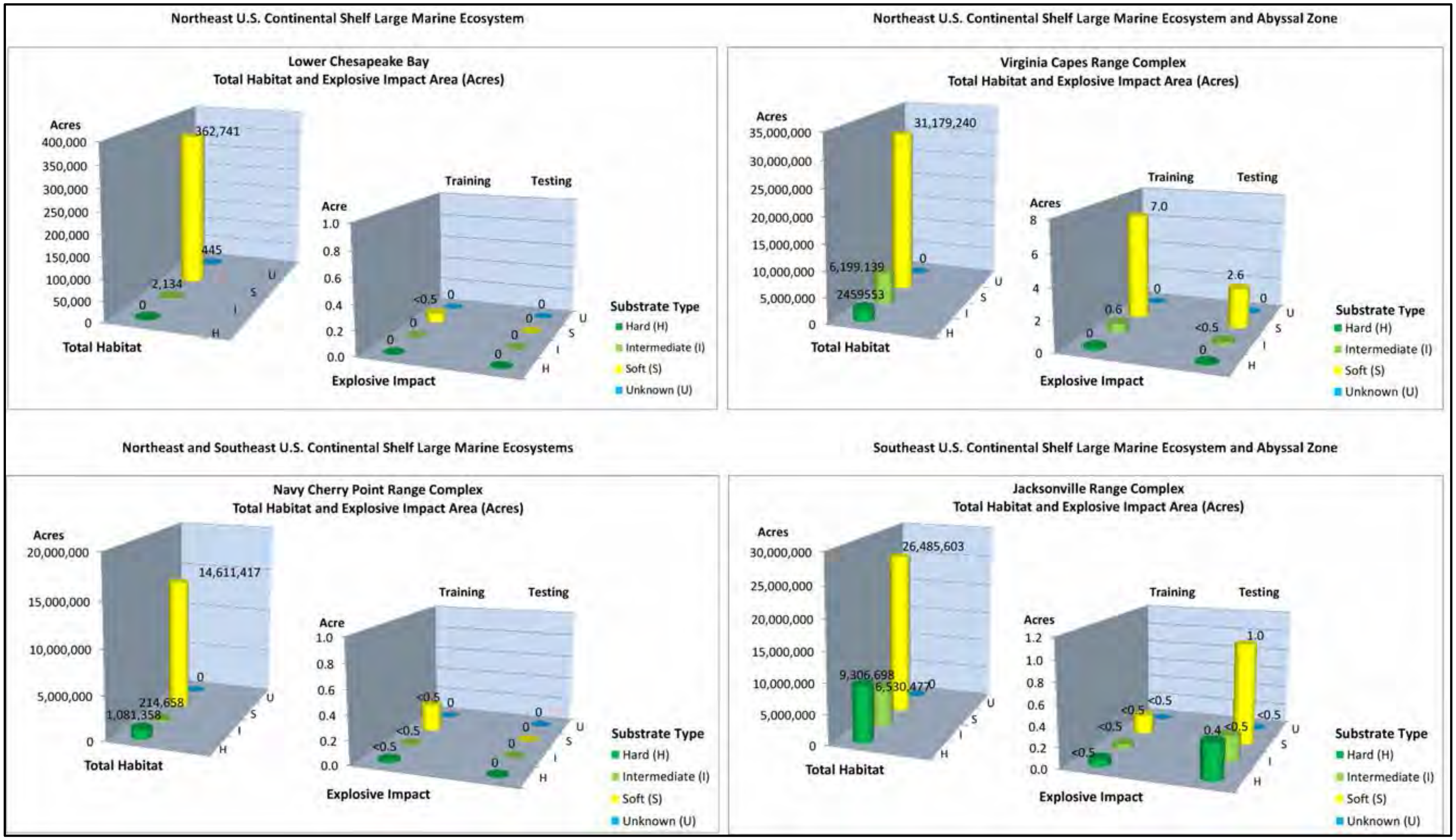


Figure 3.5-9: Alternative 1 – Proportional Impact (Acres) from Explosives by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Range Complexes of the Large Marine Ecosystems Within the Study Area

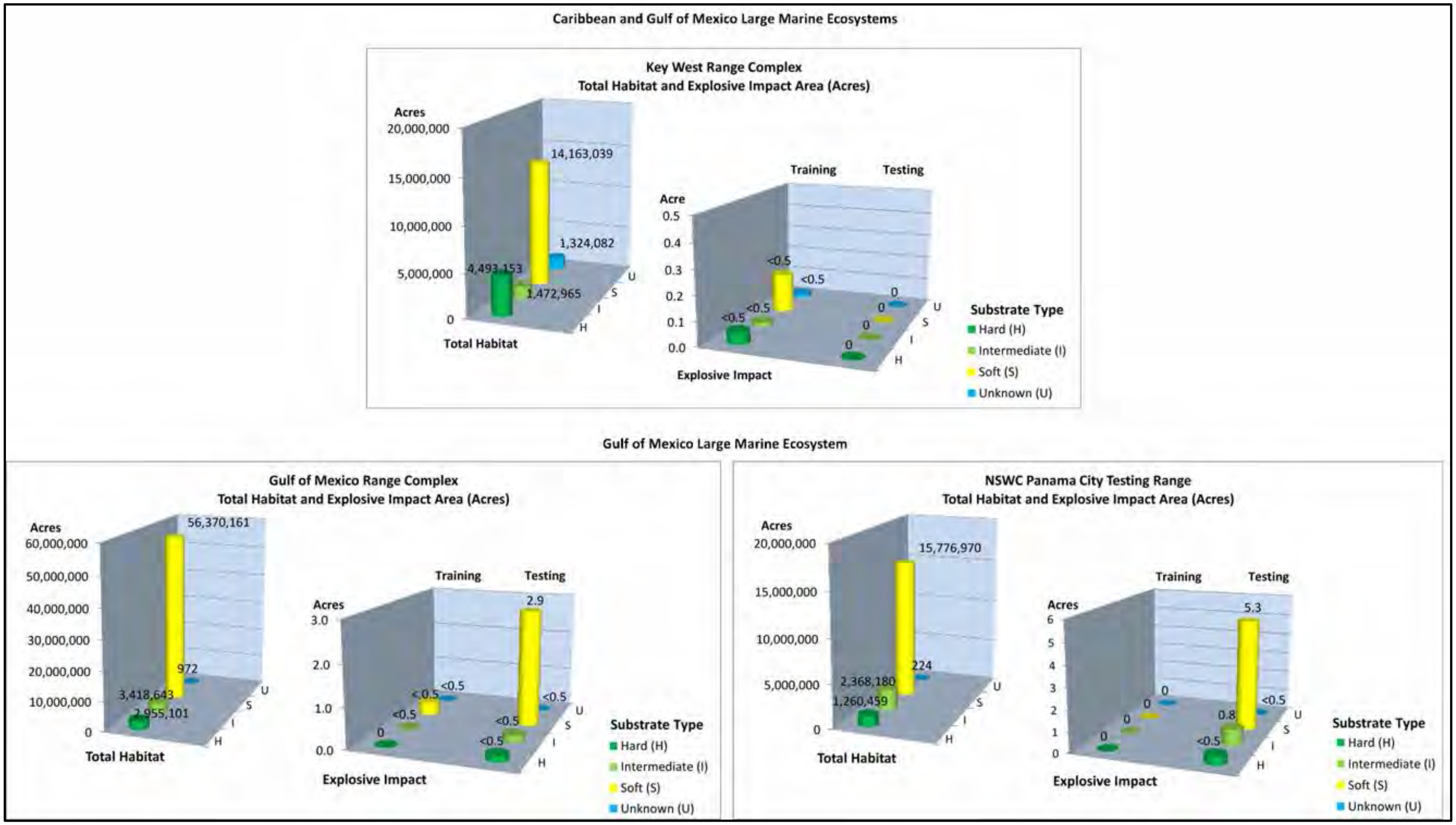


Figure 3.5-9 (Continued): Alternative 1 – Proportional Impact (Acres) from Explosives by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Range Complexes of the Large Marine Ecosystems Within the Study Area

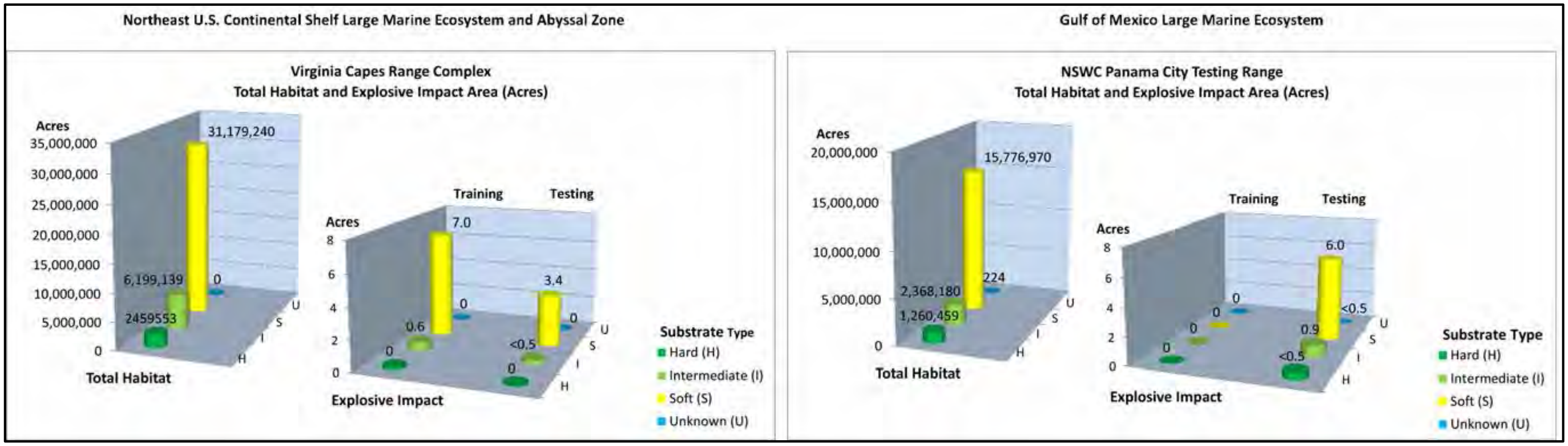


Figure 3.5-10 Alternative 2 – Proportional Impact (Acres) from Explosives by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Range Complexes of the Large Marine Ecosystems Within the Study Area

Impacts from Explosives Under Alternative 2 for Testing Activities

Relevant testing activities included in Alternative 2 that differ from Alternative 1 include NAVAIR's airborne mine neutralization system test and anti-submarine warfare tracking test–maritime patrol aircraft. Impacts from other activities would remain the same as discussed above under Alternative 1 impacts from explosives for testing. The general locations for Alternative 2 activities are listed in Appendix A (Navy Activity Descriptions) and shown on Figure 3.5-1 through Figure 3.5-4.

Based on the number of charges and impact areas per year, the worst-case scenarios for hard bottom are 4.0, 1.5, and 14.0 acres in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems, respectively (Figure 3.5-17). This represents less than 0.01 percent of hard bottom, intermediate bottom, and softbottom habitat in each area.

Analysis was conducted in order to determine the proportional impact of explosives testing on marine habitats in each of the training areas within the Study Area. Only Virginia Capes and Naval Surface Warfare Center Panama City would differ in impacts from Alternative 1 (Figure 3.5-10). Based on the proportional analysis of impacts, total explosive impacts to hard substrate from testing activities would be approximately 1.0 acre. Impacts to other substrate types would be approximately 1.5 and 13.5 acres for intermediate and soft substrates, respectively. Impacts to unknown substrate would be less than 0.5 acre. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from testing activities in each training area.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. Areas of hard bottom and other sensitive habitats could be avoided using the Protective Measures Assessment Protocol. The total footprint for impacts from high explosives over the 5-year period would be approximately 80.0 acres. However, proportional impacts would still affect less than 0.01 percent of the total area of each habitat type (hard, intermediate, and soft). Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Under Alternative 2, the areas of bottom habitat in in the large marine ecosystems affected annually by in-water detonations for testing activities would be a negligible portion of available bottom habitat (less than 0.01 percent annually). Testing events that include seafloor detonations would be infrequent and the percentage of testing area affected would be small, and the disturbed areas are likely softbottom areas that recover relatively quickly from disturbance. Therefore, in-water explosions under Alternative 2 would be limited to local and short-term impacts on marine habitat structure in the Study Area.

3.5.3.2.1.3 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various explosive stressors (e.g., underwater detonations occurring on or near the seafloor) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.3 Energy Stressors

Energy stressors are not applicable to habitats, since activities that include the use of energy-producing devices are typically conducted at or above the surface of the water and would not impact bottom habitats. Therefore, they are not analyzed further in this section.

3.5.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts of the various types of physical disturbance and strike stressors resulting from the Navy training and testing activities within the Study Area. This analysis includes the potential impacts of (1) vessels and in-water devices, (2) military expended materials (3) seafloor devices, and (4) pile driving.

Impacts from physical disturbances or strikes resulting from Navy training and testing activities on biota inhabiting soft bottom (habitat for seagrasses, clams, etc.) and hard bottom (habitat for hard corals, seaweed, sponges, etc.) substrates are discussed in Section 3.3 (Vegetation) and Section 3.4 (Invertebrates). Potential impacts to the underlying substrates (soft, intermediate, hard, or artificial) are analyzed here.

3.5.3.4.1 Impacts from Vessels and In-Water Devices

Vessels conducting training and testing activities in the Study Area include large ocean-going ships and submarines typically operating in waters deeper than 100 m, but also occasionally transiting inland waters from ports and through the operating areas. Training and testing activities also include smaller vessels operating in inland waters, typically at higher speeds (greater than 10 knots). Vessels used for training and testing activities range in size from small boats (less than 40 ft.) to nuclear aircraft carriers (greater than 980 ft.). Table 3.0-16 (Representative Vessel Types, Lengths, and Speeds) lists representative types of vessels, including amphibious warfare vessels, used during training and testing activities. Towed mine warfare and unmanned devices are much smaller than other Navy vessels, but would also disturb the water column near the device. Some activities involve vessels towing in-water devices used in mine warfare activities. The towed devices attached to a vessel by cables are smaller than most vessels, and are not towed at high speeds. Some vessels, such as amphibious vehicles, would intentionally contact the seafloor in the surf zone.

Vessels, in-water devices, and towed in-water devices could either directly or indirectly impact any of the habitat types discussed in this section, including soft and intertidal shores, soft and hard bottoms, and artificial substrates. In addition, a vessel or device could disturb the water column enough to stir up bottom sediments, temporarily increasing the local turbidity. The shore and nearshore environment is typically very dynamic because of its constant exposure to wave action and cycles of erosion and deposition. Along high-energy shorelines like ocean beaches, these areas would be reworked by waves and tides shortly after the disturbance. Along low-energy shorelines in sheltered inland waters, the force of vessel wakes can result in elevated erosion and resuspension of fine sediment (Zabawa & Ostrom, 1980). In deeper waters where the tide or wave action has little influence, sediments suspended into the water column would eventually settle. Sediment settlement rates are highly dependent on grain size. Disturbance of deeper bottom habitat by vessels or in-water devices is possible where the propeller wash interacts with the bottom. However, most vessels transiting in shallow, nearshore waters are confined to navigation channels where bottom disturbance only occurs with the largest vessels. An exception would be for training and testing activities that occur in shallow, nearshore environments. Turbidity caused by vessel operation in shallow water, propeller scarring, and vessel grounding could impact habitats in shallow-water areas. In addition, physical contact with hard bottom areas can cause structural damage to the substrate. However, direct impacts to the substrate are typically avoided because they could slow or damage the vessel or in-water device. These disturbances would not alter the overall nature of the sediments to a degree that would impair their function as habitat. The following alternatives analysis specifies where these impacts could be happening in terms of number of events with vessel movement or in-water devices training/testing in different habitat areas.

3.5.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), the majority of the training activities include vessels. These activities could be widely dispersed throughout the Study Area, but would be more concentrated near naval ports, piers, and ranges. Navy training vessel traffic would be concentrated in the Northeast U.S. Continental Shelf Large Marine Ecosystem near Naval Station Norfolk in Norfolk, Virginia, and in the Southeast U.S. Continental Shelf Large Marine Ecosystem near Naval Station Mayport in Jacksonville, Florida. Amphibious landings would be restricted to designated beaches. Large vessel movement primarily occurs within the U.S. Exclusive Economic Zone, with the majority of the traffic flowing in a direct line between Naval Stations Norfolk and Mayport. Large marine ecosystems, as well as the Gulf Stream Open Ocean Area—specifically within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes and anywhere in the Gulf of Mexico. Use of in-water devices is concentrated within the Virginia Capes Range Complex.

Because of the nature of vessel operation and intentional avoidance of bottom strikes, most shore and bottom habitats would not be exposed to vessel strikes but could be exposed to vessel disturbance by propeller wash. Groundings would be accidental and are rare. Amphibious vehicles are an exception, but only designated beaches that are naturally resilient to disturbance are used. Therefore, while vessels may affect shore and bottom habitats, adverse impacts are not likely.

Shallow water habitats within the Study Area would have a very small potential to be exposed to vessel strikes. Vessels would pose little risk to habitats in the open ocean although, in coastal waters, currents from large vessels may cause resuspension of sediment. Vessels travelling at high speeds would generally pose more of a risk through propeller action in shallow waters.

With the exception of amphibious operations, vessel disturbance and strikes affecting habitats would be extremely unlikely. Shallow-water vessels typically operate in defined boat lanes with sufficient depths to avoid propeller or hull strikes of bottom habitats. However, for some inland training activities the training areas outside of navigation channels may not have sufficient depth that it is avoidable.

The direct impact of vessels on bottom habitats is restricted to amphibious training beaches, whereas the indirect impact of propeller wash and wakes from vessels or in-water devices could impact shallow-water training areas and sheltered shoreline habitats. However, the bottom disturbance associated with propeller wash represents only a temporary resuspension of sediment in the shallowest portion of training areas. The effect of surface wakes is limited to high-speed training along relatively sheltered shorelines and is likely indistinguishable from the effect of other vessel wakes or storms in waters open to the public. Sheltered waters restricted to the public are typically harbors where no wake speeds are enforced.

There is very little likelihood of impacts to habitats because in-water devices are not expected to contact the seafloor during training activities, because operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), Navy vessel movements and in-water device usage for testing activities would be similar to those described previously under training activities.

Because of the nature of vessel and in-water device operation and intentional avoidance of bottom strikes, most habitat would not be exposed to vessel or in-water device direct strikes.

The impact of vessels and in-water devices on marine habitats would be inconsequential because the footprint of potential impact is extremely small relative to the overall availability of habitat, operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

3.5.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

Impacts from Vessels and In-Water Devices Under Alternative 2 for Training Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), Navy vessel movements and in-water device usage under Alternative 2 would be similar to those described previously under Alternative 1 training activities, although the overall vessel operations would be slightly increased due to more active hull-mounted sonar operations.

Because of the nature of vessel and in-water device operation and intentional avoidance of bottom strikes, most habitat would not be exposed to vessel or in-water device direct strikes. Amphibious landings are an exception, but these activities are conducted in designated areas that have been historically used for this type of activity and are generally devoid of any quality habitat.

The impact of vessels and in-water devices on marine habitats would be inconsequential because the footprint of potential impact is extremely small relative to the overall availability of habitat, operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

Impacts from Vessels and In-Water Devices Under Alternative 2 for Testing Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), Navy vessel movements and in-water device usage for testing activities under Alternative 2 would be similar to those described previously under Alternative 2 training activities.

Because of the nature of vessel and in-water device operation and intentional avoidance of bottom strikes, most habitats would not be exposed to vessel or in-water device direct strikes. Amphibious landings are an exception; however, they are not included in testing activities.

The impact of vessels and in-water devices on marine habitats would be inconsequential because the footprint of potential impact is extremely small relative to the overall availability of habitat, operational procedures typically avoid shallow areas and intentionally avoid vessels or devices contacting the bottom, and exposures would be localized, temporary, and would cease with the conclusion of the activity.

3.5.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Impacts from Vessels and In-Water Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., vessels and in-water devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.4.2 Impacts from Aircraft and Aerial Targets

Impacts from aircraft and aerial targets are not applicable to habitats, because aircraft and aerial targets would not contact or otherwise affect shore or bottom habitats and are not analyzed further in this section.

3.5.3.4.3 Impacts from Military Expended Materials

This section analyzes the potential for physical disturbance to marine substrates from the following categories of military expended materials: (1) non-explosive practice munitions, (2) fragments from high-explosive munitions, and (3) expended materials other than munitions, such as sonobuoys, expendable targets, and ship hulks. Note that expended materials do not include materials that are recovered or considered in-water or seafloor devices. Areas expected to have the greatest amount of expended materials are the Northeast U.S. Continental Shelf Large Marine Ecosystem, the Southeast U.S. Continental Shelf Large Marine Ecosystem, and the Gulf Stream Open Ocean Area (specifically within the Virginia Capes and Jacksonville Range Complexes). For a discussion of the types of activities that use military expended materials, where they are used, and how many events would occur under each alternative, see Tables 2.6-1 through 2.6-4. Military expended materials have the potential to physically disturb marine substrates to the extent that they impair the substrate's ability to function as a habitat. These disturbances can result from several sources, including the impact of the expended material contacting the seafloor and moving around, the covering of the substrate by the expended material, or alteration of the substrate from one type to another.

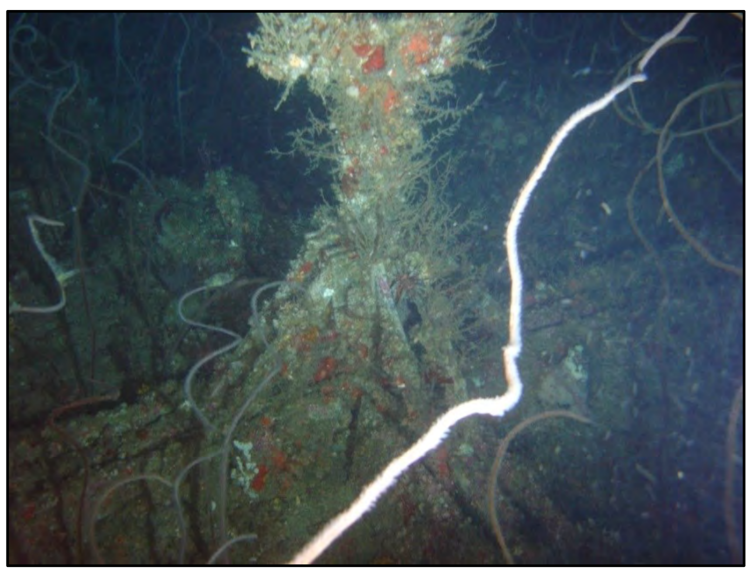
The potential for military expended materials to physically impact marine substrates as they come into contact with the seafloor depends on several factors. These factors include, but are not limited to, the size, shape, type, density, and speed of the material through the water column; the amount of the material expended; the frequency of training or testing; water depth, water currents, or other disturbances; and the type of substrate. Most of the kinetic energy of the expended material, however, is dissipated within the first few feet of the object entering the water causing it to slow considerably by the time it reaches the substrate. Because the damage caused by a strike is proportional to the force of the strike, slower speeds result in lesser impacts. Due to the water depth at which most training and testing events take place, a direct strike on either hardbottom or artificial structures (e.g., artificial reefs and shipwrecks) is unlikely to occur with sufficient force to damage the substrate. In softer substrates (e.g., sand, mud, silt, clay, and composites), the impact of the expended material coming into contact with the seafloor, if large enough and striking with sufficient momentum, may result in a depression and a localized redistribution of sediments as they are temporarily suspended in the water column. There may also be redistribution of unconsolidated sediment in areas with sufficient flow to move the sediment, creating a pattern of scouring on one side of the material and deposition on the other.

During Navy training and testing, countermeasures such as flares and chaff are introduced into marine habitats. These types of military expended materials are not expected to impact marine habitats as strike stressors, given their smaller size and low velocity when deployed compared to projectiles, bombs, and missiles.

Another potential physical disturbance that military expended materials could have on marine substrates would be to cover them or to alter the type of substrate and, therefore, its function as habitat. The majority of military expended materials that settle on hardbottom or artificial substrates, while covering the seafloor, may serve a similar habitat function as the substrate it is covering by providing a hard surface on which organisms can attach (Figure 3.5-11 and Figure 3.5-12). Similarity in attached organisms over the long term depends on similarity in structural features (Perkol-Finkel et al., 2006; Ross et al., 2016), fine surface texture, and mineral content (Davis, 2009). Natural hardbottom and artificial structures of a similar shape will eventually have similar communities of attached organisms if they have similar fine texture and mineral content. However, the smooth surface texture of intact military expended materials and lack of mineral content suggest a difference in species composition and associated

Note: Observed at approximately 350 meters in depth and 60 nautical miles east of Jacksonville, Florida. Of note is the use of the smoke float as a colonizing substrate for a cluster of sea anemones (U.S. Department of the Navy, 2010).

Figure 3.5-11: A Marine Marker Observed in an Area Dominated by Coral Rubble on the Continental Slope

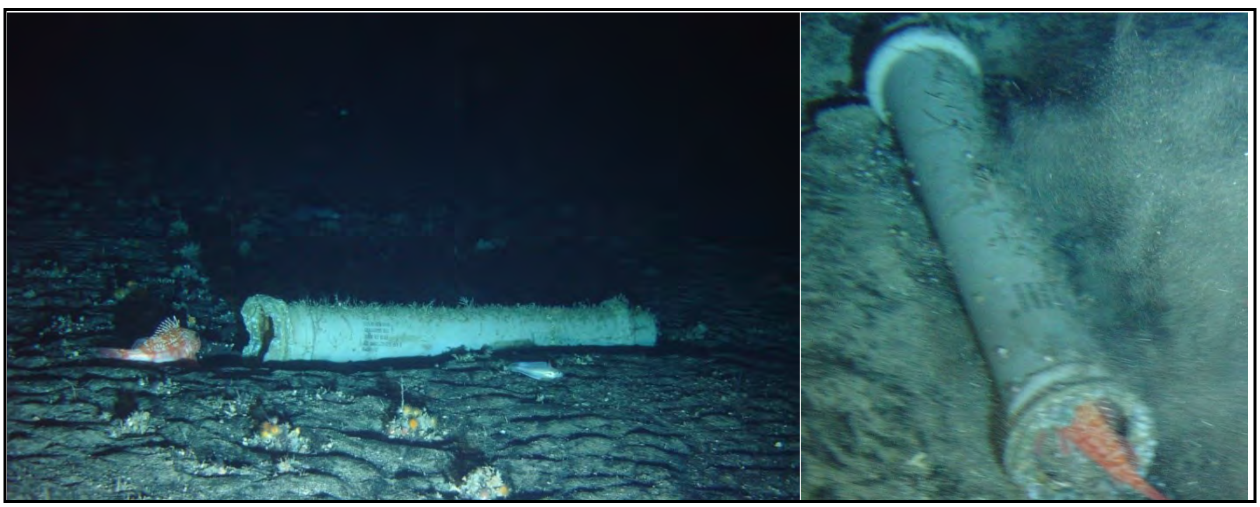


Note: Observed on the ridge system that runs parallel to the shelf break at approximately 80 meters in depth and 55 nautical miles east of Jacksonville, Florida. Of note is that encrusting organisms and benthic invertebrates readily colonize the artificial structure to a similar degree as the surrounding rock outcrop (U.S. Department of the Navy, 2010).

Figure 3.5-12: An Unidentified, Non-Military Structure on Hardbottom

functions. An exception would be expended materials, like the decelerators/parachutes utilized to deploy sonobuoys, lightweight torpedoes, expendable mobile anti-submarine warfare training targets, and other devices from aircraft, which would not provide a hard surface for colonization. In these cases, the hardbottom or artificial substrate covered by the expended material would not be physically damaged, but would have an impaired ability to function as a habitat for colonizing or encrusting organisms.

Most military expended materials that settle on soft bottom habitats, while not damaging the actual substrate, would inhibit the substrate's ability to function as a soft bottom habitat by covering it with a hard surface. This would effectively alter the substrate from a soft surface to a hard structure and, therefore, would alter the habitat to be more suitable for organisms more commonly found associated with hard bottom environments (U.S. Department of the Navy, 2010, 2011). Expended materials that settle in the shallower, more dynamic environments of the continental shelf would likely be eventually covered over by sediments due to currents and other coastal processes, or encrusted by organisms. Depending on the substrate properties and the hydrodynamic characteristics of the area, military expended materials may become buried rather quickly while in other areas they may persist on the surface of the seafloor for a more extended time. The offshore portion of the continental shelf experiences more sediment redistribution from oceanic currents (e.g., Gulf Stream) than distant surface waves. The effect of oceanic currents on sediment redistribution diminishes seaward of the continental shelf break: sediment along the continental slope and the Atlantic Basin/Abyssal Zone experience very little reworking from surface currents and waves. In the deeper waters of the continental slope and beyond where currents do not play as large of a role, expended materials may remain exposed on the surface of the substrate with minimal change for extended periods (Figure 3.5-13).



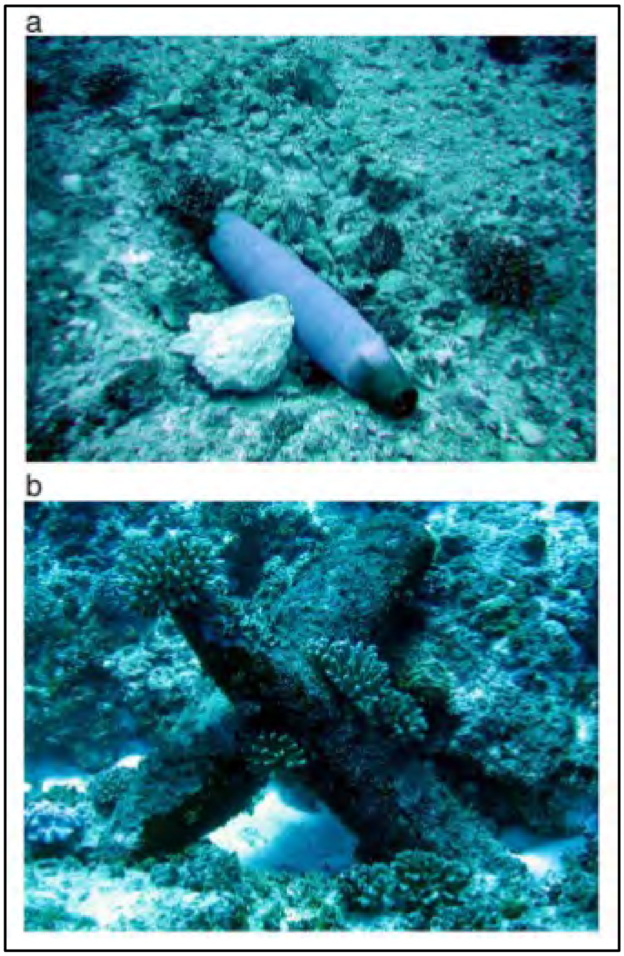
Note: The casing was observed in a sandy area on the continental slope approximately 425 meters in depth and 70 nautical miles east of Jacksonville, Florida. The casing has not become covered by sediments or encrusting organisms due to the depth and the relatively calm, current-free environment.

Figure 3.5-13: A 76-millimeter Cartridge Casing on Softbottom and a Blackbelly Rosefish (*Helicolenus dactylopterus*) Using the Casing for Protection When Disturbed

Whereas the impacts will accumulate somewhat through successive years of training and testing, some portion of the expended material will sink below the surface of shifting soft bottom habitat or become incorporated into natural hard bottom before crumbling into inorganic particulates. This will be the fate of military expended material whose density is greater than or equal to that of the underlying substrate (e.g., metal, cement, sand) (Traykovksi & Austin, 2017). Constituents of military expended material that are less dense than the underlying substrate (e.g., fabric, plastic) will likely remain on the surface substrate after sinking. In this case, the impact on substrate as a habitat is likely temporary and minor due to the mobility of such materials (refer to living resources sections for more information on the entanglement and ingestion risk posed by plastic and fabric constituents of military expended material). The impact of dense expendable materials on bottom substrate is prolonged in the large marine ecosystem areas that are seaward of the continental shelf. Between initial settlement and burial or complete degradation, these relatively stable objects will likely function as small artificial habitats for encrusting algae, attached macroalgae/seaweed, and/or sedentary invertebrates as well as small motile organisms (Figure 3.5-14).

Disturbance of the bottom from ship hulks may occur, but impairment of habitat function is not expected because the material is sunk in the abyssal zone where bottom organisms are generally small and sparsely populated (Nybakken, 1993); the deep ocean has a sparse supply of food items for sedentary deposit or filter feeders. The only densely populated areas in the deep ocean are around the occasional hydrothermal vent/cold seep.

To determine the potential level of disturbance that military expended materials have on soft, intermediate, and hard bottom substrates, an analysis to determine the impact footprint was conducted for each range complex for each alternative. Three main assumptions were made that result in the impact footprints calculated being generally considered overestimates. First, within each category of expended items (e.g., bombs, missiles, rockets, large-caliber projectiles, etc.), the size of the largest item that would be expended was used to represent the sizes of all items in the category. For example, the impact footprints of missiles used during training exercises range



a. MK 82 inert bomb (168 centimeters long) that directly impacted the seafloor at a depth of 12 meters in Z3E on 5 or 6 September 2007; photographed on 13 September 2007. Area of destruction/ disturbance was approximately 17 square meters.

b. MK 82 bombs with Pocilloporid corals, algae, etc.

Source: (Smith & Marx, 2016)

Figure 3.5-14: Military Expended Material Functioning as Habitat

from 1.5 to 40 square feet. For the analyses, all missiles were assumed to be equivalent to the largest in size, or 40 square feet. Second, it was also assumed that the impact of the expended material on the seafloor was twice the size of its actual footprint. This assumption accounts for any displacement of sediments at the time of impact as well as any subsequent movement of the item on the seafloor due to currents or other forces. This should more accurately reflect the potential disturbance to soft bottom habitats, but would overestimate disturbance to hard bottom habitats since no displacement of the substrate would occur. Third, items with casings (e.g., small-, medium-, and large-caliber munitions; flares; sonobuoys; etc.) have their impact footprints doubled to account for both the item and its casing. Items and their casings were assumed to be the same size, even though depending on the munitions, one of them is often smaller than the other.

Once the impact footprints were calculated, three analyses were performed for each range complex: (1) a worst-case scenario in which potential impact to each habitat type (soft, intermediate, and hard bottom habitats) in that range complex if all expended materials settled in areas with that substrate type, (2) a proportional analysis in which potential impact to each habitat type expended materials settled proportionally across all habitat types in the area, and (3) a 5-year scenario in which potential impact to the bottom habitats in that range complex over a 5-year period if activities continued at anticipated levels and impact accumulated over that period. During the analyses, the same dimensions were used for high-explosive munitions as were used for non-explosive practice munitions. The total area of the seafloor covered by the expended materials should be similar regardless of whether the item is intact or fragmented, despite the fact that high-explosive munitions will explode in the air, at the surface, or in the water column and only fragments would make it to the substrate.

Only the acreage in the large marine ecosystem areas was included in percentages. The areas within the Atlantic Basin and Abyssal Zone were not included in order to focus on bottom areas likely to have a combination of suitable habitat, supply of sedentary invertebrate larvae, and sufficient food particles for filtration or deposit-feeding. Artificial substrate was not included, because it was inconsistently included for mapping and it likely represented a miniscule percentage of habitat types in the large marine ecosystems.

According to surveys conducted at Farallon De Medinilla (a Department of Defense bombing range in the Mariana Archipelago) between 1997 and 2012, there was no evidence that the condition of the living resources assessed had changed or been adversely impacted to a significant degree by the training activities being conducted there. It should also be noted that the intended munition target was on the nearby land area, and water impacts were due to inaccuracy. The health, abundance, and biomass of fishes, corals, and other marine resources are comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago (Smith & Marx, 2016). However, the study noted that the decline in some important reef fish during their latest surveys was likely due to increasing attention from fishermen. Also, this is expected to be an extreme case based on the proximity to shallow-water coral reefs and the severe wave impact and associated movement of military expended materials due to the shallow margins of the islands where wave impact is most severe. Impacts to habitat from military expended material in the Study Area would be expected to be less severe. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed analyses of the impacts associated with military expended materials from Navy testing and training activities.

3.5.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

Impacts from Military Expended Materials Under Alternative 1 for Training Activities

Training activities involving military expended materials (Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas in which the training is occurring. Each range complex was evaluated to determine what level of impact could be expected under Alternative 1.

To determine the percentage of a given substrate within a range complex that may potentially be impacted by military expended materials under a worst case scenario for each of the alternatives, the total impacted area for each range complex was divided by the total amount of that particular substrate type within the same range complex as provided in Table 3.5-2 (see also Appendix F, Military Expended Materials and Direct Strike Impact Analyses).

Military expended materials associated with training exercises under a worst-case scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the training areas or range complexes. Likewise, the potential impact of the worst-case scenario on intermediate bottom habitats within each range complex does not exceed 0.01 percent of the total available intermediate bottom. Impacts to hard substrate would not exceed 0.01 percent for any of the areas. Given that the probability of these worst case scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under the Alternative 1 on hard bottom, intermediate bottom, or soft bottom substrates will be even less.

Additional analysis was conducted in order to determine the proportional impact of military expended material from training activities on marine habitats in each of the training areas within the Study Area (Figure 3.5-15). Based on the proportional analysis of impacts, total military expended materials impacts from training activities to vulnerable hard substrate would be approximately 7.5 acres. Impacts to other substrate types would be approximately 6.0, 63.0, and 5.5 acres for intermediate, soft, and unknown substrates, respectively. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses), for detailed analysis of military expended materials impacts from training activities in each range complex and other training locations.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, soft bottom habitats may recover in the short term where heavier military expended materials are buried under shifting sediments; hard bottom habitats would recover over the long term where hard, stable military expended materials become overgrown with similar organisms. The total proportional impact footprint for impacts from high explosives over the 5-year period would be approximately 36.0, 30.5, and 315.5 acres for hard bottom, intermediate bottom, and soft bottom respectively. Approximately 27.0 acres of unknown habitat would be impacted. However, total impacts would still affect less than 0.02 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Military expended materials, including small caliber projectile casings, marine markers, flares, and flare parts, would also be utilized in inland waterways. In the northeast, military expended materials would be expended in Narragansett Bay, Rhode Island; Lower Chesapeake Bay, James River and Tributaries, and York River. In the southeast, military expended material is employed in Cooper River, South Carolina; Kings Bay, Georgia; Mayport, Florida; and Port Canaveral, Florida. Impacts from training activities under Alternative 1 in inland waterways are very small, totaling only about 2.5 acres combined in the northeast inland waterways and less than 0.5 acre. In the southeast inland waterways in the worst-case scenario. Proportionally, in range complexes in the northeast, less than 0.5, 0.5, 2.5, and 0.5 acres of hard, intermediate, soft, and unknown substrate would be impacted respectively (Figure 3.5-15). In the southeast, less than 0.5 acre would be impacted in any of the substrate types (Figure 3.5-15).

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from certain activities that involve the use of military expended materials.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

Testing activities involving military expended materials (Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas the testing is occurring. Each range complex and testing range was evaluated to determine what level of impact could be expected under Alternative 1.

To determine the percentage of the total soft bottom or hard bottom substrate within the Study Area that may potentially be impacted by military expended materials under a worst case scenario for each of the alternatives, the total impacted area for each testing range was divided by the total amount of that particular substrate type within the same testing range as provided in Table 3.5-2 (see also Appendix F, Military Expended Materials and Direct Strike Impact Analyses).

Military expended materials associated with testing activities under a worst-case scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the testing areas. Likewise, the potential impact of the worst-case scenario on intermediate bottom habitats within each testing range does not exceed 0.01 percent of the total available hard bottom. Hard bottom impacts would not exceed 0.01 percent for any of the areas. Given that the probability of these worst case scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under Alternative 1 on hard bottom, intermediate bottom, or soft bottom substrates will be even less.

Additional analysis was conducted in order to determine the proportional impact of military expended material from testing activities on marine habitats in each of the ranges complexes and training areas within the Study Area (Figure 3.5-15). Based on the proportional analysis of impacts, total military expended materials impacts to hard substrate from testing activities would be approximately 6.5 acres. Impacts to other substrate types would be approximately 6.5 and 57.0 acres for intermediate and soft substrates, respectively. Approximately 0.5 acre of unknown substrate would be impacted. See Appendix F, Military Expended Materials and Direct Strike Impact Analyses, for detailed analysis of military expended materials impacts from testing activities in each range complex or other testing area.

Analysis was also conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, some habitat would recover over time, as soft substrates are dynamic systems and craters could refill. The total proportional impact footprint for impacts from high explosives over the 5-year period would be approximately 32.5, 335.5, and 282.0 acres for hard bottom, intermediate bottom, and soft bottom respectively. Approximately

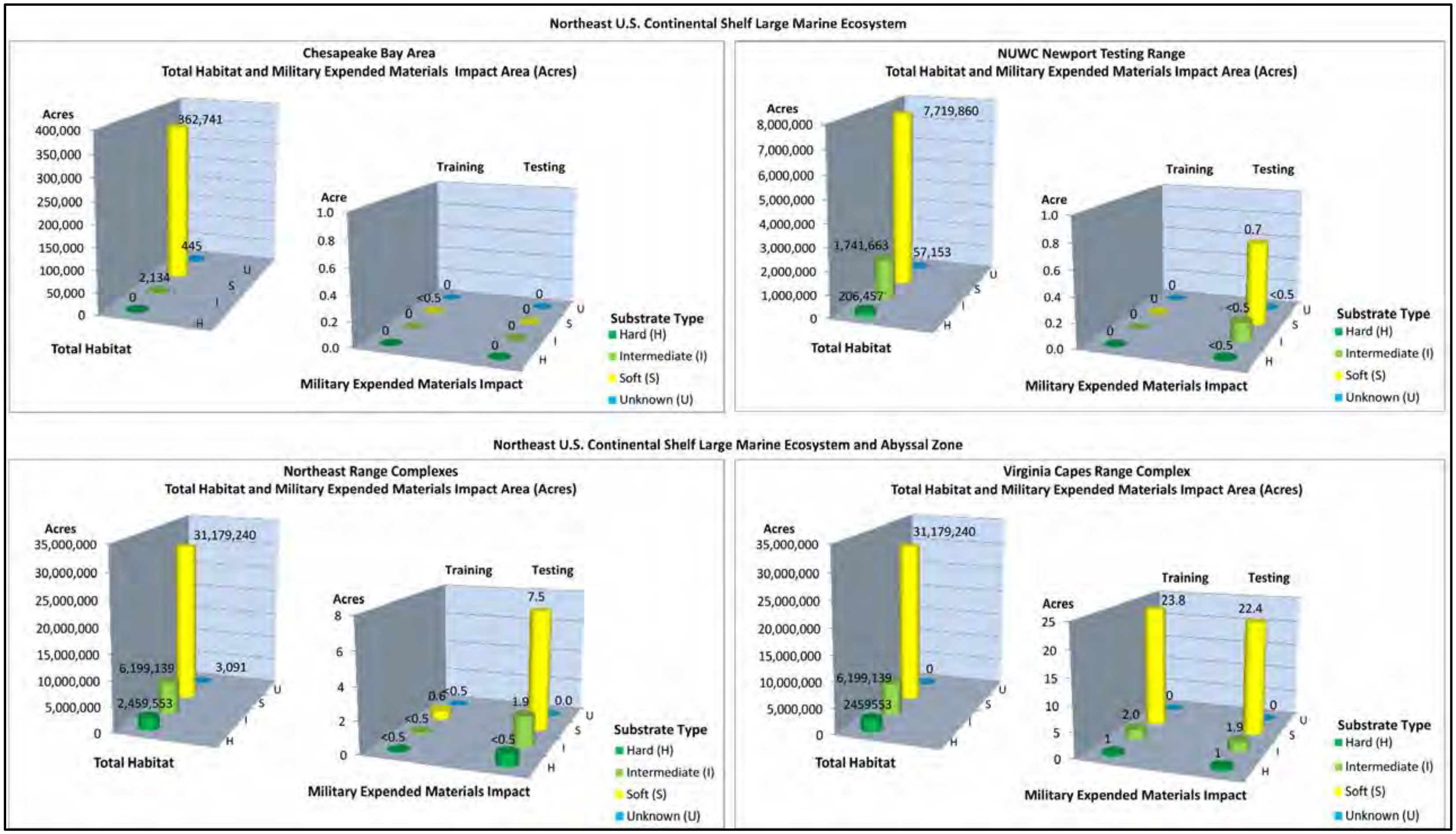


Figure 3.5-15: Alternative 1 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Testing and Training Compared to Total Habitat Within the Study Area

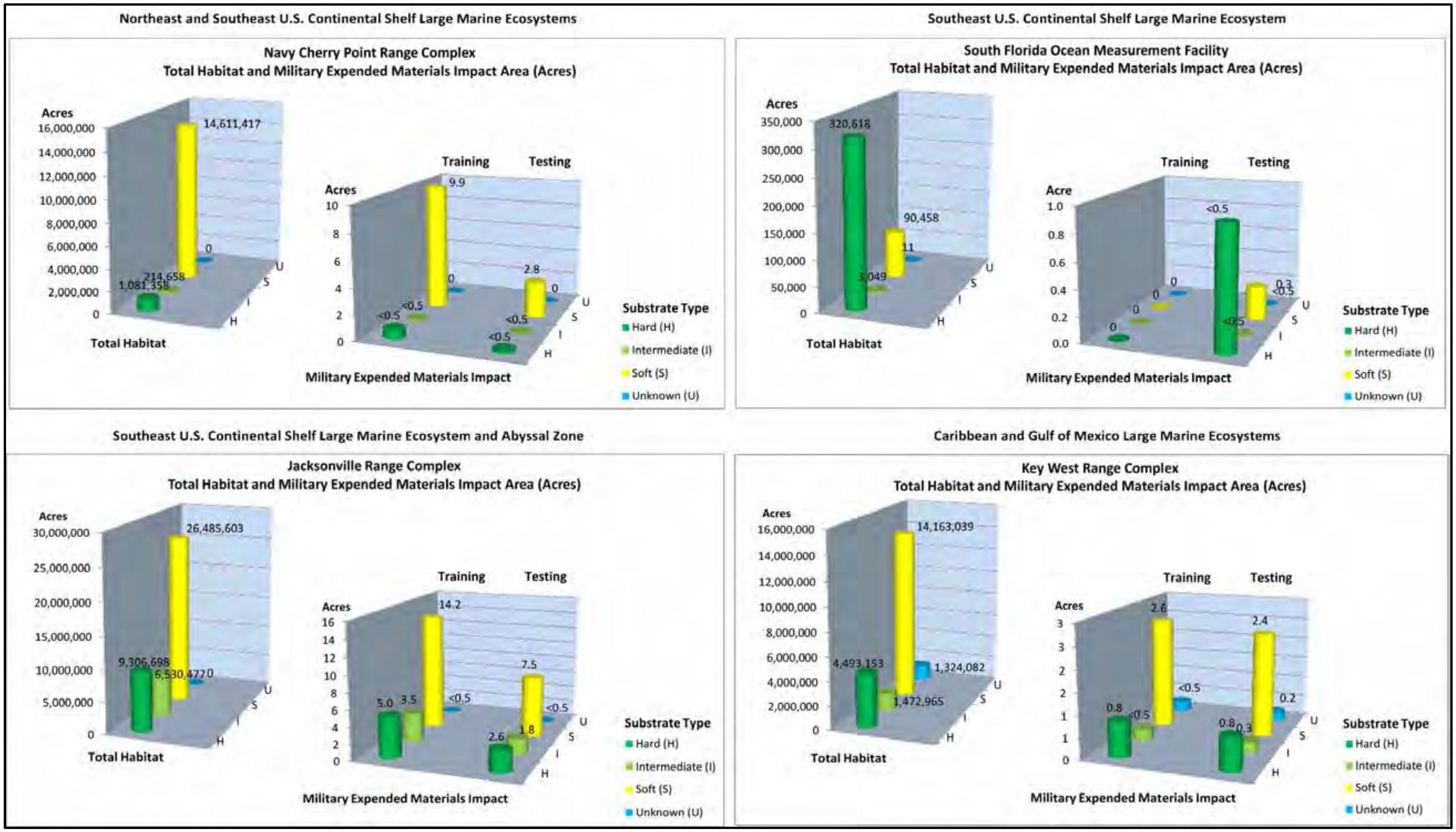


Figure 3.5-15 (Continued): Alternative 1 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Testing and Training Compared to Total Habitat Within the Study Area

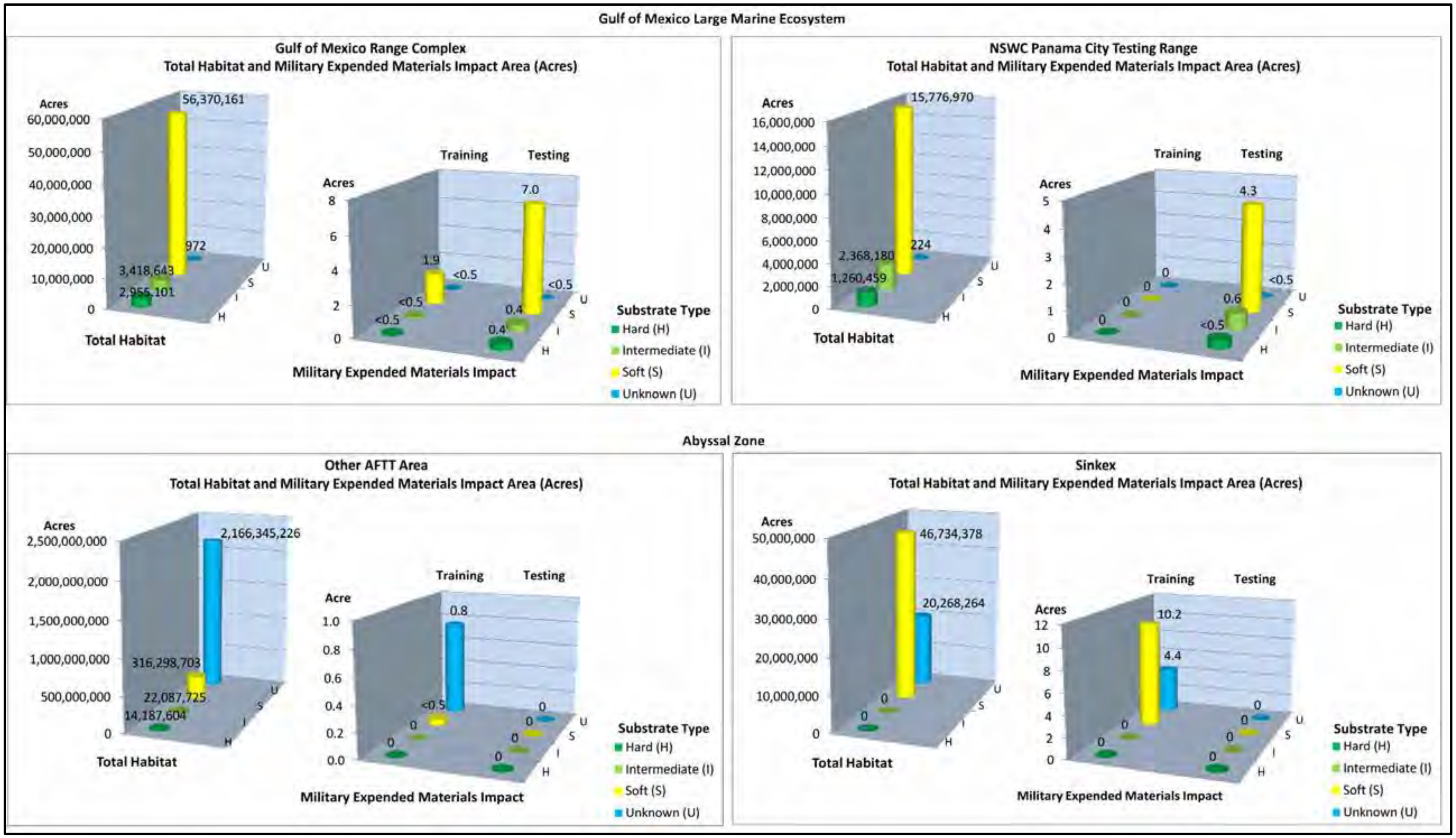


Figure 3.5-15 (Continued): Alternative 1 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Testing and Training Compared to Total Habitat Within the Study Area

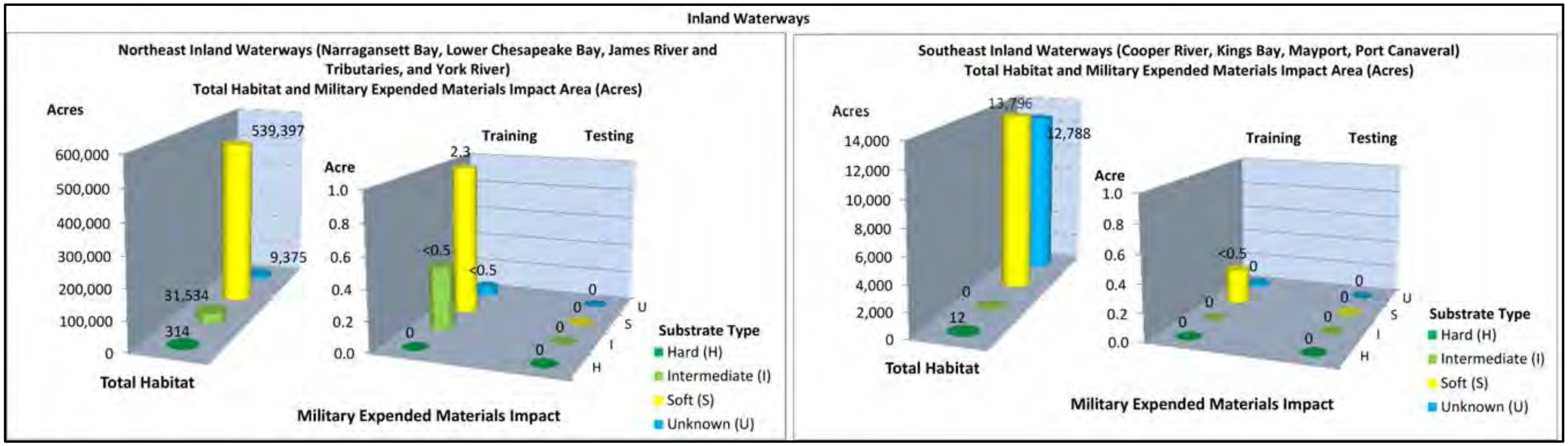


Figure 3.5-15 (Continued): Alternative 1 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Testing and Training Compared to Total Habitat Within the Study Area

1.0 acres of unknown habitat would be impacted. However, total impacts would still affect less than 0.05 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Further, many of the materials used in training are recovered to some degree: non-explosive torpedoes (100 percent), unmanned aerial systems (depends on the type and exercise), targets (depends on the type and exercise), mine shapes (depends on the exercise), and bottom-placed instruments (100 percent). For the purpose of analysis, a worst case (expended) is assumed if the recovery status was unknown. The numbers are also based on a maximum expenditure which is typically not realized in any given year.

As discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources), the Navy will implement mitigation to avoid impacts from military expended materials on habitats in mitigation areas throughout the Study Area. For example, the Navy will not conduct gunnery activities within a specified distance of shallow-water coral reefs. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from certain activities that involve the use of military expended materials.

3.5.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

Impacts from Military Expended Materials Under Alternative 2 for Training Activities

Training activities involving military expended materials (Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas the testing is occurring. Each range complex was evaluated to determine what the level of impact could be expected under Alternative 2.

As indicated in Section 3.0.3.3.4.2 (Military Expended Materials), under Alternative 2 the total number of military expended materials would be nearly identical to those analyzed under Alternative 1 (see Appendix F, Military Expended Materials and Direct Strike Impact Analyses), and the primary difference between alternatives would be due to an increase in the amount of materials (e.g., sonobuoys) associated with anti-submarine warfare activities. Activities under Alternative 2 would occur in the same geographic locations using the same types of military expended materials as Alternative 1.

To determine the percentage of the total soft bottom, intermediate bottom, or hard bottom substrate within a training range that may potentially be impacted by military expended materials under a worst case scenario for each of the alternatives, the total impacted area for each training range was divided by the total amount of that particular substrate type within the same testing range. Results of this analysis are provided in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Military expended materials related to training activities under a worst-case scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the training ranges. Likewise, the potential impact of the worst-case scenario on intermediate bottom habitats within each training range does not exceed 0.01 percent of the total available intermediate bottom. Likewise, the potential impact of the worst-case scenario on habitats within each training area, range complex, or other area does not exceed 0.01 percent of the total available hard bottom.

Analysis was conducted in order to determine the proportional impact of military expended material from training on marine habitats in each of the range complexes within the Study Area. Under Alternative 2, impacts would only differ for the Jacksonville and Gulf of Mexico Ranges complexes (Figure 3.5-16). Based on the proportional analysis of impacts, military expended material impacts to hard substrate from training activities would be less than 7.5 acres. Impacts to other substrate types would be approximately 6.0, 63.5, and 5.5 acres for intermediate, soft, and unknown substrates, respectively. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from training activities in each Training Area.

Analysis was conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, soft bottom habitats may recover in the short term where heavier military expended materials are buried under shifting sediments; hard bottom habitats would recover over the long term where hard, stable military expended materials become overgrown with similar organisms. The total proportional impact footprint for impacts from high explosives over the 5-year period would be approximately 36.5, 31.0, and 316.5 acres for hard bottom, intermediate bottom, and soft bottom respectively. Approximately 27.0 acres of unknown habitat would be impacted. However, total impacts would still affect less than 0.02 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Given that the probability of these worst case scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under Alternative 2 on either hard bottom or soft bottom substrates will be even less than shown in Figure 3.5-16.

Further, many of the military expended materials would be recovered, including, torpedoes, unmanned aerial systems, targets, mine shapes, and instruments.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

Testing activities involving military expended materials (Section 3.0.3.3.4, Physical Disturbance and Strike Stressors, and Appendix A, Navy Activity Descriptions) would have the potential to impact the marine substrates within the areas the testing is occurring. Each range complex and testing range was evaluated to determine what the level of impact could be expected under Alternative 2.

As indicated in Section 3.0.3.3.4.2 (Military Expended Materials), under Alternative 2 the total number of military expended materials would be very similar to that under Alternative 1 (see Appendix F, Military Expended Materials and Direct Strike Impact Analyses), and the primary difference between alternatives would be due to an increase in the amount of materials (e.g., sonobuoys) associated with anti-submarine warfare activities. Activities under Alternative 2 would occur in the same geographic locations using the same types of military expended materials as Alternative 1.

To determine the percentage of the total soft bottom, intermediate bottom, or hard bottom substrate within a testing range that may potentially be impacted by military expended materials under a worst case scenario for each of the alternatives, the total impacted area for each testing range was divided by the total amount of that particular substrate type within the same testing range. Results of this analysis are provided in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Military expended materials related to testing activities under a worst-case scenario would not impact more than 0.01 percent of the available soft bottom habitat annually within any of the testing ranges. Likewise, the potential impact of the worst-case scenario on intermediate bottom habitats within each testing range does not exceed 0.01 percent of the total available intermediate bottom. The potential impact of the worst-case scenario on habitats within each testing range does not exceed 0.1 percent of the total available hard bottom.

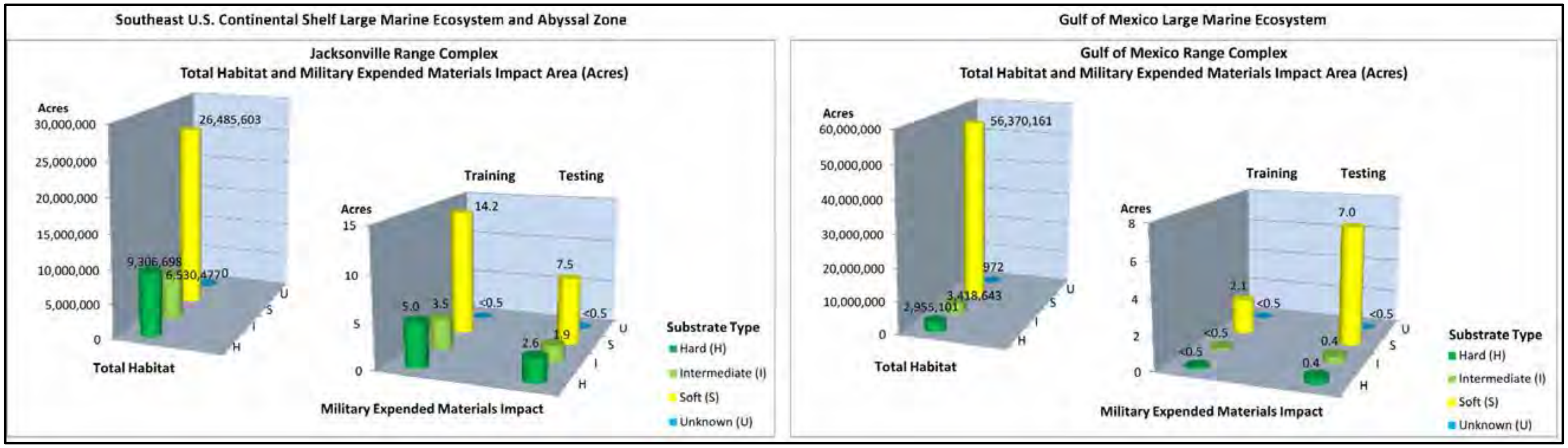


Figure 3.5-16: Alternative 2 – Proportional Impact (Acres) from Military Expended Materials by Substrate Type for Training and Testing Compared to Total Vulnerable Habitat Within the Range Complexes of the Large Marine Ecosystems Within the Study Area

Analysis was conducted in order to determine the proportional impact of military expended material from testing on marine habitats in each of the range complexes within the Study Area. Based on the proportional analysis of impacts, military expended material impacts to hard substrate from training activities would be 6.5 acres. Impacts to other substrate types would be approximately 7.0, 57.0, and less than 0.5 acres for intermediate, soft, and unknown substrates, respectively. See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed analysis of explosive impacts from training activities in each training area.

Analysis was conducted to evaluate impacts accumulating over the course of a 5-year period. The analysis assumed that all impacts would accumulate. In reality, over time, some habitat would recover as soft substrates are dynamic systems and craters could refill. The total proportional impact footprint for impacts from high explosives over the 5-year period would be approximately 33.0, 36.0, and 285.0 acres for hard bottom, intermediate bottom, and soft bottom respectively. Approximately 1.0 acre of unknown habitat would be impacted. However, total impacts would still affect less than 0.05 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted. Details of this analysis can be found in Appendix F (Military Expended Materials and Direct Strike Impact Analyses).

Given that the probability of these worst case scenarios occurring is highly unlikely, the actual impact of military expended materials within each range complex under Alternative 2 on either hard bottom or soft bottom substrates will be even less than shown in Figure 3.5-15.

Further, many of the military expended materials would be recovered, including torpedoes, unmanned aerial systems, targets, mine shapes, and instruments.

3.5.3.4.3.3 Impacts from Military Expended Materials Under the No Action Alternative

Impacts from Military Expended Materials Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., military expended materials) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.4.4 Impacts from Seafloor Devices

The types of activities that use seafloor devices are discussed in Appendix B (Activity Stressor Matrices) and where they are used and how many activities would occur under each alternative are discussed in Section 3.0.3.3.4.3 (Seafloor Devices). Seafloor devices include items that are placed on, dropped on, or moved along the substrate for a specific purpose, and include mine shapes, anchor blocks, vessel anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom placed targets that are recovered (not expended). Mine shapes are typically deployed via surface vessels or fixed-wing aircraft. These items can damage fragile abiotic or biogenic structures on the bottom, temporarily cover and effectively replace an area of bottom, and resuspend sediment when deployed/retrieved.

3.5.3.4.4.1 Impacts from Seafloor Devices Under Alternative 1

Impacts from Seafloor Devices Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, seafloor devices are deployed in the Northeast and Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems, as well as Gulf Stream Open Ocean Area—specifically within the Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes. Specific bays and inland waters where seafloor devices are deployed include Sandy Hook Bay, Earle, New Jersey; lower Chesapeake Bay, Hampton Roads, Virginia; Beaufort Inlet Channel, Morehead City, North Carolina; Cape Fear River, Wilmington, North Carolina; St. Andrew Bay, Panama City, Florida; Sabine Lake, Beaumont, Texas; and Corpus Christi Bay, Corpus Christi, Texas.

Activities involving seafloor devices have the potential to impact bottom habitats. While hard bottom exists in all these areas, activities in the Virginia Capes Range Complex, Navy Cherry Point Range Complex, and particularly the Jacksonville Range Complex have the potential to impact hard bottom.

Mine shapes or other stationary targets and anchors are typically recovered within 7 to 30 days following the completion of the training or testing events. As a result of their temporary nature, recovered mine shapes do not permanently impact the substrate on which they are placed, but will temporarily impair the ability of the substrate to function as a habitat for as long as the mine shape and anchor is in place. The impairment is due to the temporary covering by artificial substrate along with changes in the bathymetry around the structures due to scouring and deposition patterns around objects on a soft bottom. Additionally, many targets used in inshore waters are placed either pierside or at beachfront locations where the substrate is already disturbed by dredging (for pierside locations) or by nearshore currents and wave action (for beach-front locations).

Potential impacts of precision anchoring are qualitatively different from other seafloor devices because the activity involves repeated disturbance to the same area of seafloor. Precision anchoring training exercises involve releasing of anchors in designated locations. The intent of these training exercises is to practice anchoring the vessel within 300 ft. of the planned anchorage location. These training activities typically occur within predetermined shallow water anchorage locations near ports with seafloors consisting of soft bottom substrate. The level of impact to the soft sediments would depend on the size of the anchor used, which would vary according to vessel type. As most of these activities occur in areas along navigation channels subject to strong currents and shifting sediment, disturbed areas would quickly return to pre-disturbance conditions. The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on habitats in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from precision anchoring activities.

Crawlers are fully autonomous, battery-powered amphibious vehicles used for functions such as reconnaissance missions in territorial waters. These devices are used to classify and map underwater mines in shallow water areas. The crawler is capable of traveling 2 ft. per second along the seafloor and can avoid obstacles. The crawlers are equipped with various sonar sensors and communication equipment that enable these devices to locate and classify underwater objects and mines while rejecting miscellaneous clutter that would not pose a threat.

Crawlers move over the surface of the seafloor and would not harm or alter any hard substrates encountered; therefore the hard bottom habitat would not be impaired. However, fragile abiotic or biogenic structures could be harmed by the crawlers moving over the substrate (refer to living resources sections for analysis). In soft substrates, crawlers may leave a trackline of depressed sediments approximately 2 ft. wide (the width of the device) in their wake. However, since these crawlers operate in shallow water, any disturbed sediments would be redistributed by wave and tidal action shortly (days to weeks) following the disturbance. Any disturbance to the soft sediments would not impair its ability to function as a habitat.

The impact of seafloor devices on marine habitats from Alternative 1 training activities is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision anchoring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

Under Alternative 1, the use of seafloor devices occurs throughout the Study Area.

Testing activities involving the use of anchor blocks, which are used to moor minefield targets and shapes and are deployed and recovered, have the potential to impact bottom habitat throughout the Study Area. At the conclusion of the testing event, the minefield targets and shapes are typically recovered, but may be left in place.

Crawlers are used in the northeast in Narragansett Bay and waters used for testing by the Naval Undersea Warfare Center Division, Newport Testing Range; off the east coast of Florida at the South Florida Ocean Measurement Facility Testing Range; and at the Gulf of Mexico testing ranges for the Naval Surface Warfare Center, Panama City Division Testing Range. Testing activities involving the use of bottom crawling unmanned underwater vehicles within the South Florida Ocean Measurement Facility Testing Range would be limited to the Port Everglades Restricted Anchorage Area (Section 2.1.6.2, Sea and Undersea Space). In other testing areas, bottom habitats would be exposed to strike and disturbance in the relatively small area transited by bottom-crawling unmanned underwater vehicles.

Impacts to habitats from Alternative 1 testing activities are likely to be similar to those discussed above for training exercises. The impact of seafloor devices on marine habitats is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision anchoring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat. The Navy will implement mitigation to avoid potential impacts from seafloor devices on habitats in mitigation areas within the South Florida Ocean Measurement Facility, as discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources). For example, the Navy will use real-time geographic information system and Global Positioning System (along with remote sensing verification) data during deployment, installation, and recovery of anchors and mine-like objects to avoid impacts on shallow-water coral reefs and live hard bottom. Mitigation for seafloor resources was not included in the quantitative assessment of habitat impacts; however, it will help the Navy further avoid the potential for impacts on habitats from certain activities that involve the use of seafloor devices at the South Florida Ocean Measurement Facility Testing Range.

3.5.3.4.4.2 Impacts from Seafloor Devices Under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 2, seafloor devices occur in the Northeast and Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems, as well as Gulf Stream Open Ocean Area—specifically within the Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes. Specific bays and inland waters could include Sandy Hook Bay, Earle, New Jersey; lower Chesapeake Bay, Hampton Roads, Virginia; Beaufort Inlet Channel, Morehead City, North Carolina; Cape Fear River, Wilmington, North Carolina; St. Andrew Bay, Panama City, Florida; Sabine Lake, Beaumont, Texas; and Corpus Christi Bay, Corpus Christi, Texas.

Impacts to habitats from training activities under Alternative 2 are likely to be the same as those discussed above for Alternative 1 training exercises. The number of devices and locations in which they are used would be the same. The impact of seafloor devices on marine habitats is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision mooring activities, few habitats would be exposed to multiple events, (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats, and (4) sensitive habitats would tend to be avoided due to snagging or entanglement that could hinder recovery of the device. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

Under Alternative 2, the use of seafloor devices occurs in the Northeast, and Southeast U.S. Continental Shelf Large Marine Ecosystems as well as Gulf Stream Open Ocean Area—specifically within the Northeast, Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes; Naval Undersea Warfare Center Division, Newport Testing Range, South Florida Ocean Measurement Facility Testing Range, Naval Surface Warfare Center, and the Panama City Division Testing Range; nearshore locations at Newport, Rhode Island and Joint Expeditionary Base Little Creek, Virginia Beach, Virginia; and anywhere in the Gulf of Mexico.

Impacts to habitats from testing activities under Alternative 2 are likely to be similar to those discussed above for Alternative 1 testing exercises. The number of testing activities involving seafloor devices is only slightly increased (approximately 0.5 percent increase) from Alternative 1. The only locations where activities would increase are Virginia Capes Range Complex and Naval Surface Warfare Center Panama City Testing Range, where five additional activities annually would occur at each location. Impact of seafloor devices on marine habitats is likely to be inconsequential because: (1) the area exposed to the stressor is extremely small relative to overall availability of habitat of each type, (2) the activities are dispersed such that with the exception of precision mooring activities, few habitats would be exposed to multiple events, and (3) impacts would be localized and those involving soft bottom would likely be temporary due to the dynamic nature of the habitats. Activities involving seafloor devices are not expected to yield any discernable impacts on the overall availability or quality of habitat.

3.5.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Impacts from Seafloor Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., seafloor devices) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.4.5 Impacts from Pile Driving

Pile driving and removal would involve driving of piles into soft substrate with an impact hammer. Pile driving may have the potential to impact soft bottom habitats temporarily during driving, removal, and in the short-term thereafter.

3.5.3.4.5.1 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

Under Alternative 1, Elevated Causeway System training would include pile driving and removal which could occur once per year in the nearshore and surf zone at one of the following locations: Chesapeake Bay area or Navy Cherry Point Range Complex. While pile driving and removal may have the potential to impact soft bottom habitat, the impacts would be extremely limited since the number of piles is relatively small, and the duration is short (20 days for assembly and 10 days for disassembly). Piles would remain in the water for up to 60 days. Since pile driving would occur in the nearshore and surf zone areas, the dynamic nature of the soft bottom habitat is likely to return to its previous state shortly following removal of the temporary piles. However, the dispersed larvae forming new hard bottom communities may attach to the temporary structures instead of more permanent structures (see Section 3.4, Invertebrates, for details).

Impacts from Pile Driving Under Alternative 1 for Testing Activities

Pile driving stressors are not applicable to habitats since pile driving would not occur under testing activities for Alternative 1 and will not be analyzed further in this section.

3.5.3.4.5.2 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

Under Alternative 2, elevated causeway system training would include pile driving and removal which could occur once per year in the nearshore and surf zone at one of the following locations: Chesapeake Bay area or Navy Cherry Point Range Complex. While pile driving and removal may have the potential to impact softbottom habitat, the impacts would be extremely limited since the number of piles is relatively small, and the duration is short (20 days for assembly and 10 days for disassembly). Piles would remain in the water for up to 60 days. Since pile driving would occur in the nearshore and surf zone areas, the dynamic nature of the softbottom habitat is likely to return to its previous state shortly following removal of the temporary piles.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

Pile driving stressors are not applicable to habitats since pile driving would not occur under testing activities for Alternative 2 and will not be analyzed further in this section.

3.5.3.4.5.3 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical disturbance and strike stressors (e.g., pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.5.3.5 Entanglement Stressors

Entanglement stressors are not applicable to habitats due to the lack of mobility capabilities of habitats and will not be analyzed further in this section.

3.5.3.6 Ingestion Stressors

Ingestion stressors are not applicable to habitats due to the lack of ingestion capabilities of habitats and will not be analyzed further in this section.

3.5.3.7 Secondary Stressors

Secondary stressors are not applicable to habitats as they are not susceptible to impacts from secondary stressors and will not be analyzed further in this section.

3.5.4 Summary of Potential Impacts on Habitats

3.5.4.1 Combined Impacts of All Stressors Under Alternative 1

Of all the potential stressors, only explosives on or near the bottom and military expended materials have any measureable potential to impact marine substrates as habitat for biological communities. The impact area for in-water explosions and military expended materials were all much less than 1 percent of the total area of documented soft bottom or hard bottom in their respective training or testing areas for each mapped substrate type, in any range complex, over 1 year. Furthermore, impacts are expected to be negligible for unknown substrate type habitats. The impacts are unlikely to persist in most cases. Large and dense military expended material (e.g., anchor blocks, large caliber projectile casings, non-explosive bombs) deposited on the bottom along the outer continental shelf would be the most persistent. However, soft bottom habitats may recover in the short term where heavier military expended materials are buried under shifting sediments; hard bottom habitats would recover over the long term where hard, stable military expended materials become overgrown with similar organisms.

The combined impact area of explosive stressors, physical disturbances, and strike stressors proposed for training and testing events in Alternative 1 would have minimal impact on the ability of soft bottom, intermediate bottom, or hard bottom to serve their function as habitat. The total area of mapped hard bottom (Figure 3.5-1 through Figure 3.5-4) in the Study Area is over 26,110,408 acres, which dwarfs the estimated 14.0 acres of potential impacts. Training activities under Alternative 1 would have a total footprint of potential impact across all habitat types of 82.0 acres from military expended materials and 9.0 acres from explosive detonations. This also represents less than 0.01 percent of the bottom habitat within the Study Area. Testing activities under Alternative 1 would have a total footprint of potential impact of 70.5 acres from military expended materials and 14.5 acres from explosive detonations. This represents less than 0.01 percent of the bottom habitat within the Study Area. The combined total proportional impact for training and testing is primarily to soft bottom habitat, much less to hard and intermediate substrate habitats, and very little to areas with unknown substrate type (Figure 3.5-17). See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed impact analysis.

3.5.4.2 Combined Impacts of All Stressors Under Alternative 2

The combined effects of explosive stressors, physical disturbances, and strike stressors proposed for training and testing events in Alternative 2 would have minimal impact on the ability of soft bottom, intermediate bottom, or hard bottom to function as habitat. The total area of mapped hard bottom (Figure 3.5-1 through Figure 3.5-4) in the Study Area is over 26,110,408 acres, which dwarfs the estimated 7.5 acres of potential impacts. Training activities under Alternative 2 would have a total footprint of potential impact of 82.0 acres across all habitat types from military expended materials and 9.0 acres from explosive detonations. This represents less than 0.01 percent of the bottom habitat within the Study Area. Testing activities under Alternative 2 would have a total footprint of potential impact of 71.0 acres from military expended materials and 16.0 acres from explosive detonations. This also represents less than 0.01 percent of the bottom habitat within the Study Area. The combined total proportional impact for training and testing is primarily to soft bottom habitat, much less to hard bottom and intermediate bottom substrate habitats, and very little to areas with unknown substrate type (Figure 3.5-18). See Appendix F (Military Expended Materials and Direct Strike Impact Analyses) for detailed impact analysis.

3.5.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various explosives and physical disturbance and strike stressors (e.g., in-water detonations, military expended materials, seafloor devices, vessels and in-water devices, and pile driving) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

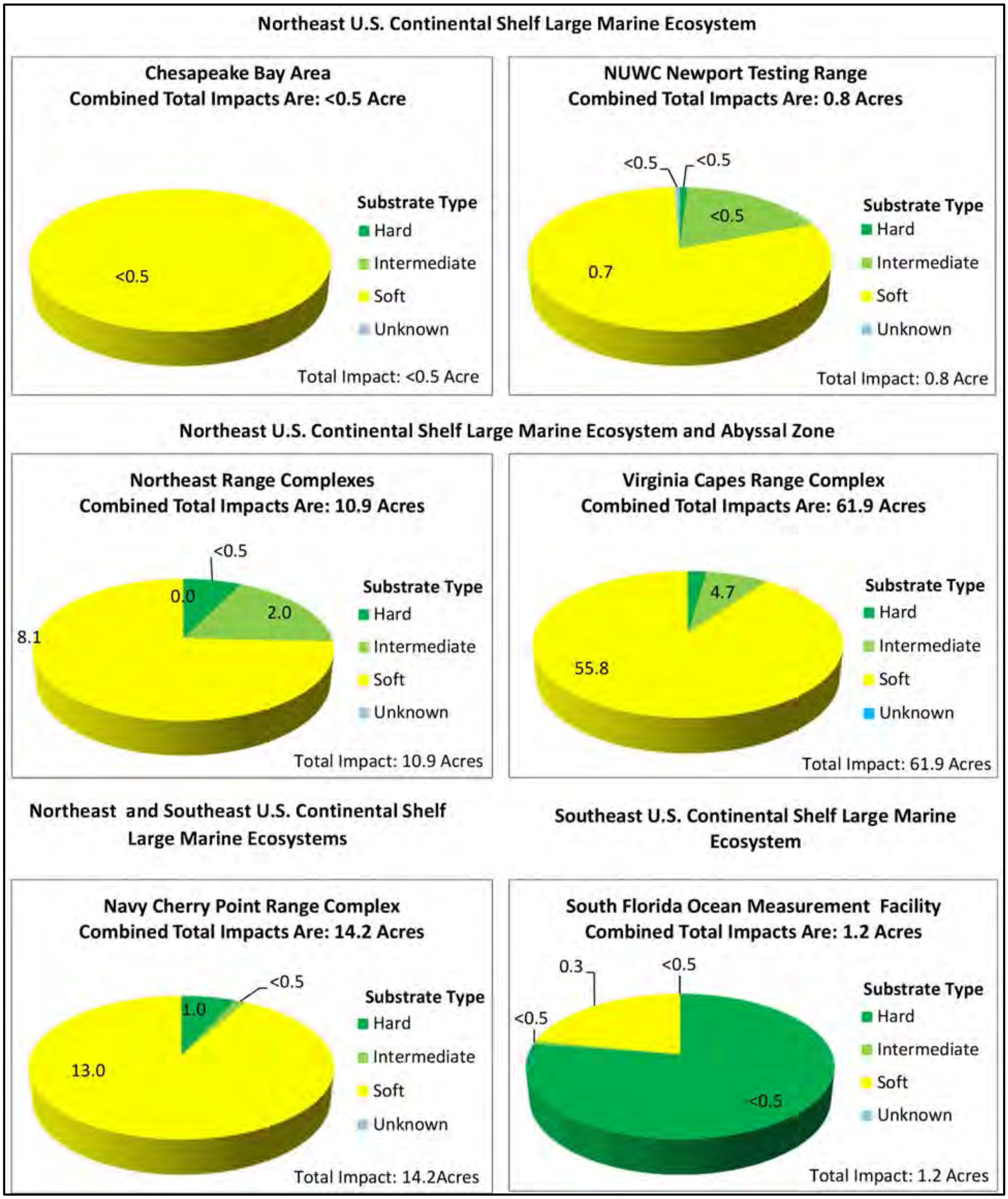


Figure 3.5-17: Alternative 1 – Combined Proportional Impact (Acres) from Explosives and Military Expended Materials for Training and Testing Within the Study Area

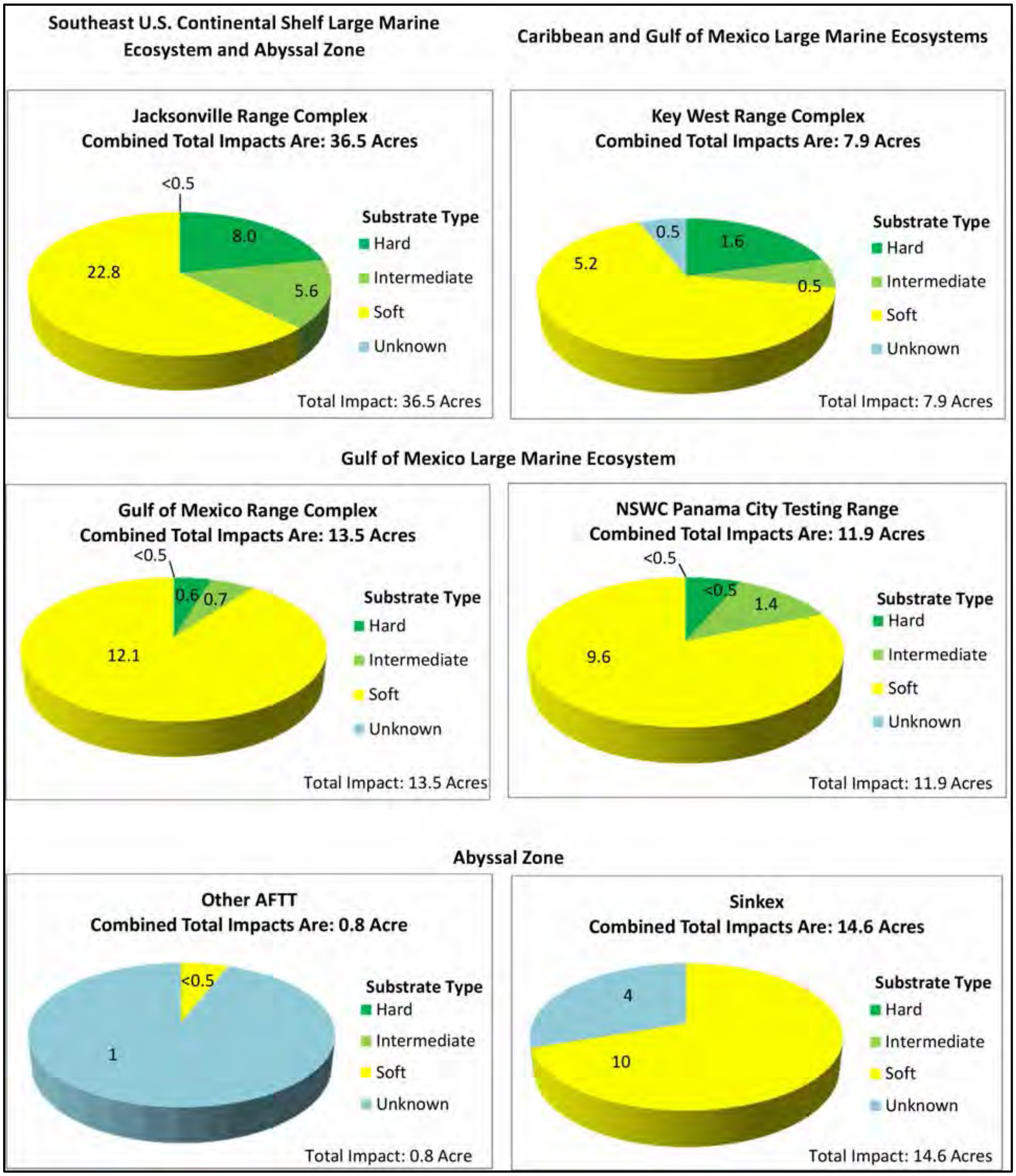


Figure 3.5-17 (Continued): Alternative 1 – Combined Proportional Impact (Acres) from Explosives and Military Expended Materials for Training and Testing Within the Study Area

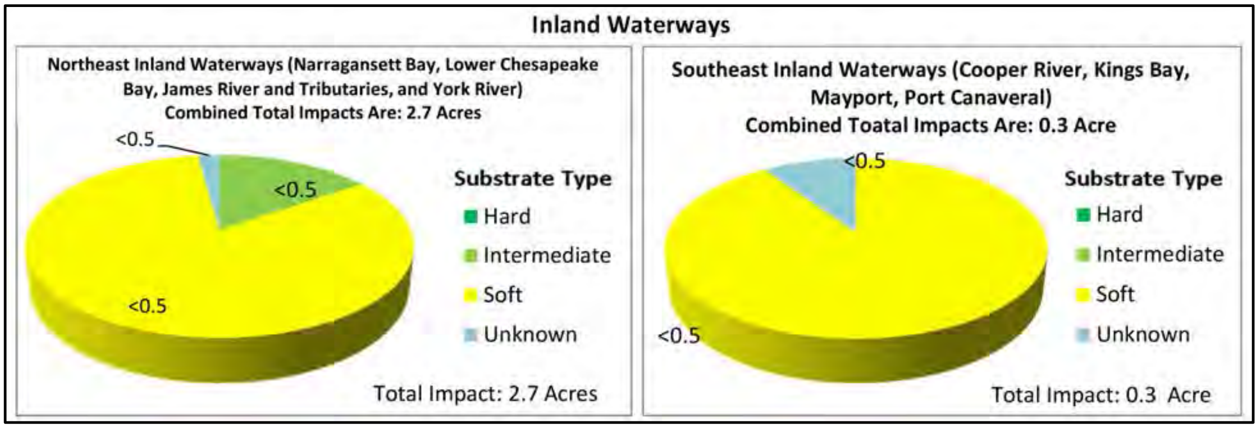


Figure 3.5-17 (Continued): Alternative 1 – Combined Proportional Impact (Acres) from Explosives and Military Expended Materials for Training and Testing Within the Study Area

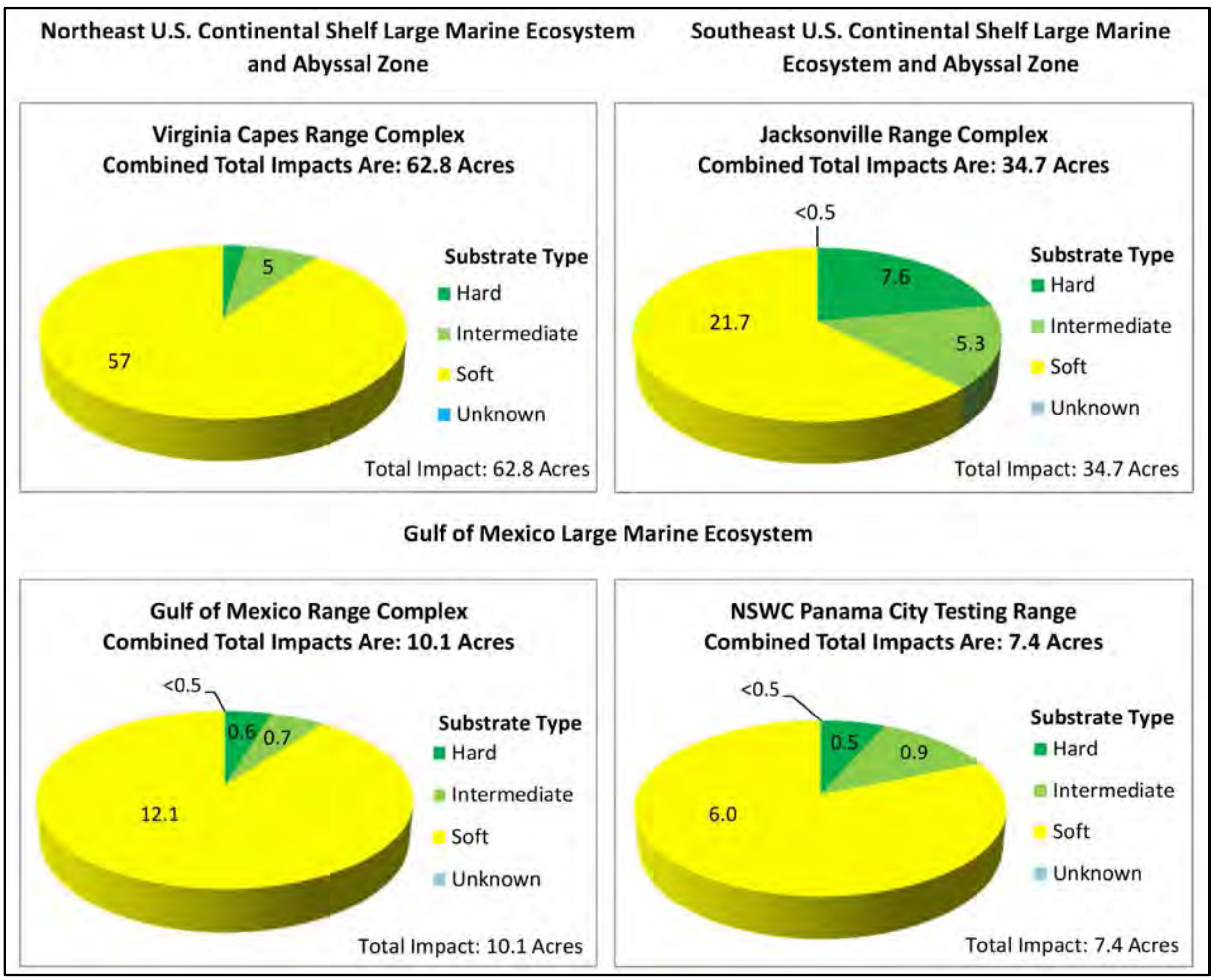


Figure 3.5-18: Alternative 2 – Combined Proportional Impact (Acres) from Explosives and Military Expended Materials for Training and Testing Within the Study Area

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3.6 Fishes

FISHES SYNOPSIS

The United States Department of the Navy (Navy) considered all potential stressors that fishes could potentially be exposed to from the Proposed Action. The following conclusions have been reached for the Preferred Alternative (Alternative 1):

- Acoustics: The use of sonar and other transducers, air guns, pile driving, vessel noise, aircraft noise, and weapons noise could result in impacts on fishes in the Study Area. Some sonars and other transducers, vessel noise, and weapons noise could result in hearing loss, masking, physiological stress, or behavioral reactions. Aircraft noise would not likely result in impacts other than brief, mild behavioral responses in fishes that are close to the surface. Air guns and pile driving have the potential to result in the same effects in addition to mortality or injury. Most impacts, such as masking or behavioral reactions, are expected to be temporary and infrequent as most activities involving acoustic stressors would be at low levels of noise, temporary, localized, and infrequent. More severe impacts such as mortality or injury could lead to permanent or long-term consequences for individuals but, overall, long-term consequences for fish populations are not expected.
- Explosives: The use of explosives could result in impacts on fishes within the Study Area. Sound and energy from explosions is capable of causing mortality, injury, hearing loss, masking, physiological stress, or behavioral responses. The time scale of individual explosions is very limited, and training and testing activities involving explosions are dispersed in space and time, therefore, repeated exposure of individual fishes are unlikely. Most effects such as hearing loss or behavioral responses are expected to be short-term and localized. More severe impacts such as mortality or injury could lead to permanent or long-term consequences for individuals but, overall, long-term consequences for fish populations are not expected.
- Energy: The use of electromagnetic devices may elicit brief behavioral or physiological stress responses only in those exposed fishes with sensitivities to the electromagnetic spectrum. This behavioral impact is expected to be temporary and minor. Similar to regular vessel traffic that is continuously moving and covers only a small spatial area during use, electromagnetic fields would be continuously moving and cover only a small spatial area during use, so population-level impacts are unlikely.
- Physical Disturbance and Strike: Vessel strikes, in-water device strikes, military expended material strikes, and seafloor device strikes present a risk for collision with fishes, particularly near coastal areas, seamounts, and other bathymetric features where densities are higher. While the potential for physical disturbance and strikes of fishes can occur anywhere vessels are operated or training and testing activities occur, most fishes are highly mobile and have sensory capabilities which enable the detection and avoidance of vessels, expended materials, or objects in the water column or on the seafloor.

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FISHES SYNOPSIS

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- Entanglement: Fishes could be exposed to multiple entanglement stressors associated with Navy training and testing activities. The potential for impacts is dependent on the physical properties of the expended materials and the likelihood that a fish would encounter a potential entanglement stressor and then become entangled in it. Physical characteristics of wires and cables, decelerators/parachutes, and biodegradable polymers, combined with the sparse distribution of these items throughout the Study Area, indicates a very low potential for fishes to encounter and become entangled in them. Because of the low numbers of fish potentially impacted by entanglement stressors, population-level impacts are unlikely.
- Ingestion: 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. Military expended materials from munitions present an ingestion risk to fishes that forage in the water column and on the seafloor. Military expended materials other than munitions present an ingestion risk for fishes foraging at or near the surface while these materials are buoyant, and on the seafloor when the materials sink. Because of the low numbers of fish potentially impacted by ingestion stressors, population-level impacts are unlikely.
- Secondary: Effects on sediment or water quality would be minor, temporary, and localized and could have short-term, small-scale secondary effects on fishes; however, there would be no persistent or large-scale effects on the growth, survival, distribution, or population-level impacts of fishes.

3.6.1 INTRODUCTION

This section analyzes the potential impacts of the Proposed Action on fishes found in the Study Area. Endangered Species Act (ESA) species that occur in the Study Area are discussed in Section 3.6.2.2 and taxonomic groupings are discussed in Section 3.6.2.3. The complete analysis of environmental consequences is in Section 3.6.3 (Environmental Consequences) and the potential impacts of the Proposed Action on marine fish species are summarized in Section 3.6.4 (Summary of Potential Impacts on Fishes).

For this Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS), marine fishes are evaluated as groups of species characterized by distribution, morphology (body type), or behavior relevant to the stressor being evaluated. Activities are evaluated for their potential effects on the marine fishes in the Study Area that are listed, proposed, or candidate species under the ESA, as well as other fishes in the Study Area generally by major marine fish groupings. 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. Other species, such as gobies and most reef fish, generally have small home ranges and restricted distributions (Helfman et al., 2009). The early life stages (e.g., eggs and larvae) of many fishes may be widely distributed even when the adults have relatively small ranges. 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 life stage, size, sex, reproductive condition, and other factors.

Approximately 78 percent of all marine fish species occur in waters less than 200 meters (m) deep and in close association with land, while 13 percent are associated with the open ocean (Moyle & Cech, 2004).

3.6.2 AFFECTED ENVIRONMENT

Three subsections are included in this section. General background information is given in Section 3.6.2.1 (General Background), which provides brief summaries of habitat use, movement and behavior, and threats that affect or have the potential to affect fishes within the Study Area. Protected species listed under the ESA are described in Section 3.6.2.2 (Endangered Species Act-Listed Species). General taxonomic groupings of fishes not listed under the ESA are briefly reviewed in Section 3.6.2.3 (Species Not Listed under the Endangered Species Act).

3.6.2.1 General Background

Fishes are the most numerous and diverse of the major vertebrate groups (Moyle & Cech, 2004). It is estimated that there are currently over 34,000 species of fish worldwide (Eschmeyer & Fong, 2017), with greater than half that number of species inhabiting the oceans.

Many factors impact the abundance and distribution of marine fishes in the seven Large Marine Ecosystems (West Greenland Shelf, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast United States (U.S.) Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea) and three open ocean areas (Labrador Sea, North Atlantic Subtropical Gyre, and Gulf Stream Current) in the Study Area. The distribution of fish species in the Study Area is influenced primarily by temperature, salinity, pH, physical habitat, ocean currents, and latitudinal gradients (Helfman et al., 2009; Macpherson, 2002). In general terms, the coastal-centered Large Marine Ecosystems support a greater diversity of coastal species, while the open ocean areas support a lower diversity of oceanic and deep-sea species (Helfman et al., 2009). The warm waters of the Loop Current in the Gulf of Mexico promote the dispersal of tropical species from the Caribbean Sea into the Northern Gulf of Mexico (Shulman, 1985). The circulation patterns of the Gulf Stream and the North Atlantic Subtropical Gyre also influence species distributions, particularly near Bermuda and Cape Hatteras, where the northernmost occurrences of sizable tropical fish assemblages are found (Love & Chase, 2007; Moyle & Cech, 2004). The Gulf Stream, described in Section 3.0.2 (Ecological Characterization of the Study Area), carries warm water to northern latitudes, where these areas can support subtropical species. For example, approximately half of the species occurrences in the Gulf of Maine are considered warm-water fish (Moyle & Cech, 2004), although some of these are sporadic or rare.

Marine fishes can be broadly categorized by their distributions within the water column or habitat usage. Moyle and Cech (2004) define the major marine habitat categories as estuaries, coastal habitats, reefs, epipelagic zone, deep sea, and the Polar regions. In the Study Area, the major habitat categories include all of the aforementioned except the Polar regions. Many marine fishes that occur in the Study Area are demersal species associated with nearshore coastal reefs or are more oceanic and live in surface waters (pelagic) further offshore (Schwartz, 1989). The highest number and diversity of fishes typically occur where the habitat has structural complexity (reef systems, continental slopes, deep canyons), biological productivity (areas of nutrient upwelling), and a variety of physical and chemical conditions (water flow, nutrients, dissolved oxygen, and temperature) (Bergstad et al., 2008; Helfman et al., 2009; Moyle & Cech, 2004; Parin, 1984). Some of the marine fishes that occur in the coastal zone migrate between marine and freshwater habitats (Helfman et al., 2009). Other distribution factors, including predator/prey relationships, water quality, and refuge (e.g., physical structure or vegetation cover) operate on more regional or local spatial scales (Reshetiloff, 2004). Also, fishes may move among habitats throughout their lives based on changing needs during different life stages (Schwartz, 1989).

Many habitat and geographic factors impact the distribution of fishes within the Study Area—including within range complexes, operating areas (OPAREAs), ports/shipyards, and testing ranges. In the Gulf of Mexico portion of the Study Area, water temperature, seafloor (benthic) habitat, and geographic location appear to be the primary factors, while in the Atlantic Ocean portion, latitudinal changes, temperature, and depth seem to be the most important factors influencing species distribution (Gordon, 2001; Love & Chase, 2007; Macpherson, 2002). Each major habitat type in the Study Area (e.g., coral reef, hard bottom, soft bottom, and beds of aquatic vegetation) supports an associated fish community with the number of species increasing with decreasing latitude (transition from north to south). However, this pattern is not as clearly defined for wide-ranging migratory open-ocean species (Macpherson, 2002). The specific characteristics of the wide diversity of habitat and biotic species that make up these habitat types within the Study Area are discussed in Section 3.3 (Vegetation), Section 3.4 (Invertebrates), and Section 3.5 (Habitats).

Some fish species in the United States are protected under the ESA and are managed by either the U.S. Fish and Wildlife Service (USFWS) or National Marine Fisheries Service (NMFS). The recreational and commercial fisheries are managed within a framework of overlapping international, federal, state, interstate, and tribal authorities. Individual states and territories generally have jurisdiction over fisheries located in marine waters within 3 nautical miles (NM) of their coast, except for Texas, the Gulf Coast of Florida, and Puerto Rico, which haves jurisdiction out to 9 NM. Federal jurisdiction includes fisheries in marine waters inside the U.S. Exclusive Economic Zone. The area stretches from the outer boundary of state waters out to 200 NM offshore of any United States coastline, except where intersected closer than 200 NM by bordering countries.

The Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act led to the formation of eight regional fishery management councils that coordinate with NMFS to manage and conserve certain fisheries in federal waters. Together with NMFS, the councils maintain fishery management plans for species or species groups comprised of fish, invertebrates, and vegetation to regulate commercial and recreational harvest within their geographic regions. The Study Area overlaps with the jurisdiction of five regional fishery management councils, as well as the range of the highly migratory species (e.g., sharks, billfishes, swordfishes, and tunas), which are managed directly by NMFS.

- **New England Fishery Management Council** includes Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut.
- **Mid-Atlantic Fishery Management Council** includes New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and North Carolina (from its northern border to Cape Hatteras).
- **South Atlantic Fishery Management Council** includes North Carolina (from Cape Hatteras to its southern border), South Carolina, Georgia, and the east coast of Florida.
- **Gulf of Mexico Fishery Management Council** includes west coast of Florida, Alabama, Mississippi, Louisiana, and Texas.
- **Caribbean Fishery Management Council** includes the Commonwealth of Puerto Rico and the U.S. Virgin Islands.
- **NMFS, Office of Sustainable Fisheries** includes all federally managed waters in the Northwestern Atlantic Ocean and the Gulf of Mexico where highly migratory species occur.

3.6.2.1.1 Habitat Use

Fishes inhabit most of the world's oceans, from warm shallow coastal habitat to cold deep-sea waters, and are found on the surface, in the water column, and at the bottom of the seven Large Marine Ecosystems (West Greenland, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea) and open ocean areas (Labrador Current, Gulf Stream, and North Atlantic Gyre) in the Study Area. The description of habitat use in this section pertains to common fishes found in the different habitats. The abiotic (non-living) components of all habitat types are addressed in Section 3.5 (Habitats), habitat-forming invertebrates (e.g., coral, sponges, etc.) are covered in Section 3.4 (Invertebrates), and marine vegetation components are discussed in Section 3.3 (Vegetation).

Fish distribution is restricted by biotic factors (competition or predation) or by abiotic components, such as temperature, salinity, dissolved oxygen, and pH or by that describe the potential range of environmental conditions a species can inhabit in the absence of predators and competitors. A species can be excluded from habitat otherwise suitable for it by competitors, predators, parasites, or lack of suitable prey (Moyle & Cech, 2004). For example, Catano et al. (2015) found that a loss of corals and the resulting decline in structural complexity, as well as management efforts to protect reefs, could alter the territory dynamics and reproductive potential of important herbivorous fish species.

Estuaries are comprised of brackish water, where freshwater mixes with saltwater to form transitional environments between rivers and the ocean. The fluctuating nature of the estuarine environment means that the fishes inhabiting or transiting through expend considerable amounts of energy adjusting to the changing conditions. Fishes found in estuaries are of five broad types: (1) freshwater (e.g., catfishes [*Ictalurus* species]), (2) diadromous species that spend part of their lives in freshwater and part of their lives in saltwater (e.g., young American shad, striped bass, Atlantic sturgeon, and Gulf sturgeon), (3) true estuarine (e.g., white perch [*Morone americana*]), (4) marine species that use estuaries but do not necessarily need them (e.g., American plaice [*Hippoglossoides platessoides*]), and (5) marine species that need estuaries for at least one stage of their lives (e.g., croakers [*Micropogonias* and *Leistomus* species]) (Moyle & Cech, 2004). Estuaries are primarily composed of soft bottom (e.g., sandy and mudflats) and many contain a variety of benthic habitat types such as seagrass beds and oyster reefs.

Marine and diadromous fishes inhabit the diverse coastal habitats on or near the edges of the continents, from the intertidal regions to the edge of the continental shelf (Moyle & Cech, 2004). The most abundant and conspicuous types of coastal habitats are hard bottom (e.g., rocky bottom which can include shell beds), soft bottom (e.g., sand, mud, silt), submerged aquatic vegetation (e.g., mangroves, salt marshes, seagrass beds, macroalgae beds), and floating macroalgae (e.g., *Sargassum*). Each of these coastal habitats has distinct types of fishes associated with it. In the Study Area, common fishes inhabiting the hard bottom habitat type include, but are not limited to gobies (Gobiidae), drums (Sciaenidae), seabasses (Serranidae), groupers (Epinephelidae), snappers (Lutjanidae), and sculpins (Cottidae), while flounder (Bothidae and Paralichthyidae) and stingrays (Dasyatidae) are found on soft bottoms. Grunts (Haemulidae) and a wide variety of other fishes are common inhabitants of submerged aquatic vegetation habitat.

Somewhere between 30 percent and 40 percent of all fish species are associated with hard bottom habitats (tropical and subtropical) such as reefs, and anywhere from 250 to 2,200 species are likely to be found in, on, or near a major complex of reefs (Moyle & Cech, 2004). Coral reef habitats are found between latitudes 30° North (N) and 30° South (S) in shallow water (usually less than 164 feet [ft.]) that is warm enough to support the growth of corals and clear enough to allow photosynthesis at moderate depths. However, some mesophotic and deepwater corals such as *Lophelia pertusa* has been found on relatively shallow reefs (180–250 m) off northeastern Florida (Ross et al., 2015). Most reef habitats are surrounded by nutrient-poor oceanic waters. Examples of some specialized carnivore fishes include flounders, coronetfishes (Fistularidae), and needlefishes (Belonidae). Compared to the total number of species of carnivorous fishes that inhabit low-latitude coral reefs, the number of herbivores is small (20 percent), but they are often the most noticeable fishes. Damselfishes (Pomacentridae), parrotfishes (Labridae), and surgeonfishes (Acanthuridae) are examples of herbivorous fishes found in reef habitat (Moyle & Cech, 2004). In the Study Area, commonly recognized reef fishes include butterfly fishes (Chaetodontidae), puffers (Tetraodontidae), tangs (Acanthuridae), triggerfishes (Balistidae), and wrasses (Labridae).

The upper 200 m of the ocean is termed the photic or epipelagic zone (Moyle & Cech, 2004). Sunlight penetrates sufficiently to support the growth of phytoplankton and macroalgae. The area between 200 m and 1,000 m is referred to as the mesopelagic zone, where light penetration is minimal (Moyle & Cech, 2004). Below the mesopelagic zone is the bathypelagic or aphotic zone, where sunlight does not penetrate. The lack of habitat complexity limits the number of fish species that inhabit the Epipelagic Zone. Less than two percent of all fish species inhabit the poor nutrient waters, with most occurring in the upper 328 ft. of the water column, where light can penetrate and permit phytoplankton growth and visual predators to see their prey. Epipelagic fishes are divided for convenience into nearshore and oceanic groups. Nearshore epipelagic fishes are overall the most commercially valuable group of fishes to humans because they typically occur in large schools, such as herring (Clupeidae) and anchovies (Engraulidae), or are particularly favored as food, such as tunas (Scombridae) and salmon. Predators on nearshore epipelagic fishes include billfishes and swordfishes (Xiphiidae), sharks (Carcharhinidae), and others. Oceanic epipelagic spend their entire life cycle either free swimming or can be associated with drifting macroalgae (*Sargassum* spp.) (Moyle & Cech, 2004). In the Study Area, examples of epipelagic open ocean fishes include sharks, tunas, billfishes and swordfishes, sauries (Scomberesocidae), and ocean sunfish (Molidae), plus the commensal remoras (Echeneidae).

Mesopelagic habitats reside below the well-lighted, well-mixed epipelagic zone. Between 400 ft. and 3,280 ft. in depth, light gradually fades to extinction, and the water temperatures decreases to 39° Fahrenheit (°F). Below 3,280 ft., bathypelagic habitats are characterized by complete darkness, low temperatures, low nutrients, low dissolved oxygen, and great pressure. This environment is the most extensive aquatic habitat on earth. The vastness of the deep-sea habitat, coupled with its probable stability through geological time, has led to the development of a diverse fish community, which accounts for 11 percent of all recorded fish species in the oceans. Lanternfishes (Myctophidae), with about 240 species, are an important group of mesopelagic deep sea fishes in terms of diversity, distribution, and numbers of individuals (Helfman et al., 2009). These species make up a large fraction of the deep scattering layer, so called because the sonic pulses of a sonar can reflect off the millions of swim bladders, often giving the impression of a false bottom (Moyle & Cech, 2004). Generally, deep-sea fishes are divided into two groups, those that are found in the water column and others associated with the seafloor. In the Study Area, the cookie cutter shark (Dalatiidae), fangtooths (Anoplogastridae), hatchetfishes (Sternoptychidae), and lanternfishes (Myctophidae) inhabit the water column while the seafloor is inhabited with grenadiers or rattails (Macrouridae), hagfishes (Myxinidae), hakes (Merlucciidae), and rays (Rajidae).

Some fishes use one habitat type over their entire life cycle, while others associate with different habitat types by life stage. Anadromous fishes such as sturgeon (Acipenseridae) and salmon (Salmonidae) hatch and rear in freshwater rivers as larvae and early juveniles and inhabit estuaries as they transition into the late-juvenile and early sub-adult life stages before entering the ocean to mature into adults. Many other marine fishes inhabit the water column as larvae and settle onto soft bottom habitat as juveniles and remain there as adults (flatfishes). The oceanic Atlantic bluefin tuna (*Thunnus thynnus*) provides an example of a species closely connected to one habitat category across their life cycle. By comparison, the Atlantic salmon (*Salmo salar*) and American shad (*Alosa sapidissima*) inhabit wide ranges of salinity and water depths that vary by season and age.

3.6.2.1.2 Movement and Behavior

Fishes exhibit a rich array of sophisticated behavior (Meyer et al., 2010). Fishes have been shown to cooperate in a variety of ways during foraging, navigation, reproduction, and predator avoidance (Fitzpatrick et al., 2006; Huntingford et al., 2006; Johnstone and Bshary, 2004). Some examples of the common types of behavior exhibited by fishes include movement or migration, schooling, feeding, and resting (Moyle & Cech, 2004).

Migratory behavior consists of mass movements from one place to another and can range in occurrence from daily to seasonal, depending on the species. Tunas, salmon, and eels migrate thousands of miles in short periods of time (e.g., a few months). Daily or seasonal migrations are typically for feeding and/or predator avoidance and can also be referred to as movement patterns. Some common movement patterns include coastal migrations, open ocean migrations, onshore/offshore movements, vertical water column movements, and life stage related migrations (e.g., eggs and larvae as part of the plankton/nekton). Migratory behavior occurs in response to changing environmental conditions, particularly temperature, or the movement and abundance of food organisms. The destinations of migratory events are often feeding or reproductive grounds. Many fishes have the ability to find their way back to a "home" area and some species use olfactory and visual cues, as well as or from chemicals released by the other fishes to return home (Moyle & Cech, 2004). Highly migratory species such as hammerhead shark (*Sphyrna* species), basking shark (*Cetorhinus maximus*), and swordfish (*Xiphias gladius*), may move across thousands of miles of open ocean. Other migratory species such as the Atlantic salmon and Atlantic sturgeon exhibit seasonal movement patterns throughout coastal continental shelf waters and beyond.

A shoal is defined as any group of fishes that remain together for social reasons, while a school is a polarized, synchronized shoal (Moyle & Cech, 2004), often swimming together in tight formations. Schools can change shape when traveling, feeding, resting, or avoiding predators. Vision and the lateral line system (defined below in Section 3.6.2.1.3) play roles in assisting schooling by allowing fish to visually orientate to one another and also sense water movements when visibility is reduced. Schooling may also be beneficial in terms of reproduction since little energy has to be expended to find a mate when sexes school together (Moyle & Cech, 2004).

Feeding behavior of fishes is influenced by many factors, including characteristics of the environment, the predators, and prey. When food is scare, fish have been observed to capture prey items of all sizes for which there is likely to be a net gain of energy for the fish, however, when food is abundant, fish will preferentially seek the prey item that produces the most energy for the least amount of effort. The body shape of a fish species, specifically the mouth, reflects the general method of feeding. Many fishes must swallow their prey whole and have specialized mouth sizes for their prey depending on the prey's shape and fin spines (Price et al., 2015). Fishes with their mouth on the underside of their body (e.g., sturgeon, rays, skates, etc.) are typically bottom feeders, while fishes with their mouths near the top of their head (e.g., mullets, halfbeaks, etc.) are typically surface feeders. Fishes that typically feed in the water column, which includes most species, have mouths that are centered in their head. Common types of feeding behavior include ambushing, drift feeding, and filter feeding and fishes may regularly switch between two or more modes of feeding behavior depending on the abundance of prey (Moyle & Cech, 2004).

3.6.2.1.3 Hearing and Vocalization

All fishes have two sensory systems which can detect sound in the water: the inner ear, which functions similarly to the inner ear in other vertebrates, and the lateral line, which consists of a series of receptors along the body of a fish (Popper & Schilt, 2008). The lateral line system is sensitive to external particle motion arising from sources within a few body lengths of the animal. The lateral line detects particle motion at low frequencies from below 1 hertz (Hz) up to at least 400 Hz (Coombs & Montgomery, 1999; Hastings & Popper, 2005; Higgs & Radford, 2013; Webb et al., 2008). The inner ears of fish contain three dense otoliths (i.e., small calcareous bodies) that sit atop many delicate mechanoelectric hair cells within the inner ear of fishes, similar to the hair cells found in the mammalian ear. Sound waves in water tend to pass through the fish's body, which has a composition similar to water, and vibrate the otoliths. This causes a relative motion between the dense otoliths and the surrounding tissues causing a deflection of the hair cells, which is sensed by the nervous system.

Although a propagating sound wave contains pressure and particle motion components, particle motion is most significant at low frequencies (up to at least 400 Hz) and is most detectible at high sound pressures or very close to a sound source. The inner ears of fishes are directly sensitive to acoustic particle motion rather than acoustic pressure (acoustic particle motion and acoustic pressure are discussed in Appendix D, Acoustic and Explosive Primer). Historically, studies that have investigated hearing in, and effects to, fishes have been carried out with sound pressure metrics. Although particle motion may be the more relevant exposure metric for many fish species, there is little data available that actually measures it due to a lack in standard measurement methodology and experience with particle motion detectors (Hawkins et al., 2015; Martin et al., 2016). In these instances, particle motion can be estimated from pressure measurements (Nedelec et al., 2016).

Some fishes possess additional morphological adaptations or specializations that can enhance their sensitivity to sound pressure, such as a gas-filled swim bladder (Astrup, 1999; Popper & Hastings, 2009b). The swim bladder can enhance sound detection by converting acoustic pressure into localized particle motion, which may then be detected by the inner ear (Radford et al., 2012). Fishes with a swim bladder generally have better sensitivity and can detect higher frequencies than fishes without a swim bladder (Popper & Hastings, 2009b; Popper et al., 2014). In addition, structures such as gas-filled bubbles near the ear or swim bladder, or even connections between the swim bladder and the inner ear, also increase sensitivity and allow for high-frequency hearing capabilities and better sound pressure detection.

Although many researchers have investigated hearing and vocalizations in fish species (Ladich & Fay, 2013; Popper et al., 2014), hearing capability data only exist for just over 100 of the currently known 34,000 marine and freshwater fish species (Eschmeyer & Fong, 2016). Therefore, fish hearing groups are defined by species that possess a similar continuum of anatomical features which result in varying degrees of hearing sensitivity (Popper & Hastings, 2009b). Categories and descriptions of hearing sensitivities are further defined in this document (modified from Popper et al., 2014) as the following:

- Fishes without a swim bladder – hearing capabilities are limited to particle motion detection at frequencies well below 1 kilohertz (kHz).
- Fishes with a swim bladder not involved in hearing – species lack notable anatomical specializations and primarily detect particle motion at frequencies below 1 kHz.
- Fishes with a swim bladder involved in hearing – species can detect frequencies below 1 kHz and possess anatomical specializations to enhance hearing and are capable of sound pressure detection up to a few kHz.
- Fishes with a swim bladder and high-frequency hearing – species can detect frequencies below 1 kHz and possess anatomical specializations and are capable of sound pressure detection at frequencies up to 10 kHz to over 100 kHz.

Data suggest that most species of marine fish either lack a swim bladder (e.g., sharks and flatfishes) or have a swim bladder not involved in hearing and can only detect sounds below 1 kHz. Some marine fishes (clupeiforms) with a swim bladder involved in hearing are able to detect sounds to about 4 kHz (Colleye et al., 2016; Mann et al., 1997; Mann et al., 2001). One subfamily of clupeids (i.e., Alosinae) can detect high- and very high-frequency sounds (i.e., frequencies from 10 to 100 kHz, and frequencies above 100 kHz, respectively), although auditory thresholds at these higher frequencies are elevated and the range of best hearing is still in the low-frequency range (below 1 kHz) similar to other fishes. Mann et al. (1997; 1998) theorize that this subfamily may have evolved the ability to hear relatively high sound levels at these higher frequencies in order to detect echolocations of nearby foraging dolphins. For fishes that have not had their hearing tested, such as deep sea fishes, the suspected hearing capabilities are based on the structure of the ear, the relationship between the ear and the swim bladder, and other potential adaptations such as the presence of highly developed areas of the brain related to inner ear and lateral line functions (Buran et al., 2005; Deng et al., 2011, 2013). It is believed that most fishes have their best hearing sensitivity from 100 to 400 Hz (Popper, 2003).

Species listed under the ESA within the Study Area include the Atlantic salmon (*Salmo salar*), shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), Gulf sturgeon (*Acipenser oxyrinchus desotoi*), smalltooth sawfish (*Pristis pectinatea*), scalloped hammerhead shark *(Sphyrna lewini*), and the Nassau grouper (*Epinephelus striatus*). Proposed threatened ESA species within the Study Area include the giant manta ray (*Manta birostris*) and the oceanic whitetip shark (*Carcharhinus longimanus*). As discussed above, most marine fishes investigated to date lack hearing capabilities greater than 1,000 Hz. This notably includes sturgeon and salmonid species that have a swim bladder that is not involved in hearing however, sturgeon sand salmon species have only been tested to date up to about 400 or 500 Hz (Hawkins & Johnstone, 1978; Kane et al., 2010; Lovell et al., 2005; Meyer et al., 2010). Sawfish, rays and sharks are cartilaginous fishes (i.e., elasmobranchs) lacking a swim bladder. Available data suggest these species can detect sounds from 20 to 1,000 Hz, with best sensitivity at lower ranges (Casper et al., 2003; Casper & Mann, 2006, 2009; Myrberg, 2001). Nassau groupers have a swim bladder that is not involved in hearing. As part of the family Epinephelidae, Nassau grouper may have a similar hearing range to the leopard coral grouper (*Plectropomus leopardus*), the larvae of which can detect sounds 100 to 2,000 Hz (Wright et al., 2008; Wright et al., 2010).

Some fishes are known to produce sound. Bony fishes can produce sounds in a number of ways and use them for a number of behavioral functions (Ladich, 2008, 2014). Over 30 families of fishes are known to use vocalizations in aggressive interactions, and over 20 families are known to use vocalizations in mating (Ladich, 2008). Sounds generated by fishes as a means of communication are generally 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, of the family sciaenidae, can produce drumming sounds ranging from 128 to 135 decibels referenced to 1 micropascal (dB re 1 µPa). Female midshipman fish apparently detect and locate the "hums" (approximately 90 to 400 Hz) of vocalizing males during the breeding season (McIver et al., 2014; Sisneros & Bass, 2003). Sciaenids produce a variety of sounds, including calls produced by males on breeding grounds (Ramcharitar et al., 2001), and a "drumming" call produced during chorusing that suggested a seasonal pattern to reproductive-related function (McCauley & Cato, 2000). Other sounds produced by chorusing reef fishes include "popping," "banging," and "trumpet" sounds; altogether, these choruses produce sound levels 35 dB above background levels, at peak frequencies between 250 and 1,200 Hz, and source levels between 144 and 157 dB re 1 µPa (McCauley & Cato, 2000).

3.6.2.1.4 General Threats

Fish populations can be influenced by various natural factors and human activities. There can be direct effects from disease or from commercial and recreational activities such as fishing, or indirect effects from reductions in prey availability or lowered reproductive success of individuals. Human-made impacts are widespread throughout the world's oceans, such that very few habitats remain unaffected by human influence (Halpern et al., 2008b). Direct and indirect effects have shaped the condition of marine fish populations, particularly those species with large body size, late maturity ages, and/or low fecundity such as some elasmobranchs (e.g., scalloped hammerhead shark, smalltooth sawfish), sturgeon (e.g., Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon), and some reef fishes (e.g., Nassau grouper), making these species especially vulnerable to habitat losses and fishing pressure (Reynolds et al., 2005). Human-induced stressors (e.g., threats) can be divided into four components, which often act on fish populations simultaneously: habitat alteration, exploitation, introduction of non-native species, and pollution (Moyle & Cech, 2004). Climate change and its resulting effects on the marine environment is another stressor on fish populations (Roessig et al., 2004).

Coastal development, deforestation, road construction, dam development, water control structures, and agricultural activities are types of habitat alteration that can affect fishes and their environment. These activities may affect the water quality of the nearshore marine environment. Threats to fishes related to poor water quality are discussed in Section 3.6.2.1.4.1 (Water Quality). Threats from exploitation, including commercial and recreational fishing and other stressors, are addressed in Section 3.6.2.1.4.2 (Commercial and Recreational Activities). Fishes living in suboptimal habitat from habitat alteration and over exploitation due to fishing may be at increased risk of contracting diseases and acquiring parasites, and are covered in Section 3.6.2.1.4.3 (Disease and Parasites). The presence of an introduced species represents a major change in the native fish community, and this topic is discussed in Section 3.6.2.1.4.4 (Invasive Species). The threats to fish from oil spills, marine debris, and noise are covered in Section 3.6.2.1.4.1 (Water Quality). Climate change and its effects on fishes is addressed in Section 3.6.2.1.4.5 (Climate Change).

3.6.2.1.4.1 Water Quality

Parameters such as temperature, dissolved oxygen, salinity, turbidity, and pH define the water quality as a component of habitat quality for fishes. Some land-based activities can directly and indirectly impact water quality in rivers, estuaries, and in the coastal waters. Sediment from activities on land may be transported to the marine environment. Sediment can impact water quality by increasing turbidity and decreasing light penetration into the water column, as well as transport contaminants into the marine environment (Allen, 2006). Increases in sediment can decrease the survival and reproduction of plankton and have food web and ecosystem level effects.

Hypoxia (low dissolved oxygen concentration) is a major impact associated with poor water quality. Hypoxia occurs when waters become overloaded with nutrients such as nitrogen and phosphorus, which enter oceans from agricultural runoff, sewage treatment plants, bilge water, and atmospheric deposition. An overabundance of nutrients can stimulate algal blooms, resulting in a rapid expansion of microscopic algae (phytoplankton) and can cause anoxic events leading to fish kills (Corcoran et al., 2013). Over the last several decades, coastal regions throughout the world have experienced an increase in the frequency of algal blooms that are toxic or otherwise harmful. Commonly called red tides, these events are now grouped under the descriptor harmful algal blooms or HABs (Anderson et al., 2002). Harmful algal blooms can produce toxins, causing human illness and massive fish and other animal mortalities. The most common harmful algal bloom species in the Gulf of Mexico is *Karenia brevis* (National Oceanic and Atmospheric Administration, 2016a).

Pollution

Chemicals and debris are the two most common types of pollutants in the marine environment. Global oceanic circulation patterns result in the accumulation of a considerable amount of pollutants and debris scattered throughout the open ocean and concentrated in gyres and other places (Crain et al., 2009). Pollution initially impacts fishes that occur near the sources of pollution, but may also affect future generations from effects to reproduction and increase mortality across life stages.

Chemical pollutants in the marine environment that may impact marine fishes include organic pollutants (e.g., pesticides, herbicides, polycyclic aromatic hydrocarbons, flame retardants, and oil) and inorganic pollutants (e.g., heavy metals) (Pew Oceans Commission, 2003). High chemical pollutant levels in marine fishes may cause behavioral changes, physiological changes, or genetic damage (Goncalves et al., 2008; Moore, 2008; Pew Oceans Commission, 2003). Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism from inhabiting contaminated habitat or sediment through the gills or skin, from ingesting food or prey containing the substance (Newman, 1998), or from ingestion of the substance directly (Moore, 2008).Bioaccumulation of pollutants (e.g., metals and organic pollutants) is also a concern to human health because people consume top predators with high pollutant loads.

Oil Spills

Groups of fish typically impacted by oil spills include surface-oriented or surface dwelling species, nearshore (within 3 NM of the shoreline) species, and species whose spawning time coincided with the timing of an oil spill (National Oceanic and Atmospheric Administration, 2010). Fishes can be impacted by the oil directly through the gills, or by consuming oil or oiled prey. Potentially harmful physiological effects to fishes from oil spills include reduced growth, enlarged livers, changes to heart and respiration rate, fin erosion, and reproductive impairment. The most damaging effects of oil on fish populations may be in harming eggs and larvae, because these stages are highly sensitive to oil at the surface, in the water column, or on the seafloor, and are subject to increased mortality and morphological deformities and impaired growth (Greer et al., 2012; Ingvarsdottir et al., 2012; National Oceanic and Atmospheric Administration, 2014). Discharges from ballast water and bilge water during routine ship operations and illegal dumping of solid waste are other sources of oil in the marine environment.

3.6.2.1.4.2 Commercial and Recreational Activities

Exploitation from commercial and recreational fishing is the single biggest cause of changes in fish populations and communities (Moyle & Cech, 2004). Historic and current overfishing largely contributed to the listing of ESA-protected marine fish species (Crain et al., 2009; Kappel, 2005). Overfishing of a resource results from legal and illegal fishing (poaching) and bycatch of resources in quantities above a sustainable level. By the end of 2015, 28 managed fish stocks in the U.S. were on the overfishing list and 38 stocks were on the overfished list, while the number of rebuilt fish stocks since 2000 increased to 39 (National Marine Fisheries Service, 2016a).

In recent decades, commercial fisheries have targeted the larger, predatory, and sometimes higher-priced fish species. Gradually, the fishing pressure will make the larger species more scarce, and fishing will move towards the smaller species, often causing negative implications for entire marine food webs (Pauly & Palomares, 2005). Other factors, such as fisheries-induced evolution and intrinsic vulnerability to overfishing, have been shown to reduce the abundance of some populations (Kauparinen & Merila, 2007). Fisheries-induced evolution describes a change in genetic composition of the population that results from intense fishing pressure, such as a reduction in the overall size and growth rates of fishes in a population. Intrinsic vulnerability describes certain life history traits (e.g., large body size, late maturity age, low growth rate, low offspring production) that result in a species being more susceptible to overfishing than others (Cheung et al., 2007).

Other threats from commercial industries to fishes include vessel strikes, sea farming, and energy production activities. Large commercial vessels (e.g., cruise liners, cargo ships) pose threats to large, slow-moving open ocean fishes while moving along the sea surface. Whale sharks (*Rhincodon typus*), basking sharks (*Cetorhinus maximus*), sturgeons, manta rays (*Manta* spp.), and ocean sunfish (*Mola mola*) are vulnerable to ship strikes (National Marine Fisheries Service, 2010d; Rowat et al., 2007; Stevens, 2007).

The threats of aquaculture operations on wild fish populations include reduced water quality, competition for food, predation by escaped or released farmed fishes, spread of disease and parasites, and reduced genetic diversity (Kappel, 2005). These threats become apparent when farmed fish escape and enter the natural ecosystem (Hansen & Windsor, 2006; Ormerod, 2003). The National Oceanic and Atmospheric Administration (2011) published the Marine Aquaculture Policy, which provides direction to enable the development of sustainable marine aquaculture.

Energy production and offshore activities associated with power-generating facilities results in direct and indirect injury and/or mortality of fishes. Injury and mortality sources include entrainment of eggs and larvae during water withdrawal and impingement of juveniles and adults (U.S. Environmental Protection Agency, 2004). Acoustic impacts from offshore wind energy development are additional sources of injury and mortality (Madsen et al., 2006).

Anthropogenic Noise

Anthropogenic noise is generated from a variety of sources, including commercial shipping, oil and gas exploration and production activities, commercial and recreational fishing (including fish-finding sonar, fathometers, and acoustic deterrent and devices), recreational boating, whale watching activities and other marine transportation vessels such as ferries, marine and coastal development (i.e., construction of bridges, ferry terminals, windfarms, etc.), and research (including sound from air guns, sonar, and telemetry). Vessel noise, in particular, is a major contributor to noise in the ocean and is intensively produced in inland waters. Commercial shipping's contribution to ambient noise in the ocean increased by as much as 12 dB between approximately the 1960s and 2005 (Hildebrand, 2009; McDonald et al., 2008). Frisk (2012) confirmed the trend, and reported that between 1950 and 2007 ocean noise in the 25 to 50 Hz frequency range has increased 3.3 dB per decade, resulting in a cumulative increase of approximately 19 dB over a baseline of 52 dB (decibels re 1 $\mu Pa^2/Hz$). The increase in noise is associated with an increase in commercial shipping, which correlates with global economic growth (Frisk, 2012). Miksis-Olds and Nichols (2015) found low-frequency ocean sound levels have decreased in the South Atlantic and Equatorial Pacific Oceans, similar to a trend of slightly decreasing low-frequency noise levels in the Northeast Pacific. In addition to vessels, other sources of underwater noise include pile-driving activity (Carlson et al., 2007b; Casper et al., 2012b; Casper et al., 2013a; Casper et al., 2013b; Dahl et al., 2015; Debusschere et al., 2014; Feist et al., 1992; Halvorsen et al., 2012b; Popper et al., 2006; Ruggerone et al., 2008; Stadler & Woodbury, 2009), sonar (Carlson et al., 2007b; Mueller-Blenkle et al., 2010; Popper et al., 2006), seismic activity (California Department of Transportation, 2001; Popper & Hastings, 2009a), and offshore construction projects (Foderaro, 2015).

Noise can cause permanent injury in some marine animals (Popper et al., 2005). Physiological responses to noise have shown a variety of results. For example, the giant kelpfish (*Heterostichus rostratus*) exhibited acute stress response when exposed to intermittent recorded boat engine noise (Nichols et al., 2015). In another study, Holles et al. (2013) found that local, low intensity noise from recreational boat engines has the capacity to disrupt settlement in coral reef fish larvae, which may lead to impacts on recruitment to adult populations.

3.6.2.1.4.3 Disease and Parasites

Fishes in poor quality environments have higher incidences of disease, due to increased stress levels and decreased immune system function and are less resilient to fight the disease. Parasites, bacteria, aquaculture conditions, environmental influences, and poor nourishment contribute to fish disease levels (National Oceanic and Atmospheric Administration, 2016d). Disease outbreaks in fishes are influenced by environmental conditions, which typically are more variable in inland waters compared to the open ocean (Snieszko, 1978). Areas with higher density fish populations, such as marine protected areas and fish farms, are at higher risk for disease compared to areas with lower densities (National Oceanic and Atmospheric Administration, 2016a; Wootton et al., 2012). Additionally, introduced species may expose native species to new diseases and parasites. Sea lice (*Lepeophtheirus* species and *Caligus* spp.) are parasites and vectors of viruses commonly associated with fish farming activities in the Study Area that can negatively impact wild fish populations in areas surrounding fish farms (Thorstad et al., 2015; Whelan, 2010).

3.6.2.1.4.4 Invasive Species

Native fish populations are affected by invasive (introduced, non-native) species by predation, competition and hybridization (Moyle & Cech, 2004). Non-native fishes pose threats to native fishes when they are introduced into an environment lacking natural predators and then either compete with native marine fishes for resources or prey upon the native marine fishes (Crain et al., 2009). Marine invasions by other non-fish species also may impact fish populations. Invasive marine algae have been found to alter the health status of native fishes feeding on the algae, which could impact the reproduction success of those populations (Felline et al., 2012).

In the Study Area, a particularly damaging invasive fish species is the predatory Indo-Pacific lionfish (*Pterois volitans* and *P. miles*). This species has spread swiftly across the Western Atlantic, producing a marine predator invasion of unparalleled speed and magnitude (Green et al., 2012). This study also found a 65 percent decline in the biomass of the lionfish's prey fishes with the increase in lionfish abundance within just two years. The increase in lionfish may have long-term impacts for the marine ecosystem (Green et al., 2012).

3.6.2.1.4.5 Climate Change

Global climate change is impacting and will continue to impact marine and estuarine fishes and fisheries (IPCC, 2014; Roessig et al., 2004). Climate change is contributing to a shift in fish distribution from lower to higher latitudes (Brander, 2010; Brander, 2007; Dufour et al., 2010; Popper & Hastings, 2009a; Wilson et al., 2010). Warming waters over the past quarter-century have driven fish populations in the northern hemisphere northward and to deeper depths (Inman, 2005).

Fishes with shifting distributions have faster life cycles and smaller body sizes than non-shifting species (Perry et al., 2005). In addition to affecting species ranges, increasing temperature has been shown to alter the sex-ratio in fish species such as the freshwater zebrafish (*Danio rerio*) that have temperature-dependent sex determination mechanisms (Ospina-Alvarez & Piferrer, 2008). Further temperature rises are likely to have profound impacts on commercial fisheries through continued shifts in distribution and alterations in community interactions (Perry et al., 2005). It appears that diadromous and benthic fish species are most vulnerable to climate change impacts (Hare et al., 2016).

Ocean acidification, the process where increasing atmospheric carbon dioxide concentrations are reducing ocean pH and carbonate ion concentrations, may have serious impacts on fish development and behavior (Raven et al., 2005). Physiological development of fishes can be affected by increases in pH that can increase the size, density, and mass of fish otoliths (e.g., fish ear stones) which would affect sensory functions (Bignami et al., 2013). Ocean acidification may affect fish larvae behavior and could impact fish populations (Munday et al., 2009). A range of behavioral traits critical to survival of newly settled fish larvae are affected by ocean acidification. Settlement-stage larval marine fishes exposed to elevated carbon dioxide were less responsive to threats than controls. This decrease in sensitivity to risk might be directly related to the impaired olfactory ability (Munday et al., 2009).

Beyond direct impacts on fishes from increasing pH ocean acidification can cause changes to the ocean chemistry which leads to increased algal blooms (Anderson et al., 2002). Ocean acidification can also lead to reef impacts such as coral bleaching and can also lead to reduced larval settlement and abundance (Doropoulos et al., 2012). Plankton are important prey items for many fish species and are also impacted by ocean acidification. Ocean acidification may cause a shift in phytoplankton community composition and biochemical composition that can impact the transfer of essential compounds to predators that eat the plankton (Bermudez et al., 2016) and can cause shifts in community composition.

Another climate change effect is ocean deoxygenation. Netburn and Koslow (2015) found that the depth of the lower boundary of the deep scattering layer is most strongly correlated with dissolved oxygen concentration, and irradiance and oxygen concentration are the key variables determining the upper boundary. This study estimated the corresponding annual rate of change of deep scattering layer depths and hypothesized that if past trends continue, the upper boundary is expected to rise at a faster rate than the lower boundary, effectively widening the deep scattering layer under climate changes scenarios. Cao et al. (2014) modeled different sensitivities of ocean temperature, carbonate chemistry, and oxygen, in terms of both the sign and magnitude to the amount of climate change. Model simulations in this study found by the year 2500, every degree increase of climate sensitivity warms the ocean by 0.8 degrees Celsius (°C) and reduces ocean-mean dissolved oxygen concentration by 5.0 percent. Conversely, every degree increase of climate sensitivity buffers CO_2-induced reduction in ocean-mean carbonate ion concentration and pH by 3.4 percent and 0.02 units, respectively. These results have great implications for understanding the response of ocean biota to climate change.

3.6.2.1.4.6 Marine Debris

Marine debris is a widespread global pollution problem and trends suggest that accumulations are increasing with increasing plastic production (Rochman et al., 2013). Debris includes plastics, metals, rubber, textiles, derelict fishing gear, vessels, and other lost or discarded items. Debris such as abandoned nets and lines also pose a threat to fishes. Due to body shape, habitat use, and feeding strategies, some fishes are more susceptible to marine debris entanglement than others (Musick et al., 2000; Ocean Conservancy, 2010). Entanglement in abandoned commercial and recreational fishing gear has caused declines for some marine fishes.

Microplastics in the marine environment are well documented, and interactions with marine biota, including numerous fish species have been described worldwide (Lusher et al., 2016). Plastic waste in the ocean chemically attracts hydrocarbon pollutants such as polychlorinated biphenyl (PCB) and dichlorodiphenyltrichloroethane, which accumulate up to one million times more in plastic than in ocean water (Mato et al., 2001). Fishes can mistakenly consume these wastes, containing elevated levels of toxins, instead of their prey. Rochman et al., (2015) found marine debris in 28 percent of the individual fish examined and in 55 percent of all fish species analyzed.

3.6.2.2 Endangered Species Act-Listed Species

In the Study Area, eight fish species are listed as endangered or threatened under the ESA (Table 3.6-1). Atlantic salmon, Atlantic sturgeon, and Gulf sturgeon are anadromous species that are primarily found in coastal waters, but which spend substantial portions of their lifecycle in estuarine and riverine waters. The shortnose sturgeon inhabits its natal river and estuary, and very rarely has been observed in coastal waters. Largetooth sawfish and smalltooth sawfish are predominately estuarine and coastal waters, but can also occur in freshwater and deeper ocean waters. Scalloped hammerhead is generally considered a marine fish but has early life stages which are estuarine. Nassau groupers are marine fishes that inhabit deep coral reefs or rocky substrate in Florida and the Caribbean.

In addition to the aforementioned listed species, there are also a number of other species that are under consideration for listing. These species are broken into two categories: candidates for listing and proposed for listing. Candidate species are any species that are undergoing a status review that have been announced in a *Federal Register* notice. Proposed species are those candidate species that were found to warrant listing as either threatened or endangered and were officially proposed as such in a *Federal Register* notice after the completion of a status review and consideration of other protective conservation measures.

There are two proposed species, the giant manta ray and oceanic whitetip shark, and three candidates species found within the Study Area, including the Alabama shad (*Alosa alabamae*), cusk (*Brosme brosme*), and dwarf seahorse (*Hippocampus zosterae*) (Table 3.6-1). NMFS also manages a proactive conservation program that allows for species with concerns regarding status and threats, but for which insufficient information is available to indicate a need for listing under the ESA. These species are listed as "species of concern." Within the Study Area, there are 14 fish species listed as such: Atlantic bluefin tuna (*Thunnus thynnus*), dusky shark (*Carcharhinus obscurus*), sand tiger shark (*Carcharias taurus*), rainbow smelt (*Osmerus mordax*), Atlantic wolffish (*Anarhichas lupus*), Atlantic halibut (*Hippoglossus hippoglossus*), striped croaker (*Corvula sanctaeluciae*), speckled hind (*Epinephelus drummondhayi*), Warsaw grouper (*Hyporthodus nigritus*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa* *aestivalis*), key silverside (*Menidia conchorum*), mangrove rivulus (*Kleptolebias marmoratus*), and opossum pipefish (*Microphis brachyurus lineatus*) (Table 3.6-1). As the species of concern are not considered for listing at this time, they will not be discussed separately in this document.

Table 3.6-1: Regulatory Status and Occurrence of Endangered Species Act-Listed Fishes in the Study Area

Regulatory Status			*Occurrence in the Study Area*		
Common Name	***Scientific Name***	***Endangered Species Act Status***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Atlantic Salmon (Gulf of Maine Distinct Population Segment)	*Salmo salar*	Endangered	N/A	West Greenland Shelf, Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf	Kennebec River Estuary, ME
Atlantic Sturgeon (New York Bight, Chesapeake Bay, Carolina, & South Atlantic Distinct Population Segments)	*Acipenser oxyrinchus oxyrinchus*	Endangered	N/A	Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf	Kennebec River Estuary, ME; Narragansett Bay and Rhode Island Sound, RI; Thames River Estuary, CT; Sandy Hook Bay, NJ; lower Chesapeake Bay, VA; Beaufort Inlet Channel, and Cape Fear River, NC; Kings Bay, GA; St. Johns River, FL
Largetooth Sawfish	*Pristis pristis*	Endangered	Extirpated	Extirpated	Extirpated
Shortnose Sturgeon	*Acipenser brevirostrum*	Endangered	N/A	Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf	Kennebec River Estuary, ME; Narragansett Bay and Rhode Island Sound, RI; Thames River Estuary, CT; Sandy Hook Bay, NJ; Cape Fear River, NC; Kings Bay, GA; St. Johns River, FL
Smalltooth Sawfish	*Pristis pectinata*	Endangered	N/A	Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	St. Andrew Bay, FL; Pascagoula River Estuary, MS; Sabine Lake and Corpus Christi Bay, TX
Atlantic Sturgeon (Gulf of Maine Distinct Population Segment)	*Acipenser oxyrinchus oxyrinchus*	Threatened	N/A	Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf	Kennebec River Estuary, ME; Narragansett Bay and Rhode Island Sound, RI; Thames River Estuary, CT; Sandy Hook Bay, NJ; lower Chesapeake Bay, VA

Table 3.6-1: Regulatory Status and Occurrence of Endangered Species Act-Listed Fishes in the Study Area (continued)

Regulatory Status			*Occurrence in the Study Area*		
Common Name	***Scientific Name***	***Endangered Species Act Status***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Gulf Sturgeon	*Acipenser oxyrinchus desotoi*	Threatened	N/A	Gulf of Mexico	St. Andrew Bay, FL; Pascagoula River Estuary, MS
Nassau Grouper	*Epinephelus striatus*	Threatened	N/A	Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	N/A
Scalloped Hammerhead (Central and Southwest Atlantic Distinct Population Segment)	*Sphyrna lewini*	Threatened	N/A	Caribbean Sea	N/A
Giant Manta Ray	*Manta birostris*	Proposed Threatened	North Central Atlantic Gyre, Gulf Stream	Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	N/A
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Proposed Threatened	North Central Atlantic Gyre, Gulf Stream	Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	N/A
Alabama Shad	*Alosa alabamae*	Candidate	N/A	Gulf of Mexico	St. Andrew Bay, FL; Pascagoula River Estuary, MS
Cusk	*Brosme brosme*	Candidate	Labrador Current, North Central Atlantic Gyre, Gulf Stream	Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf	N/A

Table 3.6-1: Regulatory Status and Occurrence of Endangered Species Act-Listed Fishes in the Study Area (continued)

Regulatory Status			***Occurrence in the Study Area***		
Common Name	***Scientific Name***	***Endangered Species Act Status***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Dwarf Seahorse	*Hippocampus zosterae*	Candidate	N/A	Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	St. Johns River and St. Andrew Bay, FL; Pascagoula River Estuary, MS; Sabine Lake and Corpus Christi Bay, TX
Alewife	*Alosa pseudoharengus*	Species of Concern	Gulf Stream	Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf	Kennebec River Estuary, ME; Narragansett Bay and Rhode Island Sound, RI; Thames River Estuary, CT; Sandy Hook Bay, NJ; lower Chesapeake Bay, VA; Beaufort Inlet Channel and Cape Fear River, NC; Kings Bay, GA; St. Johns River, FL
Atlantic Bluefin Tuna	*Thunnus thynnus*	Species of Concern	North Central Atlantic Gyre, Gulf Stream	Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	N/A
Atlantic Halibut	*Hippoglossus hippoglossus*	Species of Concern	Labrador Current; North Central Atlantic Gyre; Gulf Stream	West Greenland Shelf, Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf	N/A
Atlantic Wolffish	*Anarhichas lupus*	Species of Concern	Labrador Current, North Central Atlantic Gyre, Gulf Stream	West Greenland Shelf, Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf	N/A

Table 3.6-1: Regulatory Status and Occurrence of Endangered Species Act-Listed Fishes in the Study Area (continued)

Regulatory Status			*Occurrence in the Study Area*		
Common Name	***Scientific Name***	***Endangered Species Act Status***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Blueback Herring	*Alosa aestivalis*	Species of Concern	Gulf Stream	Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf	N/A
Dusky Shark	*Carcharhinus obscurus*	Species of Concern	Gulf Stream	Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	Juveniles only; Sandy Hook Bay, NJ; lower Chesapeake Bay, VA
Key Silverside	*Menidia conchorum*	Species of Concern	N/A	Gulf of Mexico	N/A
Mangrove Rivulus	*Kleptolebias marmoratus*	Species of Concern	N/A	Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean	Mangroves throughout Study Area
Opossum Pipefish	*Microphis brachyurus lineatus*	Species of Concern	Gulf Stream	Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	St. Andrew Bay, FL; Pascagoula River Estuary, MS; Sabine Lake and Corpus Christi Bay, TX
Rainbow Smelt	*Osmerus mordax*	Species of Concern	N/A	Scotian Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf	Kennebec River Estuary, ME; Narragansett Bay and Rhode Island Sound, RT; Thames River Estuary, CT; Sandy Hook Bay, NJ
Speckled Hind	*Epinephelus drummondhayi*	Species of Concern	N/A	Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	Gulf Stream
Striped Croaker	*Corvula sanctaeluciae*	Species of Concern	N/A	Southeast U.S. Continental Shelf, Caribbean Sea	N/A

Table 3.6-1: Regulatory Status and Occurrence of Endangered Species Act-Listed Fishes in the Study Area (continued)

Regulatory Status			*Occurrence in the Study Area*		
Common Name	***Scientific Name***	***Endangered Species Act Status***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Warsaw Grouper	*Hyporthodus nigritus*	Species of Concern	Gulf Stream	Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, Caribbean Sea	N/A

[1]Candidate and species of concern status does not carry any procedural or substantive protections under the ESA, but is provided for informational purposes.
[2]N/A = not applicable

3.6.2.2.1 Atlantic Salmon (*Salmo salar*)

3.6.2.2.1.1 Status and Management

The Gulf of Maine Distinct Population Segment of Atlantic salmon was listed as federally endangered in 2000 (65 *Federal Register* 69459). During 2009, the Gulf of Maine Distinct Population Segment was expanded to include Maine's Penobscot, Kennebec, and Androscoggin rivers, which support remnant wild populations (74 *Federal Register* 29300). The Atlantic salmon is co-managed by NMFS and USFWS because its lifecycle spans marine, estuarine, and freshwater habitats. Although Atlantic salmon may occur elsewhere (e.g., hatchery programs and aquaculture), only the Gulf of Maine Distinct Population Segment is protected under the ESA.

The National Oceanic and Atmospheric Administration recognized 45 areas as critical habitat for the Atlantic salmon located in Maine (Figure 3.6-1). The designated habitat excludes marine waters beyond estuaries. Critical habitat includes all perennial rivers, estuaries, and lakes connected to the marine environment in the 45 designated critical habitat areas, except those areas specifically excluded by tribal, economic, or military uses. The only critical habitat estuary within the Study Area is the Kennebec River Estuary, which has a military exclusion for the contractor-owned shipyard at Bath, Maine, due to national security. Atlantic salmon critical habitat includes sites for spawning and egg incubation, sites for juvenile rearing, and migration corridors. Although successful migration is also essential to the conservation of the species, NMFS was unable to identify the essential features of marine migration and feeding habitat. Therefore, critical marine habitat areas were not designated.

In 2015, NMFS focused efforts to protect species that are most at risk of extinction in the near future. The Atlantic salmon was selected as one of the eight species because of their critically low abundance and declining population trends. Key actions include reconnecting the Gulf of Maine with headwater streams, increasing the number of juveniles successfully emigrating into the marine environment, reducing mortality in international fishery in West Greenland waters, and increasing the understanding and ability to improve survival in the marine environment (National Marine Fisheries Service, 2016b).

3.6.2.2.1.2 Habitat and Geographic Range

Atlantic salmon is an anadromous and iteroparous (does not die after spawning like other salmon) species. After hatching, juveniles rear in their natal rivers and estuaries. After juveniles complete the smolting process (e.g., physiologically transforming into marine form called a smolt), they enter the estuarine portion of the Study Area in the Gulf of Maine, primarily at night, during the late spring when water temperatures reach 10° C (50° F) (Sheehan et al., 2012) and school in coastal waters primarily in the upper 3 m (10 ft.), although may occur in deeper waters (Hedger et al., 2009). Adults migrate back to their natal river to spawn.

Labrador Current Large Marine Ecosystem. By mid-summer, smolts migrate to the Gulf of Maine along the Scotian Shelf Large Marine Ecosystem, reaching the Newfoundland-Labrador Shelf Large Marine Ecosystem and the Grand Banks (Fay et al., 2006), as indicated by tag recoveries (McCormick et al., 1998). For much of their first summer, sub-adults inhabit the coastal waters off Canada, the Southern Grand Banks (Newfoundland-Labrador Shelf Large Marine Ecosystem), the Labrador Sea, and the northern Gulf of St. Lawrence (Reddin & Short, 1991). Decreasing nearshore water temperatures in autumn trigger offshore (greater than 3 NM from shoreline) movements (Dutil & Coutu, 1988). Sub-adults overwinter in the Labrador Sea south of Greenland. Small percentages return to Gulf of Maine coastal rivers after their first winter at sea (Fay et al., 2006).

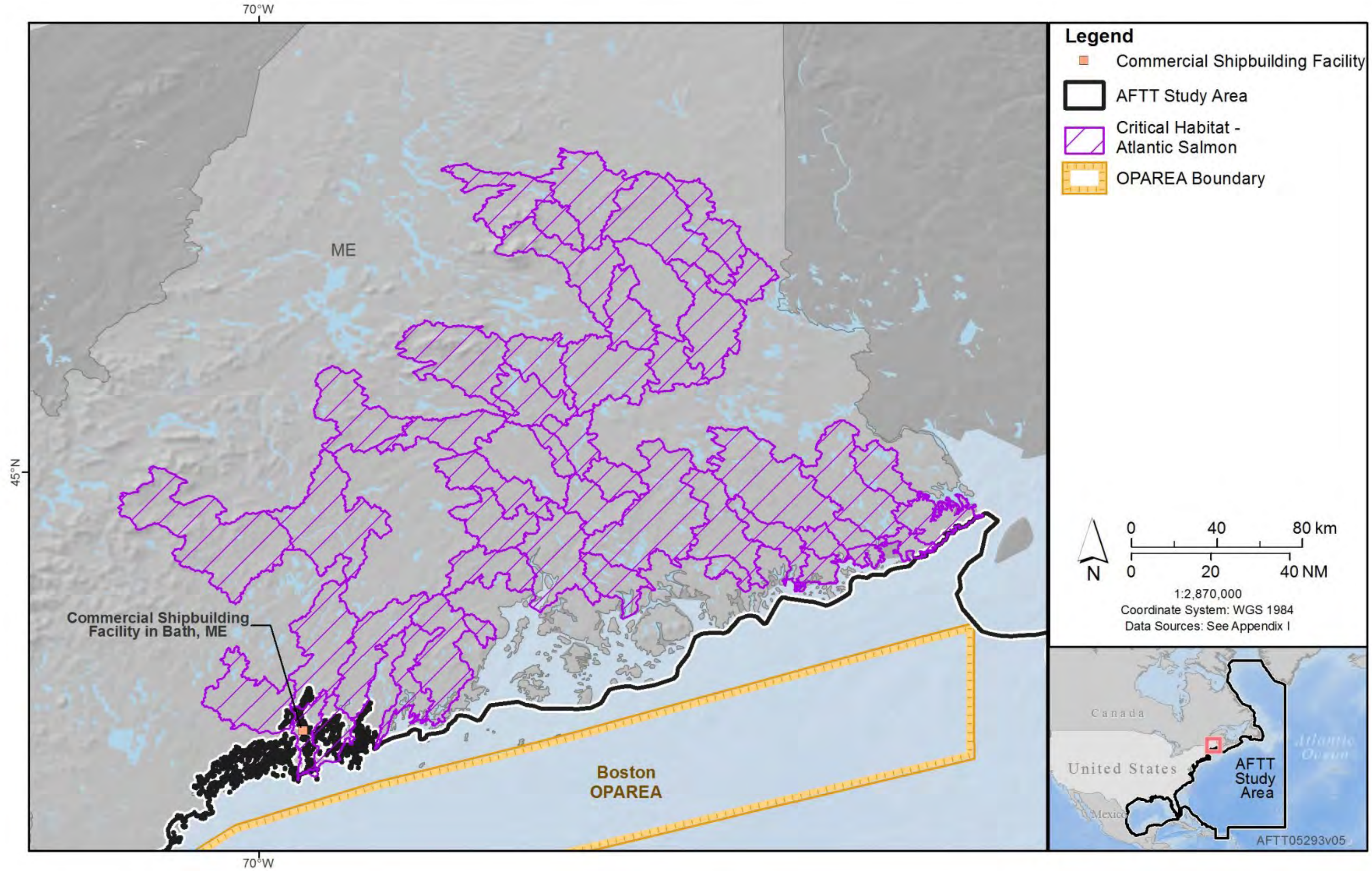
West Greenland Shelf Large Marine Ecosystem. Atlantic salmon migrate great distances in the open ocean to reach feeding areas in the West Greenland Shelf Large Marine Ecosystem and in the Davis Strait between Labrador and Greenland, nearly 2,500 miles (mi.) from their natal rivers (Fay et al., 2006; Reddin & Short, 1991). North American and European stocks co-occur in these areas while feeding (Fay et al., 2006). They spend up to two years feeding before returning to Gulf of Maine coastal rivers to spawn (Reddin & Short, 1991).

Northeast U.S. Continental Shelf Large Marine Ecosystem. The historic range of Atlantic salmon in the northwestern Atlantic Ocean includes coastal drainages from northern Quebec, Canada, to Connecticut. Smolts migrate into marine habitats during approximately two weeks each spring, usually during May (McCormick et al., 1998). Spawning adults migrate into estuaries and natal rivers throughout the spring and summer with the peak occurring in June (Fay et al., 2006).

3.6.2.2.1.3 Population Trends

By the end of the 19th century, Atlantic salmon had been extirpated from the Androscoggin, Merrimack, and Connecticut Rivers. The Gulf of Maine Distinct Population Segment represents the last wild population. Populations have been extirpated or decreased from land use practices and development that eliminated spawning and rearing habitat and reduced water quality. The population remains in decline. With added conservation efforts, adult returns remain extremely low. The National Oceanic and Atmospheric Administration (2006) reported an estimated extinction risk of 19–75 percent within the next 100 years for the Gulf of Maine Distinct Population Segment, which included the on-going hatchery supplementation.

Adult return rates have continued to decline since the 1980s which indicates low marine survival (Chaput, 2012). Population estimates have rarely exceeded 5,000 in any given year since 1967, whereas historical abundances (excluding the Penobscot River) likely exceeded 100,000 (Fay et al., 2006). Numerous conservation and restoration practices have slowed the population decline, but have not increased recovery. Similar to salmon populations on the West Coast of the U.S., changes in ocean conditions affect recovery rates.



Note: AFTT = Atlantic Fleet Training and Testing, OPAREA = Operating Area

Figure 3.6-1: Critical Habitat Areas for Atlantic Salmon in and Adjacent to the Study Area

3.6.2.2.1.4 Predator and Prey Interactions

Upon ocean entry, smolts feed on fish larvae (Haugland et al., 2006), amphipods, euphausiids, and small fish (Fraser, 1987; Hislop & Youngson, 1984; Hislop & Shelton, 1993; Jutila & Toivonen, 1985). As they grow, small fishes become an increasingly dominant component of their diet. Striped bass, cod, haddock, fish-eating birds, and marine mammals feed on smolts and subadults in the marine environment. Adults prey on capelin, Atlantic herring, and sand lance (Hansen & Windsor, 2006). Adults are vulnerable to predation by seals and cormorants (Fay et al., 2006).

3.6.2.2.1.5 Species-Specific Threats

Incremental increases in marine survival (survival from emigrating smolts to adult returns) have a much greater impact on the population than comparable increases in freshwater survival (Legault, 2005), however, the factors contributing to low marine survival are not well understood. A review of existing studies indicates that mortality during the early marine migration varies between 8 and 71 percent, with predation being the most common cause of low survival in rivers and estuaries (Thorstad et al., 2015). In recent decades, individuals have migrated to sea at a younger age; these smaller smolts are subject to increased mortality (Russell et al., 2012). Sea lice infestation of farmed fish is a major cause of mortality of adults (Gargan et al., 2012). Parasitic crustaceans have also been noted to cause mortality and are common in areas with large aquaculture populations (Krkosek et al., 2013).

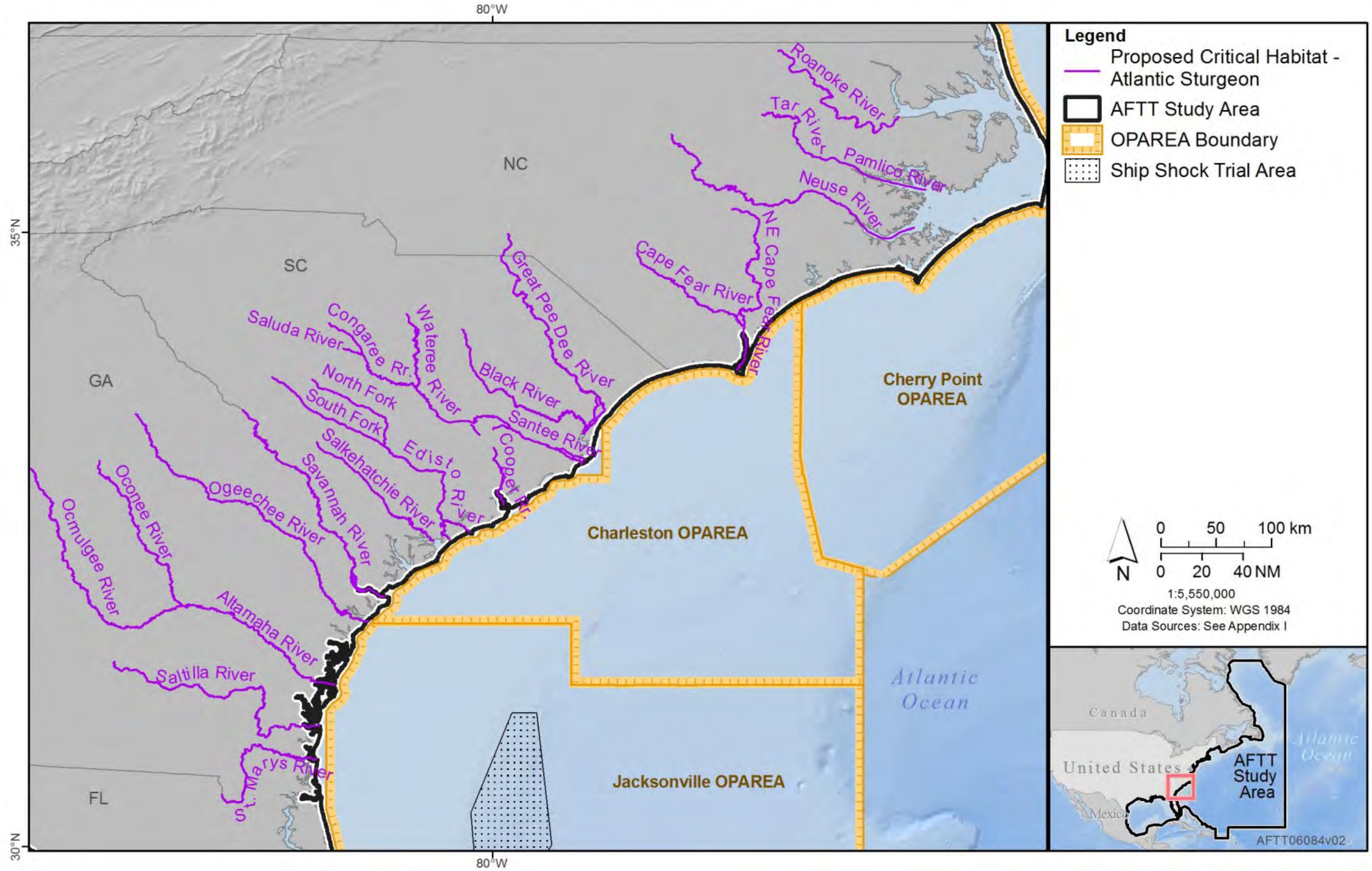
The primary threats impacting the juvenile life stages include restricted fish passage (Baum, 1997), degraded water quality and aluminum toxicity (Kroglund et al., 2007), commercial aquaculture (Hansen & Windsor, 2006), and lack of spawning habitat (Fay et al., 2006). Increases in juvenile survival could enhance the probability of recovery, but only if marine survival is also increased. Current research shows that the catch and release recreational fishery does not negatively impacted the adult population during the spawning migration (Lennox et al., 2016).

3.6.2.2.2 Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)

3.6.2.2.2.1 Status and Management

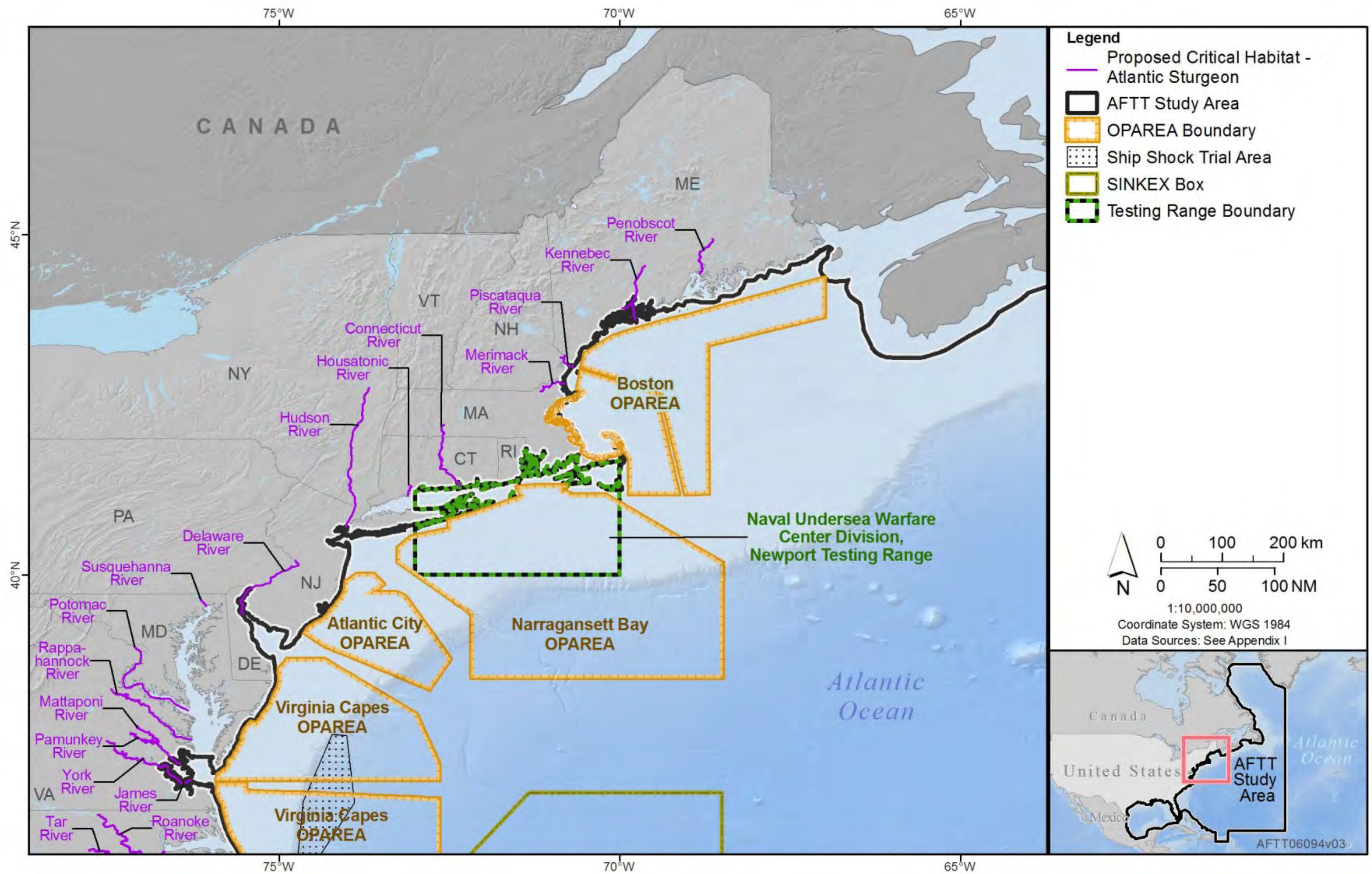
Atlantic sturgeon is co-managed by Atlantic States Marine Fisheries Commission and NMFS. Sharp declines in the abundance of Atlantic sturgeon resulting from historic overfishing, pollution, habitat loss, and habitat degradation led the Atlantic States Marine Fisheries Commission to issue a coast-wide moratorium on the commercial harvest in state waters in 1998 (63 *Federal Register* 9967). This was followed closely by a similar moratorium in federal waters issued by NMFS in early 1999 (64 *Federal Register* 9449). When the population continued to decline, National Oceanic and Atmospheric Administration listed the species as endangered or threatened throughout its range in 2012 (77 *Federal Register* 5880; 77 *Federal Register* 5914). The Chesapeake, New York Bight, Carolina, and South Atlantic Distinct Population Segments are listed as endangered and the Gulf of Maine Distinct Population Segment as threatened.

In June, 2016, NMFS proposed to designate critical habitat (Figure 3.6-2 and Figure 3.6-3). Proposed critical habitat for the Carolina Distinct Population Segment of Atlantic sturgeon contain approximately 1,241 mi. of aquatic habitat within the following rivers: the Roanoke, Tar-Pamlico, Neuse, Cape Fear, and Northeast Cape Fear rivers in North Carolina; and the Waccamaw, Pee Dee, Black, Santee, North Santee, South Santee, Cooper, and Bull rivers in South Carolina. In addition, NMFS proposed to designate unoccupied areas for the Carolina Distinct Population Segment totaling 238 mi. of aquatic habitat within the Cape Fear River, North Carolina and in the Santee, Wateree, Congaree, and Broad rivers, Lake Marion, Lake Moultrie, and the Diversion and Rediversion canals in South Carolina.



Note: AFTT = Atlantic Fleet Training and Testing, OPAREA = Operating Area

Figure 3.6-2: Proposed Critical Habitat for Atlantic Sturgeon in and Adjacent to the Southern Portion the Study Area



Note: AFTT = Atlantic Fleet Training and Testing, OPAREA = Operating Area, SINKEX = Sinking Exercise

Figure 3.6-3: Proposed Critical Habitat for Atlantic Sturgeon in and Adjacent to the Northern Portion of the Study Area

Proposed critical habitat for the South Atlantic Distinct Population Segment contain approximately 1,809 mi. of aquatic habitat within the Edisto, Combahee-Salkehatchie, and Savannah rivers in South Carolina; and the Ogeechee, Altamaha, Ocmulgee, Oconee, Satilla, and St. Marys rivers in Georgia. In addition, an unoccupied area within the Savannah River for the South Atlantic Distinct Population Segment that contains 21 mi. of aquatic habitat has been proposed.

3.6.2.2.2.2 Habitat and Geographic Range

Subadult and adult Atlantic sturgeon inhabits the Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, and Southeast U.S. Continental Shelf Large Marine Ecosystems, likely year-round. Juveniles, sub-adults, and adults also inhabit many of the estuarine and riverine systems that are included in the Study Area (e.g., Kennebec River in Maine, Chesapeake Bay, James River and York River in Virginia, Cooper River in South Carolina, St. Johns River in Florida, and St. Marys River and Kings Bay in Georgia). Larvae are not known to inhabit the Study Area.

Atlantic sturgeon are fairly well studied during their juvenile and spawning life phases in riverine environments, but their sub-adult and adult estuarine and marine phases are less understood. Females spawn highly adhesive eggs on cobble substrate located on river bottoms, which are fertilized by males. Breece et al. (2013) found that spawning habitat was influenced by salinity and substrate composition. Larvae hatch out in four to seven days, and newly hatched young are active swimmers, frequently leaving the bottom and swimming throughout the water column. After 9 to 10 days, the yolk sac is absorbed and the larvae begin to show more strictly benthic behavior. Juveniles remain riverine and estuarine residents for two to six years before migrating to the Atlantic Ocean. After reaching 76–92 centimeters (cm) in length (30 to 36 in.), subadults move from natal estuaries into the marine environment, and may undertake long range migrations (Atlantic Sturgeon Status Review Team, 2007). Sub-adults disperse widely both north and south along the Atlantic coast and beyond the continental shelf (Bain, 1997). Sub-adults and adults were found to be strongly associated within a narrow range of depths 10–50 m over gravel and sand and, to lesser extent, silt and clay (Stein et al., 2004) and in temperatures around 20° C (Breece et al., 2016). Age of sexual maturity varies from 5 to 34 years depending on latitude, averaging 15 years (Atlantic Sturgeon Status Review Team, 2007). Sturgeon in the southern parts of the range tend to mature faster, but experience shorter lifespans than sturgeon in the northern portions of the range. Despite extensive mixing in coastal waters, adults return to their natal river to spawn as indicated from tagging records. During non-spawning years, adults remain in marine waters either year-round or seasonally venture into either natal or non-natal estuarine environments (Bain, 1997; Hager et al., 2016). As part of a Navy-funded research effort, Hager et al. (2016) found that sturgeon implanted with acoustic transmitters in the York River system in Virginia spent the summer and fall seasons of non-spawning years in either the mainstem of the Chesapeake Bay, the Delaware Bay and the Delaware River, or along the coast of New York and in the Hudson River.

Spawning was originally thought to occur only in the spring along the Atlantic coast; however, recent research indicates that spawning primarily occurs in the fall in the South Atlantic rather than spring (Balazik, 2012; Balazik & Musick, 2015; Hager, 2015; Kahn et al., 2014; Smith et al., 2015). Males and females return to the ocean shortly after spawning. The highly adhesive eggs are deposited on cobble substrate. Juveniles (e.g., larvae life stage) hatch out in 4–7 days, assume a demersal existence, and begin to move downstream into their natal estuary, where they remain for a period of time ranging from months to years (Atlantic Sturgeon Status Review Team, 2007). Breece et al. (2013) found that spawning habitats in the Delaware River were influenced by salinity levels and substrate composition, which have been heavily impacted by dredging activities and climate change.

Newfoundland-Labrador Shelf, Scotia Shelf, Northeast U.S. Continental Shelf, and Southeast U.S. Continental Shelf Large Marine Ecosystem.

Sub-adult and adult Atlantic sturgeon inhabits the Newfoundland-Labrador Shelf, Scotia Shelf, Northeast U.S. Continental Shelf, and Southeast U.S. Continental Shelf Large Marine Ecosystem year-round. Atlantic sturgeon can range as far north as the coast of Labrador, and as far south as the St. Johns River in Florida.

3.6.2.2.2.3 Population Trends

Atlantic sturgeon is a long-lived (average life span of 60 years), late maturing, estuarine dependent, iteroparous, and anadromous species. Twelve genetically distinct population segments along the U.S. Atlantic coast have been differentiated (Stein et al., 2004). The Hudson River population seemed somewhat large in 1995 with 9,500 juveniles recorded (National Marine Fisheries Service, 2009b). The mean annual spawning stock size has been estimated at 870 adults, although about half may be of hatchery origin (National Marine Fisheries Service, 2007). The Delaware River population has only a few individuals remaining. St. Johns River, Florida spawning population appears to be extinct (Fox et al., 2016; National Marine Fisheries Service, 2007; Waldman & Wirgin, 1998). The species has been historically overfished throughout its range with landings peaking around the turn of the 20th century followed by drastic declines thereafter (Smith & Clugston, 1997).

Historically, Atlantic sturgeon were recorded in 38 rivers from St. Croix, Maine to the Saint Johns River, Florida. As of 2007, they were only known to still occupy 35 rivers (Atlantic Sturgeon Status Review Team, 2007). However, spawning populations have been discovered in at least five new rivers since this estimate and preliminary research indicates there are likely spawning populations in several more rivers that have yet to be fully investigated. In the early 1600s, Atlantic sturgeon has been considered an important fishery (Jerome et al., 1965). In the mid-1800s, incidental catch of Atlantic sturgeon in the shad and river herring seine fisheries indicated that the species was very abundant (Armstrong & Hightower, 2002). By 1870, females were collected for their eggs, which were sold as caviar. By 1890, over 3,350 metric tons were landed from rivers along the Atlantic coast (Smith & Clugston, 1997). Despite a moratorium on commercial fishing for this species since 1998, there has been no indication of recovery. The lack of recovery is attributed to coastal development, pollution, poor water quality, and habitat degradation and loss.

3.6.2.2.2.4 Predator and Prey Interactions

Atlantic sturgeon prey upon benthic invertebrates such as isopods, crustaceans, worms, and molluscs (National Marine Fisheries Service, 2010c). It has also been documented to feed on fish (Bain, 1997). Evidence of predation on sturgeon is scant, but it’s speculated that juveniles may be eaten by the American alligator (*Alligator mississippiensis*), alligator gar (*Atractosteus spatula*), striped bass (Dadswell, 2006), and sharks.

3.6.2.2.2.5 Species-Specific Threats

Overfishing of females for caviar prior to the 1900s resulted in large population declines. Current threats include: bycatch in fisheries targeting other species; habitat degradation from dredging, dams, and water withdrawals; passage impediments including locks and dams; and ship strikes (Atlantic Sturgeon Status Review Team, 2007; Balazik et al., 2012; Brown & Murphy, 2010; Foderaro, 2015). The copepod (*Dichelesthium oblongum*) parasitizes 93 percent of the Atlantic sturgeon sampled in the New York

Bight. High parasite load, stress, and reduced immune suppression has been associated with Atlantic sturgeon inhabiting areas of poor water quality (e.g., sewage contamination) (Fast et al., 2009).

3.6.2.2.3 Largetooth Sawfish (*Pristis pristis*)

3.6.2.2.3.1 Status and Management

In July 2011, NMFS listed the largetooth sawfish, a type of elasmobranch (shark), as endangered throughout its U.S. range (76 *Federal Register* 40822), although the last confirmed record of this species in U.S. waters was from Port Aransas, Texas, in 1961. The largetooth sawfish has undergone severe range reduction in the United States (Del Monte-Luna et al., 2009; National Marine Fisheries Service, 2009c). NMFS determined that there is inadequate management of this species throughout most of its range (74 *Federal Register* 37767). Until a recovery plan is developed, the smalltooth sawfish recovery plan (National Marine Fisheries Service, 2009c) may be used to manage the largetooth sawfish because the species are similar (Seitz & Poulakis, 2006). Research has determined that largetooth sawfish recovery may take decades because of a low rate of population growth. No critical habitat is designated for this species (76 *Federal Register* 40822).

3.6.2.2.3.2 Habitat and Geographic Range

Gulf of Mexico Large Marine Ecosystem. The largetooth sawfish inhabits shallow, subtropical-tropical, estuarine and marine waters in the southwestern portion of the Gulf of Mexico Large Marine Ecosystem, but it is also known from freshwater habitats in large Central American rivers or lake systems outside the Study Area (WildEarth Guardians, 2009). This species moves between freshwater and marine habitats, and some type of dispersal between these systems may be assumed (Kyne & Feutry, 2013).

The largetooth sawfish typically remains close to the bottom of sand or muddy sand, generally in depths less than 35 ft. (11 m) (Kyne & Feutry, 2013). The largetooth sawfish can tolerate a range of salinities, moving freely between salinity gradients (74 *Federal Register* 37671), and is reported in brackish water near river mouths, large embayments, and partially enclosed systems. Largetooth sawfish may occupy deep holes or be found over mud and sand (75 *Federal Register* 25174). Red mangroves and shallow habitats of varying salinity are important nursery habitats for the largetooth sawfish; these shallow habitats support an abundance of prey (WildEarth Guardians, 2009). The complexity of such habitats also provides juveniles with refuges from larger shark species (74 *Federal Register* 37671).

3.6.2.2.3.3 Population Trends

The presence of this species in U.S. waters is under review because it has not been documented in the United States in several decades (74 *Federal Register* 37671). Some largetooth sawfish may rarely and briefly enter U.S. waters along the Texas coast (WildEarth Guardians, 2009), although further research is needed to determine exactly where that population occurs (75 *Federal Register* 25174).

3.6.2.2.3.4 Predator and Prey Interactions

The largetooth sawfish uses its saw while foraging, either by stirring up the substrate to expose crustaceans or by stunning and slashing schooling fish (75 *Federal Register* 25174). Largetooth sawfish have been documented in the stomachs of American crocodile, narrowtooth sharks, bull sharks, and tiger sharks also prey on various species of sawfishes (Florida Museum of Natural History, 2017a).

3.6.2.2.3.5 Species-Specific Threats

Factors contributing to the decline of the largetooth sawfish include habitat degradation, commercial harvest, gear entanglements, fisheries bycatch, low productivity, and the market for rostral saws (WildEarth Guardians, 2009).

3.6.2.2.4 Shortnose Sturgeon (*Acipenser brevirostrum*)

3.6.2.2.4.1 Status and Management

In 1967, the U.S. Department of Interior listed the shortnose sturgeon as endangered throughout its range (32 *Federal Register* 4001). The species remained listed following enactment of the ESA in 1973 (Wippelhauser & Squiers, 2015). NMFS has recognized 19 Distinct Population Segments. These include New Brunswick, Canada (1); Maine (2); Massachusetts (1); Connecticut (1); New York (1); New Jersey/Delaware (1); Maryland/Virginia (1); North Carolina (1); South Carolina (4); Georgia (4); and Florida (2) (National Marine Fisheries Service, 1998a). In September 2014, a petition was created to list the population within the St. John River in New Brunswick, Canada as a distinct population segment under the ESA. Critical habitat for this species remains under development.

3.6.2.2.4.2 Habitat and Geographic Range

The geographic range of shortnose sturgeon runs along eastern North America from the Saint John River, New Brunswick, Canada to the St. Johns River, Florida (Kynard, 1997; National Marine Fisheries Service, 1998b). After hatching in rivers, larvae orient into the current and away from light, generally staying near the bottom and seeking cover. Within two weeks, the larvae emerge from cover and swim in the water column, moving downstream from the spawning site. Within two months, juvenile behavior mimics adults, with active swimming (Deslauriers & Kieffer, 2012) and foraging at night along the bottom (Richmond & Kynard, 1995). The species primarily occurs in rivers and estuaries of the Northeast and Southeast U.S. Continental Shelf Large Marine Ecosystems, occasionally moving into the nearshore coastal waters (Dadswell, 2006; National Marine Fisheries Service, 1998b; Richmond & Kynard, 1995). In estuaries, juveniles and adults occupy areas with little or no current over a bottom composed primarily of mud and sand (Secor et al., 2000). Adults are found in deep water (10–30 m) in winter and in shallower habitat (2–10 m) during summer (Welsh et al., 2002). Juveniles are known to occur in the Study Area, particularly in the St. Johns River in Florida.

3.6.2.2.4.3 Population Trends

Shortnose sturgeon is a long-lived (average life span 30 years), riverine and estuarine habitat dependent, iteroparous, and anadromous species. Populations were stable or possibly increasing in the 1990s (Wippelhauser et al., 2015). Certain subpopulations have increased in recent years, particularly the Hudson River stock (Bain, 1997; Stein et al., 2004). Several strong cohorts (i.e., groups of fish born in the same year within a population or stock) had higher-than-expected survival during the 1980s and 1990s, then recovery slowed during the late 1990s (Woodland & Secor, 2007). Abundances in the Hudson River population exceed recovery criteria (Bain, 1997; Woodland & Secor, 2007). The Delaware River supports 8,445 individuals (Welsh et al., 2002).

3.6.2.2.4.4 Predator and Prey Interactions

Prey varies with season between northern and southern river systems. In northern rivers, some sturgeon feed in freshwater during summer and over sand-mud bottoms in the lower estuary during fall, winter, and spring (National Marine Fisheries Service, 1998b). In southern rivers, feeding has been observed during winter at or just downstream the saltwater and freshwater interface (Kynard, 1997). In the Southeast U.S. Continental Shelf Large Marine Ecosystem, shortnose sturgeon reduces feeding activity during summer months (Sulak & Randall, 2002).

The shortnose sturgeon feeds by suctioning worms, crustaceans, molluscs, and small fish from the bottom (National Marine Fisheries Service, 1998b; Stein et al., 2004). Juveniles have been found in the stomachs of yellow perch (*Perca flavescens*). Predation on sub-adults and adults is not well-documented; however, sharks are likely predators in the marine environment (National Marine Fisheries Service, 1998b).

3.6.2.2.4.5 Species-Specific Threats

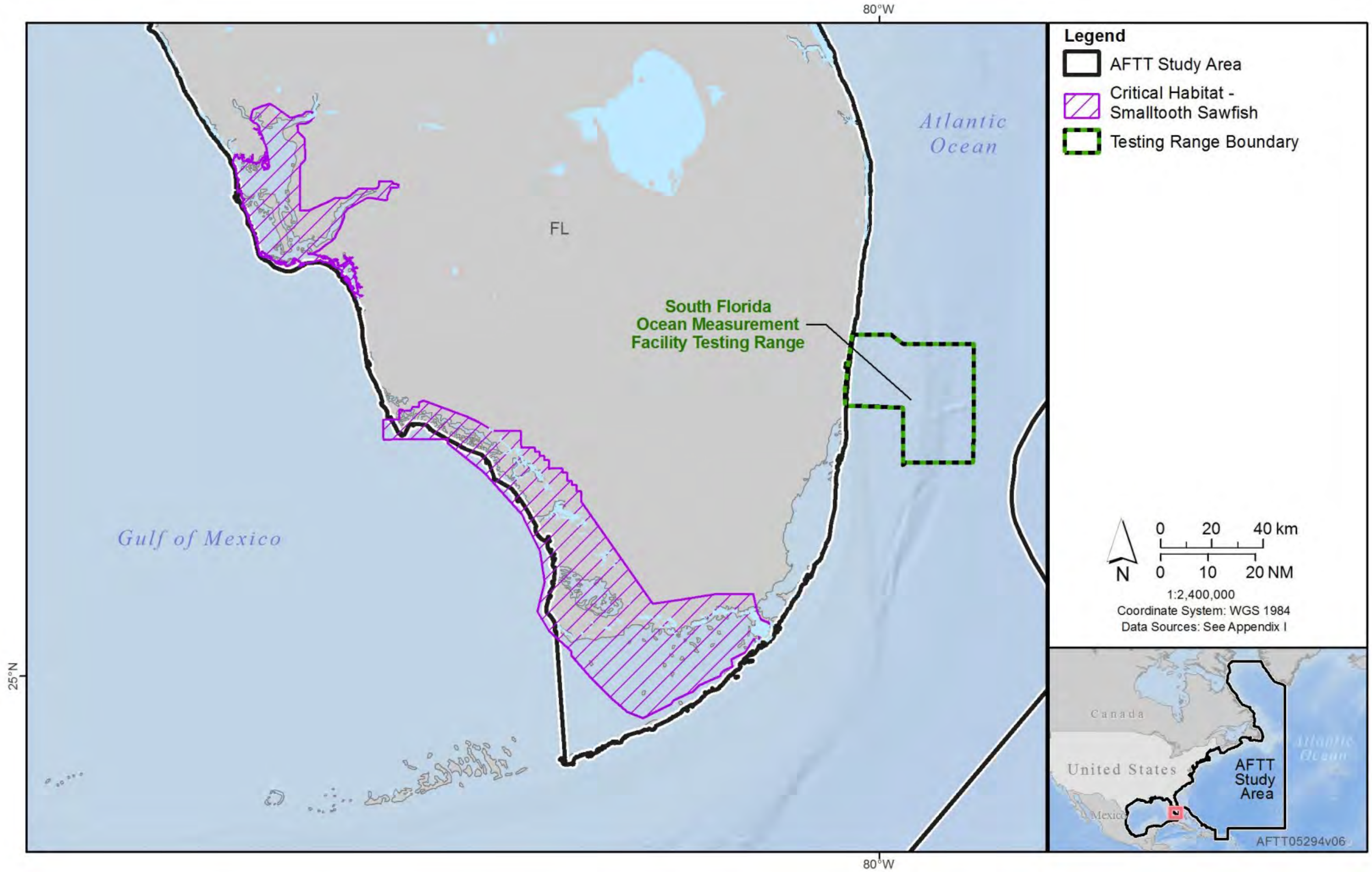
The population decline has been attributed to pollution, overharvest in commercial fisheries (including bycatch), and its resemblance to the formerly commercially valuable Atlantic sturgeon (Bain et al., 2007; National Marine Fisheries Service, 1998a). Other risk factors include poaching, non-native species, poor water quality in spawning and nursery habitats, contaminants (e.g., heavy metals, pesticides, and organochlorine compounds), siltation from dredging, bridge construction and demolition, impingement on power plant cooling water intake screens, impoundment operations, and hydraulic dredging operations (Collins et al., 2000; National Marine Fisheries Service, 1998a).

3.6.2.2.5 Smalltooth Sawfish (*Pristis pectinata*)

3.6.2.2.5.1 Status and Management

The smalltooth sawfish was once common in the Gulf of Mexico and along the east coast of the United States. Today, the severely depleted population is restricted mostly to southern Florida (Poulakis & Seitz, 2004; Simpfendorfer, 2006; Simpfendorfer et al., 2011). The Distinct Population Segment of smalltooth sawfish in the United States, between Florida and Cape Hatteras, North Carolina, was listed as endangered under the ESA by NMFS in 2003 and by USFWS in 2005 (70 *Federal Register* 69464), and it is co-managed by both agencies (National Marine Fisheries Service, 2010a).

Critical habitat for smalltooth sawfish is located at Charlotte Harbor Estuary and the Ten Thousand Islands portion of the Everglades. Most of this critical habitat lies in the boundaries of the federally managed Everglades National Park, Rookery Bay Aquatic Preserve, and Cape Romano-Ten Thousand Islands Aquatic Preserve (National Marine Fisheries Service, 2009c). Critical habitat includes red mangroves and shallow habitats characterized by variable salinities with water depths between the mean high water line and 1 m measured at mean lower low water. The Key West Range Complex does not overlap these areas; the northeastern boundary (Warning Area-174) of the Key West Range Complex is within approximately 9 NM of critical habitat at its closest point (Figure 3.6-4).



Note: AFTT = Atlantic Fleet Training and Testing, LME = Large Marine Ecosystem

Figure 3.6-4: Critical Habitat Areas for Smalltooth Sawfish in and Adjacent to the Study Area

3.6.2.2.5.2 Habitat and Geographic Range

The smalltooth sawfish typically inhabit shallow tropical or subtropical estuarine and marine waters associated with sandy and muddy deep holes, limestone hard bottom, coral reefs, sea fans, artificial reefs, and offshore drilling platforms (Poulakis & Seitz, 2004). Nursery areas of the smalltooth sawfish include estuaries and mangroves with the roots providing refuge from predators (National Marine Fisheries Service, 2009c, 2010b; Seitz & Poulakis, 2006; Simpfendorfer & Wiley, 2005). Juveniles exhibit a high site fidelity to nearshore areas and residence up to 55 days, and upstream movement toward preferred lower salinity conditions (Poulakis et al., 2012; Simpfendorfer et al., 2011). Larger individuals may occur to a depth of 120 m (Poulakis & Seitz, 2004; Simpfendorfer, 2006), although adults are known to spend more time in shallower habitat than in deeper waters (Simpfendorfer & Wiley, 2005).

Southeast U.S. Continental Shelf Large Marine Ecosystem. The species is recorded in the Southeast U.S. Continental Shelf Large Marine Ecosystem area of the Study Area, but its range is primarily southern Florida. Historic records indicate that this species may have made summer migrations northward along the Atlantic coast.

Gulf of Mexico Large Marine Ecosystem. The smalltooth sawfish also occurs in the Gulf of Mexico Large Marine Ecosystem portion of the Study Area, particularly at river mouths (e.g., Mississippi River) (National Marine Fisheries Service, 2009c; Simpfendorfer, 2006).

3.6.2.2.5.3 Population Trends

No population estimates exist of the smalltooth sawfish. The best available data suggest that the current population is a small fraction of its historical size (National Marine Fisheries Service, 2010a; Simpfendorfer, 2006). Data collected in the Everglades National Park since 1972 suggest that the population has stabilized, and may be increasing. Between 1989 and 2004, the population increased by approximately 5 percent (Carlson et al., 2007a).

3.6.2.2.5.4 Predator and Prey Interactions

Smalltooth sawfish are nocturnal feeders and use the saw-like rostrum to disrupt the substrate to expose crustaceans and to stun and slash schooling fish. Juveniles are preyed upon by bull sharks and other shark species inhabiting shallow coastal waters (National Marine Fisheries Service, 2009c).

3.6.2.2.5.5 Species-Specific Threats

Factors contributing to the historic population decline included habitat degradation, commercial harvest, gear entanglements, bycatch in fisheries, poaching, and the illegal market for the saw-like rostrum (WildEarth Guardians, 2009).

3.6.2.2.6 Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

3.6.2.2.6.1 Status and Management

The Gulf sturgeon and the Atlantic sturgeon are members of the same species, but do not overlap geographically. The Gulf sturgeon was federally listed in 1991 as threatened in the Gulf of Mexico Large Marine Ecosystem (56 *Federal Register* 49653) (Florida, Alabama, Louisiana, and Mississippi) and is co-managed by NMFS and USFWS. The fishery for the species has been closed since being listed. Bycatch along the Gulf coast was a major source of mortality (U.S. Fish & Wildlife Service, 1995), and efforts to reduce bycatch include gear modifications for nearshore trawl fisheries (Smith & Clugston, 1997). NMFS and USFWS concluded that the Gulf sturgeon population was stable and had achieved recovery objectives (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 2009).

Critical habitat include abundant prey items across life stages (e.g., detritus, aquatic invertebrates) and suitable spawning substrate, aggregation areas, flow regime, water quality, sediment quality, and safe, unobstructed migratory passage corridors. Most elements of the critical habitat are not applicable to the marine portions of the Study Area. The Panama City OPAREA and Naval Surface Warfare Center, Panama City Division Testing Range overlaps with Gulf sturgeon critical habitat (Figure 3.6-5). This critical habitat (Unit 11) encompasses Florida nearshore Gulf of Mexico waters in Escambia, Santa Rosa, Okaloosa, Walton, Bay, and Gulf counties in Florida. Unit 11 provides a migration corridor for Gulf sturgeon enroute from winter habitat and feeding grounds in the Gulf of Mexico to spring and summer spawning and hatching habitat in the Yellow, Choctawhatchee, and Apalachicola rivers. Gulf sturgeon inhabits the nearshore coastline between Pensacola and Apalachicola bays, in depths of less than 6 m during winter (Fox et al., 2000, 2002).

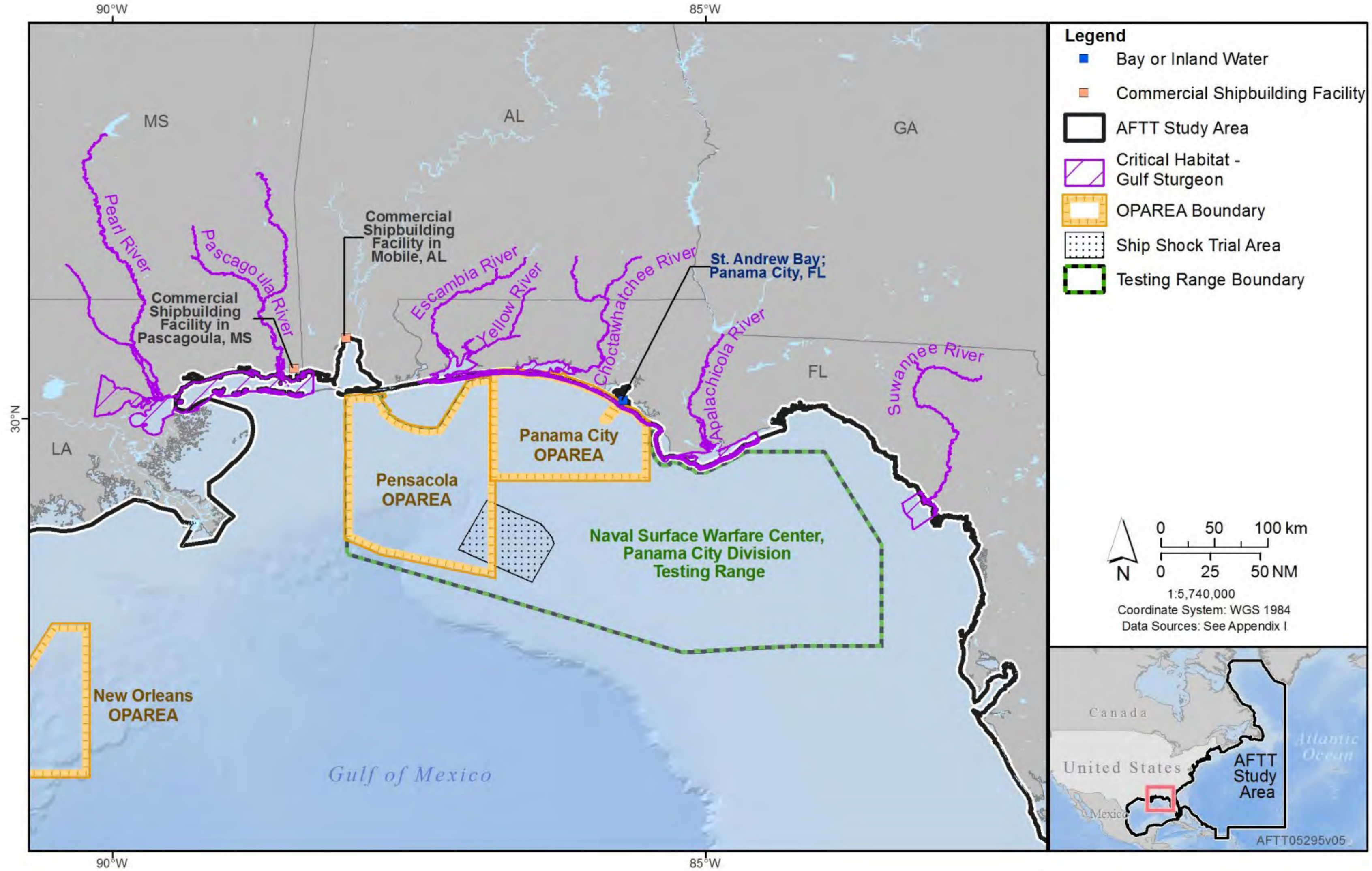
3.6.2.2.6.2 Habitat and Geographic Range

Adults inhabit nearshore waters from October thru February (Robydek & Nunley, 2012) with distribution influenced by prey availability (Ross et al., 2009), particularly within the Suwannee River estuary (Harris et al., 2005). The spring spawning migration toward natal rivers begins as riverine water temperatures reach 64°F to 72°F (Edwards et al., 2003; Heise et al., 2004; Rogillio et al., 2007). Spawning areas include the Suwannee, Apalachicola, Escambia, Choctawhatchee, and Pascagoula rivers (Chapman & Carr, 1995; Craft et al., 2001; Fox et al., 2000; Wooley & Crateau, 1985). Spawning occurs during autumn in some watersheds (e.g., Suwannee) (Randall & Sulak, 2012). Once post-spawned adults leave rivers, they remain within 1,000 m of the shoreline (Robydek & Nunley, 2012) and often inhabit estuaries and nearshore bays in water less than 10 m deep (Ross et al., 2009). Some individuals, particularly females between spawning years (Fox et al., 2002; Ross et al., 2009) move into deeper offshore waters for short periods during cold weather (Sulak et al., 2009).

Sub-adult and adult foraging grounds include barrier island inlets with strong tidal currents and estuaries less than 2 m deep with clean sand substrate (Fox et al., 2002; Harris et al., 2005; Ross et al., 2009). Gulf sturgeon winter near beaches of northwestern Florida and southeast of the mouth of St. Andrew Bay (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 2009), while others moved northeast of St. Andrew Bay at depths ranging from 4 to 12 m (12 to 40 ft.) at 0.5 to 2 mi. offshore, and likely feeding on prey associated with fine sand and shell hash substrates (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 2009).

By December, only the young-of-the-year and juveniles remain in the rivers (Carr & Carr, 1996; Foster & Clugston, 1997). Young-of-the-year nursery habitat includes riverine sandbars and shoals (Carr & Carr, 1996). Juveniles show high site fidelity rates for riverine habitats used during spring and summer (Rudd et al., 2014), prefer sand or vegetated habitats (Wakeford, 2001), tolerate high salinity levels for extended durations, and appear to use estuaries infrequently (Sulak et al., 2009).

Gulf of Mexico Large Marine Ecosystem. This anadromous species occurs in the Gulf of Mexico Large Marine Ecosystem in bays, estuaries and rivers, and in the marine environment from Florida to Louisiana (National Marine Fisheries Service, 2010b).



Note: AFTT = Atlantic Fleet Training and Testing, OPAREA = Operating Area

Figure 3.6-5: Critical Habitat Areas for Gulf Sturgeon in and Adjacent to the Study Area

3.6.2.2.6.3 Population Trends

Gulf sturgeon populations are stable or slowly increasing (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 2009). Current population levels in four of the seven river systems in the recovery plan are likely at or exceeding the mean carrying capacity, given the current levels of available habitat. In the remaining three rivers, extant Gulf Sturgeon populations are likely below their estimated carrying capacity levels (Ahrens & Pine, 2014). Population estimates in the Pearl and Pascagoula Rivers are lacking because research has been limited since hurricanes Ivan in 2004 and Katrina in 2005 (Rogillio et al., 2007).

3.6.2.2.6.4 Predator and Prey Interactions

Prey varies on life stage, but Gulf sturgeon is considered an opportunistic feeder. Adults typically do not feed while in freshwater, and may lose from 12 to 30 percent of their body weight while inhabiting rivers. In estuarine and marine habitats, they prey upon a wide range of benthic invertebrates (Florida Museum of Natural History, 2017b). Sharks are likely predators while sturgeon inhabit the marine environment (Florida Museum of Natural History, 2017b).

3.6.2.2.6.5 Species-Specific Threats

Factors contributing to the decline include overfishing and habitat loss. Threats include dams (e.g., Pearl, Alabama, and Apalachicola Rivers), dredged material disposal, channel maintenance, oil and gas exploration, shrimp trawling, and poor water quality (U.S. Fish and Wildlife Service & National Marine Fisheries Service, 2009). Other threats include potential hybridization with non-native sturgeon from aquaculture farms and diseases.

3.6.2.2.7 Nassau Grouper (*Epinephelus striatus*)

3.6.2.2.7.1 Status and Management

The Nassau grouper is listed as threatened under the ESA in the Study Area (81 *Federal Register* 42268). Designation of critical habitat remains under study. Commercial and recreational landings declined in both pounds landed and average fish size from 1986 and 1991. As a result, moratoriums on take and possession were established in 1996 (National Marine Fisheries Service, 2015).

By 2000, abundance had decreased approximately 60 percent over the last three generations (Cornish & Eklund, 2003). This decline is attributed to intensive fishing efforts on or near the spawning aggregation sites (Beets & Hixon, 1994; Colin, 1992). Failure of recovery in response to fishing moratoriums combined with concerns over habitat loss have guided management efforts toward the establishment of marine protected areas as a more effective means of preserving the species and its habitat, which are typically near current and historical spawning aggregation sites (81 *Federal Register* 42268).

3.6.2.2.7.2 Habitat and Geographic Range

Nassau grouper is a long-lived, late-maturing perch-like bony fish. This species is a solitary fish apart from spawning aggregations (Starr et al., 2007). These fish inhabit high-relief coral reefs and rocky bottoms from nearshore to a depth of 100 m and rest on or near the bottom, with juveniles inhabiting seagrass beds and patch reefs (Bester, 2012). This species also occupies caves and large overhangs (National Marine Fisheries Service, 2015). Spawning aggregation sites are typically located near significant geomorphological features, such as projections (promontories) of the reef as little as 50 m from the shore (81 *Federal Register* 42268).

Nassau grouper congregate in large numbers at specific areas to spawn after the appropriate water temperature and moon phase cues (usually within a period of 10 days overlapping the full moon) between January and February (Archer et al., 2012; National Marine Fisheries Service, 2015; Semmens et al., 2006). Spawning aggregations of several thousand individuals have been reported (Bester, 2012).

Southeast U.S. Continental Shelf Large Marine Ecosystem. The geographic range within Study Area is limited to the southeast coast of Florida.

Gulf of Mexico Large Marine Ecosystem. Within the Study Area, Nassau grouper occur in Flower Gardens Bank; Dry Tortugas National Park; and Key West, Florida (Bester, 2012).

Caribbean Sea Large Marine Ecosystem. Range within the Study Area includes Florida and areas near Puerto Rico.

3.6.2.2.7.3 Population Trends

The current worldwide population of Nassau grouper is approximately 10,000 individuals and continues to decline (Cornish & Eklund, 2003). Subpopulations in the United States appear stable, but Caribbean stocks are in decline. Deoxyribonucleic acid (DNA) analyses indicate no evidence of genetically distinct subpopulations; thus, Nassau grouper are considered as a single population (Bernard et al., 2012; Cornish & Eklund, 2003). More recent research has shown strong genetic differentiation in subpopulations in the Caribbean that may correlate to larvae dispersal barriers (Jackson et al., 2014).

3.6.2.2.7.4 Predator and Prey Interactions

Nassau groupers are preyed upon by barracuda (*Sphyraena barracuda*), king mackerel (*Scomberomorus cavalla*), moray eels (*Gymnothorax* spp.), sandbar sharks (*Carcharhinus plumbeus*), great hammerhead sharks (*Sphyrna mokarran*), and although rare, other groupers (Bester, 2012).

Adult Nassau grouper is an opportunistic ambush predator, feeding on a variety of fishes, shrimps, crabs, lobsters, and octopuses (Sadovy & Eklund, 1999). Adults have been observed feeding on the invasive lionfish in the Caribbean and are currently being studied as a potential biocontrol option (Mumby et al., 2011). Nassau grouper larvae are filter and particulate feeders that prey on dinoflagellates, fish larvae, and mysids (Sadovy & Eklund, 1999).

3.6.2.2.7.5 Species-Specific Threats

Nassau grouper is sensitive to over-exploitation due to slow growth rate, late reproduction age (five-plus years), large size, and long lifespan (Morris et al., 2000; Sadovy & Eklund, 1999). The decline in population is the result of overharvest and collapse of spawning aggregations (Aguilar-Perera, 2006; Ehrhardt & Deleveaux, 2007) and is exacerbated by coastal development (Stallings, 2009).

Damage to spawning sites limits reproductive success of adults if alternative habitats are unavailable. Loss of macroalgae and seagrass beds is damaging to Nassau grouper populations, as it often results in low recruitment rates (Sadovy & Eklund, 1999).

Fishing moratoriums have been ineffective at preventing illegal harvest that occurs in Puerto Rico and other U.S. waters. Declines have also resulted from overfishing with spear guns and bycatch of juvenile in fine mesh nets (National Marine Fisheries Service, 2015).

The marine isopod *Excorallana tricornis* is a known parasite of the Nassau grouper, sometimes resulting in infestations immediately following spawning (Semmens et al., 2006).

3.6.2.2.8 Scalloped Hammerhead Shark (*Sphyrna lewini*)

3.6.2.2.8.1 Status and Management

The Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead population are listed as threatened under the ESA (79 *Federal Register* 52576). The Northwest Atlantic and Gulf of Mexico Distinct Population Segment of scalloped hammerhead sharks has not been listed under the ESA at this time. There are no designated critical habitat marine areas within the jurisdiction of the United States.

The scalloped hammerhead shark fishery is managed under the Large Coastal Shark Management Unit by NMFS through the Final Consolidated Atlantic Highly Migratory Species Fisheries Management Plan (Miller et al., 2013).

3.6.2.2.8.2 Habitat and Geographic Range

The scalloped hammerhead shark is a coastal and semi-oceanic species distributed in temperate to tropical waters (Froese & Pauly, 2016). Scalloped hammerhead sharks inhabit the surface to depths of 275 m (Duncan & Holland, 2006) of the Study Area. Coastal waters with temperatures between 23 °C and 26°C are preferred habitats (Castro, 1983; Compagno, 1984), with animals generally remaining close to shore during the day and moving into deeper waters to feed at night (Bester, 1999). Ketchum et al. (2014b) found scalloped hammerheads formed daytime schools at specific locations in the Galapagos Islands, but dispersed at night, spending more time at the northern islands during part of the warm season (December–February) compared to the cool. Ketchum et al. (2014a) used acoustic telemetry to show that scalloped hammerheads were highly selective of location (i.e., habitat on up-current side of island) and depth (i.e., top of the thermocline) while refuging, where they may carry out essential activities such as cleaning and thermoregulation, and also perform exploratory vertical movements by diving the width of the mixed layer and occasionally diving below the thermocline while moving offshore, most likely for foraging. Hoffmayer et al. (2013) also found that tagged sharks exhibited consistent and repeated diel vertical movement patterns, making more than 76 deep nighttime dives to a maximum depth of 964 m, possibly representing feeding behavior. A genetic marker study suggests that females remain close to coastal habitats, while males disperse across larger open ocean areas (Daly-Engel et al., 2012). Scalloped hammerhead sharks that are part of the Central and Southwest Atlantic Distinct Population Segment are only found in the southernmost portion of the Study Area in the vicinity of Puerto Rico. Scalloped hammerhead sharks that occur in other portions of the Study Area are not protected under the ESA.

In the western Atlantic, their range extends from New Jersey to points south of the Study Area, including the Gulf of Mexico and the Caribbean Sea (Bester, 1999) with seasonal migration along the eastern United States. Juveniles rear in coastal nursery areas (Duncan & Holland, 2006) with all ages occurring in the Gulf Stream, but rarely inhabits the open ocean (Kohler & Turner, 2001).

3.6.2.2.8.3 Population Trends

The scalloped hammerhead shark has undergone substantial declines throughout its range (Baum et al., 2003). There is some evidence of population increase in the Southeast U.S. Continental Shelf Large Marine Ecosystem (Ward-Paige et al., 2012). Landings of scalloped hammerhead sharks peaked at 8,000 metric tons in 2002 and declined to 1,000 metric tons in 2009 (Food and Agriculture Organization of the United Nations, 2005, 2009). Modeling results estimate the overall population range from approximately 142,000 to 169,000 individuals in 1981 and between 24,000 and 28,000 individuals in 2005 (Miller et al., 2013).

3.6.2.2.8.4 Predator and Prey Interactions

Scalloped hammerhead sharks have few predators. Sharks locate potential prey by odor, particularly from injured prey, or low-frequency sounds, inner ear (vibrations), lateral line (turbulence) with vision coming into play at closer range (Moyle & Cech, 2004). They feed primarily at night (Compagno, 1984) on a wide variety of fishes such as sardines, herring, anchovies, and jacks, and also feed on invertebrates, including squid, octopus, shrimp, crabs, and lobsters (Bester, 1999).

3.6.2.2.8.5 Species-Specific Threats

The primary threat is from fishing mortality by the foreign commercial shark fin fishery (Miller et al., 2013). Longline mortality is estimated between 91 and 94 percent (National Marine Fisheries Service, 2011) total shark bycatch in the swordfish and tuna longline fisheries and shrimp trawls in the Gulf of Mexico (Branstetter, 2002). This species is highly susceptible to bycatch due to schooling habits (Food and Agriculture Organization of the United Nations, 2012).

3.6.2.2.9 Giant Manta Ray (*Manta birostris*)

3.6.2.2.9.1 Status and Management

The giant manta ray was proposed to be listed as a threatened species under ESA by NMFS on January 12 2017 (82 *Federal Register* 3694). Based on the best scientific and commercial information available, including the status review report (Miller & Klimovich, 2016), and after taking into account efforts being made to protect these species, NMFS determined that the giant manta ray is likely to become an endangered species within the foreseeable future throughout a significant portion of its range.

3.6.2.2.9.2 Habitat and Geographic Range

Giant manta rays are considered seasonal visitors to productive coastlines with regular upwelling, including oceanic island shores, and offshore pinnacles and seamounts. They utilize sandy bottom habitat and seagrass beds, as well as shallow reefs, and the ocean surface both inshore and offshore. The species ranges globally and is distributed in tropical, subtropical, and temperate waters They can migrate seasonally usually more than 1,000 km (approximately 621 mi.), however not likely across ocean basins (National Oceanic and Atmospheric Administration, 2016c).

Northeast U.S. Continental Shelf Large Marine Ecosystem. The ecosystem is highly productive with upwelling from Cape Hatteras to the Gulf of Maine (National Oceanic and Atmospheric Administration, 2016b). Giant manta rays occur in the Northeast U.S. Continental Shelf Large Marine Ecosystem for feeding on plankton in the upwelling region.

Southeast U.S. Continental Shelf Large Marine Ecosystem. Occasional short-lived plankton blooms occur along the Gulf Stream front and in intrusions into the Southeast U.S. Continental Shelf Large Marine Ecosystem (Aquarone, 2009). This draws giant manta rays to feed in this large marine ecosystem during these occasions. Shelf fronts are separated by wintertime cold air outbreaks, river discharge, tidal mixing, and wind-induced coastal upwelling, all of which attract giant manta rays for feeding, and to seagrass floors (Aquarone, 2009).

Caribbean Sea Large Marine Ecosystem. In the Caribbean Sea Large Marine Ecosystem, there are localized upwelling areas and nearshore habitats like coral reefs, mangroves, and seagrass beds (Heileman & Mahon, 2008). All of these areas attract giant manta rays for feeding and attendance at cleaning stops on coral reefs where fishes groom the rays by eating parasites off of them (Food and Agriculture Organization of the United Nations, 2013).

Gulf of Mexico Large Marine Ecosystem. The Loop Current, which is created by oceanic waters entering the Gulf of Mexico Large Marine Ecosystem from the Yucatan channel and exiting through the Straits of Florida, has upwelling along its edges, as well as in its rings and eddies that are associated with it (Heileman & Rabalais, 2008). These rings, eddies, and upwelling zones are areas where giant manta rays could be found feeding.

3.6.2.2.9.3 Population Trends

No stock assessments exist for the giant manta ray. Most estimates of subpopulations are based on anecdotal observations by divers and fishermen, with current populations estimated between 100 and 1,500 individuals (Miller & Klimovich, 2016). Giant manta rays reach maturity at age 10 and have one pup every two to three years (National Oceanic and Atmospheric Administration, 2016c).

3.6.2.2.9.4 Predator and Prey Interactions

Manta rays prey exclusively on plankton (Defenders of Wildlife, 2015b). The gill plates of the giant manta ray filters the water as they swim, straining out any plankton that is larger than a grain of sand (Defenders of Wildlife, 2015b).

3.6.2.2.9.5 Species-Specific Threats

Threats to giant manta rays include fisheries and bycatch, destruction or modification of habitat, and disease and predation. The international market highly values the gill plates of the giant manta ray for use in traditional medicines. They also trade their cartilage and skins and consume the manta ray meat or use it for local bait. Bycatch occurs in purse seine, gillnet, and trawl fisheries as well (National Oceanic and Atmospheric Administration, 2016c). Fisheries exist outside the Study Area in Indonesia, Sri Lanka, India, Peru, Mexico, China, Mozambique, and Ghana (Food and Agriculture Organization of the United Nations, 2013). Other potential threats include degradation of coral reefs, interaction with marine debris, marine pollution, and boat strikes (Food and Agriculture Organization of the United Nations, 2013).

3.6.2.2.10 Oceanic Whitetip Shark (*Carcharhinus longimanus*)

3.6.2.2.10.1 Status and Management

NMFS completed a comprehensive status review of the oceanic whitetip shark and based on the best scientific and commercial information available, including the status review report (Young et al., 2016), proposed on December 29, 2016 that this species warrants listing as a threatened species under ESA (81 *Federal Register* 96304).

3.6.2.2.10.2 Habitat and Geographic Range

Oceanic whitetip sharks are found worldwide in warm tropical and subtropical waters between the 20° North and 20° South latitude near the surface of the water column (Young et al., 2016). In the Western Atlantic, oceanic whitetips occur from Maine to Argentina, including the Caribbean and Gulf of Mexico. This species has a clear preference for open ocean waters, with abundances decreasing with greater proximity to continental shelves. Preferring warm waters near or over 20° C (68° F), and offshore areas, the oceanic whitetip shark is known to undertake seasonal movements to higher latitudes in the summer (National Oceanic and Atmospheric Administration, 2016e) (National Oceanic and Atmospheric Administration, 2016e) and may regularly survey extreme environments (deep depths, low temperatures) as a foraging strategy (Young et al., 2016). The presence of oceanic whitetip sharks increases further away from the continental shelf in deep water areas, but it prefers to inhabit the surface waters in deep water areas at less than 328 ft. (Defenders of Wildlife, 2015a).

Newfoundland-Labrador Shelf Large Marine Ecosystem. During warming periods, the ocean whitetip shark may be present. Long-term steady warming has been observed in the ecosystem since 1957 and has accelerated since the mid-1990s, with the sea surface temperature rising by 1.8° C in 15 years from 4.6° C to 6.4° C (Aquarone & Adams, 2009). As the sea temperature increases, the oceanic whitetip shark would be more likely to occur in this area.

Northeast U.S. Continental Shelf Large Marine Ecosystem. The oceanic whitetip shark has declined in the northwest Atlantic and western central Atlantic (Baum et al., 2015). It could occur in the offshore open ocean areas.

Southeast U.S. Continental Shelf Large Marine Ecosystem. Oceanic whitetip sharks would be more likely to occur far offshore in the open sea in waters that are 200 m deep near the surface of the water column, although some have been recorded to occur at depths of 152 m (Baum et al., 2015).

Caribbean Sea Large Marine Ecosystem. The oceanic whitetip shark would occur in the open ocean offshore portions of the Caribbean Sea Large Marine Ecosystem. They would occur near the surface of the water column of 200 m deep or deeper areas in the ecosystem area (Baum et al., 2015). Sharks would be less likely to occur in the shallow habitats such as coral reefs, mangroves, and seagrass beds (Heileman & Mahon, 2008).

Gulf of Mexico Large Marine Ecosystem. Oceanic whitetip sharks are a species that prefers warmer waters, and is more likely to occur during the summer months (Baum et al., 2015). This species would likely occur near the surface of deep open ocean waters offshore. An analysis of the Gulf of Mexico used U.S. pelagic longline surveys in the mid-1950s and U.S. pelagic longline observer data in the late-1990s and estimated a decline of the species in the Gulf over the 40-year time period. However, due to temporal changes in fishing gear and practices over the time period, the study may have exaggerated or underestimated the magnitude of population decline (Baum et al., 2015).

3.6.2.2.10.3 Population Trends

Population trend information is not clear or available. Information shows that the population has declined and that there is evidence of decreasing average weights of the sharks that have been encountered. The oceanic whitetip shark has declined by 70 percent throughout the Atlantic region (Defenders of Wildlife, 2015a).

3.6.2.2.10.4 Predator and Prey Interactions

As one of the major apex predators in the tropical open ocean waters, the oceanic whitetip shark feeds on fishes and cephalopods. As a high level predators, the oceanic whitetip shark, with its large size (Ebert et al., 2015) and long life, builds up high levels of pollutants due to bioaccumulation and bio-magnification impacting their physiology negatively (Defenders of Wildlife, 2015a).

3.6.2.2.10.5 Species-Specific Threats

Threats include pelagic longline and drift net fisheries bycatch, targeted fisheries (for the shark fin trade), and threatened destruction or modification of its habitat and range (Baum et al., 2015; Defenders of Wildlife, 2015a). Legal and illegal fishing activities in the Atlantic have caused significant population declines for the oceanic whitetip shark. It is caught as bycatch in tuna and swordfish longlines in the northwest Atlantic and Gulf of Mexico. Habitat degradation has occurred due to pollutants in the environment that bioaccumulate and biomagnify to high levels in their bodies due to their high position in the food chain, long life, and large size (Defenders of Wildlife, 2015a).

3.6.2.2.11 Alabama Shad (*Alosa alabamae*)

3.6.2.2.11.1 Status and Management

The Alabama shad was added to the Candidate Species List by NMFS in 1997 (62 *Federal Register* 3756). In 2004 it was classified to the level of a Species of Concern (69 *Federal Register* 19975). The status of the Alabama shad has yet to be updated from Candidate.

3.6.2.2.11.2 Habitat and Geographic Range

This anadromous and euryhaline (able to adapt to a wide range of salinities) fish species occurs as far north as the Ohio River in West Virginia and Mississippi tributaries, south to the Gulf of Mexico. They are believed to only occur in northern Gulf of Mexico rivers from the Mississippi east to the Suwannee in Florida (Smith et al., 2011). They are known specifically to occur in St. Andrew Bay, Florida, and the Pascagoula River Estuary, Mississippi. Although they are preferential to cooler river waters that have high dissolved oxygen and pH levels, there have been no studies on the thermal tolerances of Alabama shad (Smith et al., 2011). Juveniles have been found in waters as warm as 32° C, while adults have been found spawning in waters of 10° C (Smith et al., 2011). The velocity of the water is an important habitat feature, as the Alabama sad is rarely found in still waters of rivers. Flooding in the spring may be of critical importance as a spawning cue for adult fishes (Smith et al., 2011). The movement of the Alabama shad may be similar to the American shad in that they may move to deeper, quieter areas of the river channels at night (Freeman et al., 2009).

Gulf of Mexico Large Marine Ecosystem. There is very little information available on the Alabama shad's use of marine environments such as the Gulf of Mexico Large Marine Ecosystem. As anadromous fish, they migrate up river in the spring to spawn and return to the Gulf in the late summer or fall (Smith et al., 2011). They spend the winter months in the marine environment outside of river systems (Smith et al., 2011).

3.6.2.2.11.3 Population Trends

The Alabama shad population has declined and has been extirpated from portions of its historical range (Smith et al., 2011). The historical range extended to inland eastern Oklahoma, Iowa, and West Virginia, while current distributions are found in some Gulf coast drainages and the majority of the states that fall within the historical range of the species contain fewer Alabama shad today than they did historically (Smith et al., 2011). The population has declined mainly due to fragmentation as rivers are more modified by levees, dams, locks, and navigational passages.

Despite the decline of the overall population and abundance, data from the Smith et al. (2011) study indicate that the current range of the Alabama shad is stable and in some cases the riverine systems have the capability for population increase. The following rivers contain spawning populations based on the same study; Suwannee River, Apalachicola-Chattahoochee-Flint River Basin, Choctawhatchee River, Escambia River, and Pascagoula River (Smith et al., 2011). The total population of the species is unknown, population estimates of migrating Alabama shad near the Jim Woodruff Lock and Dam in 2005 and 2007 varied from year to year from greater than 30,000 to less than 25,000 fish (NatureServe, 2010).

3.6.2.2.11.4 Predator and Prey Interactions

Alabama shad appear to feed very little or not at all while in fresh water to spawn, as evidenced by a lack of food in their stomachs when captured (Freeman et al., 2009; Louisiana Department of Wildlife and Fisheries, 2012). Juvenile Alabama shad feed on aquatic dipterans and small fishes in the Apalachicola and other river drainages (Freeman et al., 2009). At sea the prey interactions of Alabama shad are unknown (Freeman et al., 2009). Generally this fish species eats phytoplankton, aquatic insects, crustaceans, small fishes, and vegetation (Louisiana Department of Wildlife and Fisheries, 2012).

3.6.2.2.11.5 Species-Specific Threats

The greatest species-specific threat to the Alabama shad is human encroachment. Human encroachment on their habitat occurs through dams, dredging, and pollution (Smith et al., 2011). Construction and operation of hydroelectric power plants in spawning and development habitat in rivers are a primary cause of the species declining numbers (Smith et al., 2011). Dams and locks degrade water quality and change water flow and temperature in the rivers. Dredging, agricultural operations, and reservoir construction on tributaries in the Alabama shad range are also threats to the survivorship of the Alabama shad (Smith et al., 2011).

3.6.2.2.12 Cusk (*Brosme brosme*)

3.6.2.2.12.1 Status and Management

The cusk was added to the Candidate Species List by NMFS on March 9, 2007 (72 *Federal Register* 10710). NMFS is in the process of a status review for the cusk and soliciting scientific and commercial information pertaining to the species.

3.6.2.2.12.2 Habitat and Geographic Range

Cusk inhabit small shoals on rock, pebble, and gravel bottoms at depths between 60 and 1,805 ft. (20 and 550 m) (Collette & Klein-MacPhee, 2002) and temperatures ranging from 32°F to 50°F (0°C to 10°C) (National Marine Fisheries Service, 2009a). Cusk eggs are buoyant; after hatching, larvae remain near the surface, then settle to the bottom as 2 in. (5 cm) juveniles (Fisheries and Oceans Canada, 2004). Adult cusk are solitary and remain in offshore waters; they are rarely captured in waters less than 65 to 100 ft. (20 to 30 m) deep (Knutsen et al., 2009). Unlike other cods, cusk rarely leave the seafloor, and do not disperse very far once settled into a particular habitat area (Collette & Klein-MacPhee, 2002).

Scotian Shelf Large Marine Ecosystem. The cusk occurs around the Scotian Shelf Large Marine Ecosystem (National Marine Fisheries Service, 2009a).

Newfoundland-Labrador Shelf Large Marine Ecosystem. Cusks occur around the Strait of Belle Isle and on the Grand Banks of Newfoundland in the Newfoundland-Labrador Shelf Large Marine Ecosystem (National Marine Fisheries Service, 2009a), and infrequently at the southern tip of Greenland in the Labrador Current Open Ocean Area (National Marine Fisheries Service, 2009a).

Northeast U.S. Continental Shelf Large Marine Ecosystem. The cusk is limited geographically by its need for cold water; it ranges only as far south as the Northeast U.S. Continental Shelf Large Marine Ecosystem around New Jersey (National Marine Fisheries Service, 2009a).

3.6.2.2.12.3 Population Trends

Fisheries data indicate substantial decreases in biomass and abundance of cusk, most likely because of fishery harvest; U.S. landings dropped from approximately 4,200 tons (3,800 metric tons) in the early

1980s to 87 tons (79 metric tons) in the year 2004 (Collette & Klein-MacPhee, 2002; National Marine Fisheries Service, 2009a). Very little fisheries-independent data exists for this species.

3.6.2.2.12.4 Predator and Prey Interactions

The cusk feeds primarily on crustaceans and shellfish, fishes (including flatfish and gurnard), and occasionally on sea stars. However, little information is available on its diet because most cusk have emptied their stomach contents by the time they reach the surface, making stomach-content analysis very difficult (Fisheries and Oceans Canada, 2004). The primary food composition (by percent weight) is crustaceans (51 percent), fishes (16 percent), and echinoderms (15 percent), with some variation by region (Collette & Klein-MacPhee, 2002). The most frequent predator of cusk are spiny dogfish (*Squalus acanthias*), but other fishes (cods, hakes, skates, and flounders) and marine mammals (hooded seal [*Cystophora cristata*] and grey seal [*Halichoerus grypus*]) also feed on cusk (Collette & Klein-MacPhee, 2002).

3.6.2.2.12.5 Species-Specific Threats

Threats to cusk are poorly understood. Bycatch of cusk by commercial fisheries targeting cod and haddock is likely the primary cause of decline in both the United States and Canada (Fisheries and Oceans Canada, 2004; National Marine Fisheries Service, 2009a). Canada established a bycatch limit of 1,000 tons of cusk in 1999 and reduced it to 750 tons of cusk in 2003 (Crozier et al., 2004). Deepwater seismic testing within cusk habitat by the oil and gas industry could impact fish closely associated with the seafloor (Fisheries and Oceans Canada, 2011).

3.6.2.2.13 Dwarf Seahorse (*Hippocampus zosterae*)

3.6.2.2.13.1 Status and Management

The dwarf seahorse was added to the Candidate Species List by NMFS on May 4, 2012 (77 *Federal Register* 26478).

3.6.2.2.13.2 Habitat and Geographic Range

The dwarf seahorse has a restricted geographic range within the Study Area, inhabiting tropical and subtropical/warm-temperate waters of Florida, the Gulf of Mexico, and the Caribbean (Masonjones & Lewis, 1996). It primarily occurs in south Florida estuaries and in the Florida Keys. The dwarf seahorse prefers protected bays/lagoons with low water flow, high organic content, mid- to high-salinities and depths less than 6 ft. (Bruckner, 2005; Foster & Vincent, 2004). The species is almost exclusively associated with seagrass beds, particularly eelgrass (Zostera species) (Bruckner, 2005). It is more abundant in areas with higher seagrass density, canopy cover, and seagrass shoot density (Bruckner, 2005). Other habitats used by the dwarf seahorse include mangrove areas, unattached algae, and inshore drifting vegetation (Center for Biological Diversity, 2011; Hoese & Moore, 1998; Tabb & Manning, 1961).

While most seahorse species exhibit strong site-fidelity, in terms of home ranges and spawning habitat (Curtis & Vincent, 2006; Masonjones & Lewis, 1996), Masonjones et al. (2010) suggest that further seahorse dispersal outside of home ranges may occur. Dispersal may be enhanced by clinging to drifting Sargassum or floating debris within inshore habitats (Curtis & Vincent, 2006; Masonjones & Lewis, 1996). Spawning occurs between February and November (Foster & Vincent, 2004).

Southeast U.S. Continental Shelf Large Marine Ecosystem. The dwarf seahorse's primary range includes south Florida estuaries and the Florida Keys (77 *Federal Register* 26478).

Gulf of Mexico Large Marine Ecosystem. Bruckner et al. (2005) report that the dwarf seahorse is uncommon in many areas in the Gulf of Mexico (77 *Federal Register* 26478), with fewer than 20 independent collection records from the following locations: Lower Laguna Madre, South Apalachee Bay, North Apalachee Bay, Corpus Christi Bay, St. George Sound, East Mississippi Sound, Aransas Bay, Terrebonne/Timbalier Bays, Chandeleur Sound, Perdido Bay, and Pensacola Bay (Beck & Odaya, 2001).

Caribbean Sea Large Marine Ecosystem. The dwarf seahorse's primary range includes all portions of the Caribbean (77 *Federal Register* 26478).

3.6.2.2.13.3 Population Trends

There are no published data on current global population trends or total numbers of mature dwarf seahorses; however, some population data exist in Florida based on numbers derived from the commercial seahorse fishery. NMFS reported a five-fold increase in seahorse landings between 1991 and 1992 (from 14,000 harvested in 1991 to 83,700 harvested in 1992), with the increased landings primarily attributed to dwarf seahorses (77 *Federal Register* 26478). Over a longer period, the number of dwarf seahorses landed during 1990–2003 ranged from 2,142 to 98,779 individuals per year (Bruckner, 2005). Additional density data are from ichthyoplankton tows conducted in portions of southern Florida and range from 0 to 6 seahorses per 100 cubic meters in subtidal pools, seagrass beds, in channels, and along restored marsh edges (Masonjones et al., 2010; Powell et al., 2002).

3.6.2.2.13.4 Predator and Prey Interactions

Seahorses are ambush predators, consuming primarily live, mobile nekton, such as small amphipods and other invertebrates (Bruckner, 2005).

3.6.2.2.13.5 Species-Specific Threats

Dwarf seahorses are the second most sought after fish exported from Florida in the aquarium trade (77 *Federal Register* 26478). They are dried and sold at curio shops as souvenirs (Bruckner, 2005) and also are in high demand in the traditional Chinese medicine trade (77 *Federal Register* 26478).

The petition for listing (Center for Biological Diversity, 2011) describes other natural or manmade factors that may be threatening the dwarf seahorse, including life history characteristics, bycatch mortality, illegal fishing, hurricanes or tropical storms, and invasive species. The petition also suggests that the current status of the dwarf seahorse may be related to low-frequency boat motor noise, based on a single lab study (77 *Federal Register* 26478). However, the actual negative impacts of boat motor noise on the health, behavior, and reproductive success of wild populations of dwarf seahorses in their natural habitat remain unclear at this time (77 *Federal Register* 26478).

In addition to species-specific threats, threats to the dwarf seahorse's primary habitat of seagrass are further described in Section 3.7.2.8 (Seagrasses, Cordgrasses, and Mangroves). Additional information on threats to dwarf seahorses are detailed by NMFS and Center for Biological Diversity (Center for Biological Diversity, 2011).

3.6.2.3 Species Not Listed Under the Endangered Species Act

Taxonomic categories of major fish groups are provided in Table 3.6-2 and are described further in this section to supplement information on fishes of the Study Area that are not ESA-protected species. These fish groups are based on the organization presented by Moyle and Cech (2004), Nelson et al. (2016), Helfman et al. (2009), and Froese and Pauly (2016). These groupings are intended to organize the extensive and diverse list of fishes that occur in the Study Area and serve as a means to structure the analysis of potential impacts on fishes with similar physiological characteristics and habitat use. Exceptions to these generalizations exist within each group and are noted wherever appropriate in the analysis of potential impacts. For simplicity, the fishes are presented in generally accepted evolutionary order.

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area

Major Fish Groups			***Occurrence in the study Area***		
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Jawless fishes (Orders Myxiniformes and Petromyzontiformes)	Primitive, cartilaginous, eel-like vertebrates, parasitic or feed on dead fish	Hagfishes, Lampreys	Seafloor	Seafloor	Water column, seafloor
Ground Sharks, Mackerel Sharks, Carpet Sharks, and Bullhead Sharks (Orders Carcharhiniformes, Lamniformes, Orectolobiformes, and Heterodontiformes)	Cartilaginous, two dorsal fins or first large, an anal fin, and five gill slits	Great white, Oceanic whitetip, Scalloped and smooth hammerheads, Tiger sharks, sand tiger sharks, nurse sharks, whale sharks	Water column, Seafloor	Water column, Seafloor	Water column
Frilled and Cow Sharks, Sawsharks, Dogfish, and Angel Sharks (Orders Hexanchiformes, Pristiophoriformes, Squaliformes, and Squatiniformes)	Cartilaginous, anal fin and nictitating membrane absent, 6-7 gill slits	Dogfish, Frill, Sawshark, Sevengill, Sixgill sharks	Water column, Seafloor	Water column, Seafloor	Seafloor
Stingrays, Sawfishes, Skates, Guitarfishes, and Electric Rays (Orders Myliobatiformes, Pristiformes, Rajiformes, and Torpediniformes)	Cartilaginous, flat-bodied, usually five gill slits	Caribbean, Electric, Giant manta rays, Largetooth and smalltooth sawfishes, Stingrays, Thorny skate	Water column, Seafloor	Water column, Seafloor	Water column, seafloor
Ratfishes (Order Chimaeriformes).	Cartilaginous, placoid scales	Chimaera, Rabbitfish Ratfishes	Seafloor	Seafloor	N/A

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the study Area*		
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Sturgeons (Order Acipenseriformes)	Primitive, ray-finned, cartilaginous, bony plates, heterocercal tail	Atlantic, Gulf, Shortnose	N/A	Surface, water column, seafloor	Surface, water column, seafloor
Gars (Order Lepisosteiformes)	Primitive, slender body. ganoid scales, heterocercal tail; needle-like teeth	Alligator Longnose and Shortnose	N/A	N/A	Surface, water column
Herrings and allies (Order Clupeiformes)	Silvery, Lateral line on body and fin spines absent, usually scutes along ventral profile	Alabama shad. Anchovies, Herrings, Shads	N/A	Surface, water column	Surface, water column
Tarpons and allies (Orders Elopiformes, and Albuliformes)	Body encased in silvery scales, mouth large, mostly a single dorsal fin, some with tapered tail fin, spines absent	Bonefishes, Ladyfish, Malacho, Tarpons	Water column, seafloor	Surface, water column	Surface, water column, seafloor
Eels and allies (Orders Anguilliforms, Notacanthiformes, and Saccopharyngiformes)	Body very elongate, usually scaleless with pelvic fins and fin spines absent	American, Conger, Cutthroat, Duckbill, Halosaur, Morays, Pike, Sawtooth, Short-tailed, Spiny, Gulper, Pelican	Water column, seafloor	Water column, seafloor	Water column, seafloor
Salmonids (Order Salmoniformes)	Silvery body, adipose fin present	Arctic char, Atlantic salmon, Atlantic whitefish	Surface, water column	Surface, water column	Surface, water column

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area (continued)

Major Fish Groups			***Occurrence in the study Area***		
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
Argentines and allies (Order Argentiniformes)	Body silvery, and elongate; fin spines absent, adipose fin sometimes present, pelvic fins and ribs sometimes absent	Barreleyes, Deep-sea smelts, Slickheads, Tubeshoulders	Water column, seafloor	Seafloor	N/A
Catfishes (Order Siluriformes)	Barbels on head, spines on dorsal and pectoral fins, scaleless, adipose fin present	Sea Catfishes	N/A	Seafloor	Seafloor
Bristlemouths and allies (Orders Stomiiformes)	Photophores present, adipose and chin barbels fin sometimes present	Dragonfishes, Fangjaws, Hatchetfishes, Lightfishes,	Water column, seafloor	N/A	N/A
Greeneyes and allies (Order Aluopiformes)	Upper jaw protrusible adipose fin present, forked tail usually present	Barracudinas, Daggertooth, Greeneyes, Lizardfishes, Pearleyes, Waryfishes	Surface, water column, seafloor	Water column, seafloor	N/A
Lanternfishes and allies (Order Myctophiformes)	Small-sized, adipose fin, forked tail and photophores usually present	Lanternfishes	Water column, seafloor	N/A	N/A
Hakes and allies (Order Gadiformes)	Long dorsal and anal fins; no true spines, spinous rays present in dorsal fin, barbels present	Cods, Codlings, Cusk, Grenadiers, Hakes, Whiptails	Water column, seafloor	Water column, seafloor	Surface, water column, seafloor
Brotulas and allies (Order Ophidiiformes)	Pelvic absent or far forward and filamentous,	Brotulas, Cusk-eels	Water column, seafloor	Water column, seafloor	Water column, seafloor

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the study Area*		
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
	no sharp spines, Dorsal and anal fins joined to caudal fins				
Toadfishes and allies (Order Batrachoidiformes)	Body compressed; head large, mouth large with tentacles; two dorsal fins, the first with spines	Toadfish, Midshipman	N/A	Seafloor	Seafloor
Anglerfishes and allies (Order Lophiiformes)	Body globulose, first spine on dorsal fin usually modified, pelvic fins usually absent	Anglerfishes, Footballfishes, Frogfishes, Goosefishes, Sea devils	Water column, seafloor	Seafloor	Seafloor
Flying Fishes (Order Beloniformes)	Jaws extended into a beak; pelvic fins very large wing-like; spines absent	Flying fishes, Halfbeaks, Needlefishes Sauries	Surface, water column	Surface, water column	Surface, water column
Killifishes (Order Cyprinodontiformes)	Protrusible upper jaw; fin spines rarely present; single dorsal fin	Goldenspot, Killifishes, Rivulines, Sheepshead Minnows	N/A	N/A	Water column
Silversides (Order Atheriniformes)	Small-sized, silvery stripe on sides, pectoral fins high, first dorsal fin with flexible spine, pelvic fin with one spine	Atlantic, Beach, Inland, Rough,	N/A	Surface, water column	Surface, water column
Opahs and allies (Order Lampriformes)	Upper jaw protrusible; pelvic fins forward on body, below or just behind	Crestfishes, Oarfishes, Opahs, Ribbonfishes, Tapertails, Tube-eyes	Water column	N/A	N/A

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area (continued)

Major Fish Groups			***Occurrence in the study Area***		
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
	insertion of pectoral fins				
Squirrelfishes and allies (Order Beryciformes)	Body usually round, one dorsal fin often set far back, pelvic fins absent, fin spines often present	Bigscales, Fangtooths, Pricklefish, Slimeheads, Squirrelfishes Whalefishes	Water column, seafloor	Water column, seafloor	N/A
Dories and allies (Order Zeiformes)	Body deeply compressed, protrusible jaws, spines in dorsal fin, pelvic fin spines sometimes present	Boarfishes, Dories, Oreos, Tinselfishes	Water Column, seafloor	Water column, seafloor	N/A
Pipefishes (Order Syngnathiformes)	Snout tube-like, mouth small, scales often modified bony plates	Cornetfish, Dwarf Seahorse, Snipefishes	Water Column, seafloor	Water Column, seafloor	Seafloor
Sticklebacks (Order Gasterosteiformes)	mouth small, scales often modified bony plates	Blackspotted, threespine, fourspine, ninespine sticklebacks	Water Column, seafloor	Water Column, seafloor	Seafloor
Scorpionfishes (Order Scorpaeniformes)	Usually strong spines on head and dorsal fin; cheeks with bony struts, pectoral fins usually rounded	Poachers, Sculpins, Sea robins, Snailfishes	Water Column, seafloor	Water Column, seafloor	Seafloor
Mullets (Order Mugiliformes)	Streamline body, forked tail, hard angled mouth, large scales	Striped, white, fantail, mountain mullet	Spawn in offshore waters	Surface, water column, seafloor	Surface, water column, seafloor
Perch-like Fishes and Allies (Order Perciformes)	Deep bodied, to moderately elongate, 1-2 dorsal fins,	Angelfishes, Cardinal Fishes, Drums, Grunts, Groupers,	Water column, seafloor	Surface, water column, seafloor	Water column, seafloor

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the study Area*		
Group Names	***Description***	***Representative Species***	***Open Ocean***	***Large Marine Ecosystems***	***Inland Waters***
	large mouth and eyes, and throracic pelvic fins	Jacks, Remoras, Snappers, Striped bass			
Wrasses and Allies (Order Perciformes)	Compressed body, scales large, well-developed teeth, usually colorful	Hogfishes, Parrotfishes, Wrasses, Damselfishes	N/A	Seafloor	Seafloor
Eelpouts and Allies (Order Perciformes)	Eel-like body, long dorsal and anal fins, pelvic fins usually absent	Gunnels, Ocean pout, Pricklebacks, Wolfeels	Seafloor	Seafloor	Seafloor
Stargazers (Order Perciformes)	Body elongated, lower jaw usually projecting beyond upper jaw, pelvic and anal fins with spines	Stargazers	Water column, seafloor	Water column, seafloor	Water column, seafloor
Blennies, Gobies, and Allies (Order Perciformes)	Body eel-like to sculpin-like, pelvic fins reduced or fused	Barfin goby, Freckled blenny, Bridled goby, Sleepers, Wormfishes	N/A	Seafloor	Seafloor
Surgeonfishes (Order Perciformes)	Body deeply compressed laterally, mouth small, scales usually small, pelvic fins with spines	Blue tang, Surgeonfishes	N/A	Seafloor	N/A
Tunas and Allies (Order Perciformes)	Large mouth, inlets and keels usually present, pelvic fins often absent or reduced, fast swimmers	Barracudas, Billfishes, Swordfishes, Tunas	Surface, water column	Surface, water column	Juvenile barracudas only

Table 3.6-2: Major Taxonomic Groups of Fishes in the Atlantic Fleet Training and Testing Study Area (continued)

Major Fish Groups			*Occurrence in the study Area*		
Group Names	*Description*	*Representative Species*	*Open Ocean*	*Large Marine Ecosystems*	*Inland Waters*
Butterfishes (Order Perciformes)	Snout blunt and thick, teeth small, maxilla mostly covered by bone	Ariommatids, Driftfishes, Medusafishes	Surface, water column, seafloor	Surface, water column, seafloor	N/A
Flatfishes (Order Pleuronectiformes)	Body flattened; eyes on one side of body	Flounders, Halibuts, Soles, Tonguefishes	Seafloor	Seafloor	Seafloor
Pufferfishes (Order Tetraodontiformes)	Skin thick or rough sometimes with spines or scaly plates, pelvic fins absent or reduced, small mouth with strong teeth coalesced into biting plate	Filefishes, Ocean sunfishes, Triggerfishes	Water column	Surface, water column, seafloor	Surface, water column, seafloor

N/A = not applicable

3.6.2.3.1 Jawless Fishes-Hagfishes (Order Myxiniformes) and Lampreys (Order Petromyzontiformes)

Hagfishes and lampreys are primitive, cartilaginous, vertebrates with very limited external features often associated with fishes, such as fins and scales (Helfman et al., 2009). Both groups inhabit marine water column and soft bottom seafloor habitats in depths greater than 30 m and below 13° C in the West Greenland Shelf, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems.

Hagfish reproduction and early development has not been observed and captive breeding has been unsuccessful (Powell et al., 2005). Females lay leathery eggs on the seafloor and when the eggs hatch they are essentially miniature adults. Hagfishes prey on dying fishes or feed on dead fishes. Some hagfishes have commercial fishery importance as their external "skin" is used for making "eel leather" goods.

Lampreys are anadromous and larvae are buried in the soft bottoms of river backwaters (Moyle & Cech, 2004). Juvenile lampreys filter feed on algae and detritus. Adults are parasitic and use their oral disc mouth to attach to other fishes and feed on their blood (Moyle & Cech, 2004; Nelson et al., 2004). Hagfishes and lampreys have no known predators.

3.6.2.3.2 Ground Sharks (Orders Carcharhiniformes), Mackerel Sharks (Order Lamniformes), Carpet Sharks (Order Orectolobiformes)

Ground Sharks and allies (bull, dusky, hammerheads, oceanic whitetip, and tiger) are cartilaginous fishes with two dorsal fins, an anal fin, five gill slits, and eyes with nictitating membranes. Reproduction includes internal fertilization with the young born fully developed. These sharks are highly migratory. They are found in the water column and bottom/seafloor habitats in the Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and open ocean areas. These sharks are associated with hard and soft bottoms, nearshore and open ocean surface waters, and deep-sea habitats.

Mackerel Sharks and allies (great white, makos, and porbeagle) are cartilaginous fishes with a large first dorsal fin that is high, erect, and angular or somewhat rounded, anal fin with a keel, and a mouth extending behind the eyes. Reproduction includes internal fertilization with young being produced by means of eggs that are hatched within the body of the female. They are found in the water column and bottom/seafloor habitats in the West Greenland Shelf, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and open ocean areas. These sharks are associated with nearshore and open ocean surface water habitats.

Carpet Sharks and allies are a diverse group inhabiting coral and rocky reefs in the order Orectolobiformes. This group includes whale sharks which are the largest shark in the group and are one of three filter feeding sharks. Many of the carpet sharks, such as whale shark are also highly migratory. Carpet sharks all share certain characteristics, including their mouth being completely in front of eyes, both dorsal fins without spines, five pairs of gill slits, and an anal fin being present. Nurse sharks are also in this group and are usually yellowish-tan to dark brown, average around 8 to 9 ft. long, and can weigh over 200 pounds. They are nocturnal, scouting the sea bottom for prey such as crustaceans, molluscs and stingrays. They spend most of the day resting on sandy bottom or in caves or reef crevices. Whale sharks are another member of the carpet sharks group and are the largest shark in the world, growing to a length of over 40 ft.

3.6.2.3.3 Frilled and Cow Sharks (Order Hexanchiformes), Sawsharks (Order Pristiophoriformes), Dogfish Sharks (Order Squaliformes), and Angel Sharks (Order Squatiniformes)

Frill and cow sharks (sevengill, sixgill) are cartilaginous fishes, generally characterized by lacking traits such as an anal fin, and nictitating membrane; they do possess six to seven gill slits, compared to five gill slits found in all other sharks. Reproduction includes internal fertilization with young being produced by means of eggs that are hatched within the body of the female. They are associated with deep-sea habitats in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Sawshark (Bahamas) is a cartilaginous fish characterized by two spineless dorsal fins, absent anal fin, and five to six gill openings. Reproduction includes internal fertilization with young emerging from eggs that are hatched within the body of the female. This species is associated with deep-sea habitats in the Southeast U.S. Continental Shelf and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016).

Dogfish Sharks are cartilaginous fishes with both dorsal fins spines, not grooved, caudal peduncle with a pair of lateral keels. Reproduction includes internal fertilization with young emerging from eggs that are hatched within the body of the female. They are associated with soft bottom and deep-sea habitats in the West Greenland Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Angel sharks (Atlantic and sand) are cartilaginous fishes with flat, batoid-like body, two small spineless dorsal fins behind pelvic fins, and anal fin absent. Reproduction includes internal fertilization with young emerging from eggs that are hatched within the body of the female. They are associated with soft bottom habitat in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

3.6.2.3.4 Stingrays (Order Myliobatiformes), Sawfishes (Order Pristiformes), Skates and Guitarfishes (Order Rajiformes), and Electric Rays (Order Torpediniformes)

Stingrays and allies (eagle ray, manta) are cartilaginous fishes, distinguished by flattened bodies, enlarged pectoral fins that are fused to the head and gill slits that are placed on their ventral surfaces. Reproduction includes internal fertilization with the young born fully developed. They are associated with reefs, nearshore open ocean, bottom habitat, seagrass beds, and deep sea water column habitat in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

Sawfishes and allies inhabit inshore tropical areas in warm-temperate contiental waters and can be found in ocean waters out to 400 ft. in depth. They are also found and in muddy bays, estuaries, river mouths, off of large continental islands, and in fresh water in rivers or lakes (Compagno & Last, 1984). They can be found at or near the surface of the water column, but are usually bottom dwellers that rest in mud or sandy soft bottoms. They may occur over the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Compagno & Last, 1984).

Skates and guitarfishes are cartilaginous fishes, distinguished by flattened bodies, two reduced dorsal fins, and a reduced caudal fin. Reproduction includes internal fertilization and deposition of egg sacks. They are associated with soft bottom habitat in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems. Species in this group are associated with soft bottom habitat (Froese & Pauly, 2016; Moyle & Cech, 2004).

Electric rays are cartilaginous fishes, distinguished by flattened bodies, two well-developed dorsal fins and caudal fin. Two large kidney shaped organs in a disc on either side of the electric ray's head distinguish it from others, as these organs are able to produce strong electric shock at will (Madl & Yip, 2000). Reproduction includes internal fertilization with young being produced by means of eggs that are hatched within the body of the female. Two species, the Atlantic torpedo ray (*Torpedo nobiliana*) and lesser electric ray (*Narcine bancroftii*), occur in the Study Area. They are associated with soft bottom habitat in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004).

3.6.2.3.5 Ratfishes (Order Chimaeriformes)

Ratfishes (chimera, rabbitfish, and ratfish) are cartilaginous fishes, with smooth skin largely covered by placoid scales, and their color can range from black to brownish gray. Reproduction includes internal fertilization and deposition of egg capsules. Fishes in this group are associated with soft bottom and deep-sea habitats in the West Greenland Shelf, Scotian Shelf, Newfoundland-Labrador Shelf, Northeast

U.S. Continental Shelf, Southeast U.S. Continental Shelf, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016).

3.6.2.3.6 Sturgeons (Order Acipenseriformes)

Sturgeons (Atlantic, Gulf, and shortnose) are cartilaginous, long-lived, late-maturing fishes with a heterocercal tail, an elongated spindle-like body that is smooth-skinned, scaleless and armored with five lateral rows of bony plates. They are found in riverine, estuarine, and marine environments in the water column, bottom, and seafloor habitats in the Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems. Sturgeons historically had commercial and recreational fishery importance. They are broadcast spawners (females release eggs into the water where the eggs are fertilized by males) and fertilized eggs attach to bottom substrate until hatching. Juveniles and adults prey upon bottom invertebrates such as clams and fishes. Sturgeons have few known predators.

3.6.2.3.7 Gars (Order Lepisosteiformes)

Gars (alligator, longnose, shortnose, and Florida) are mostly cartilaginous fishes with a slender body encased in heavy ganoid scales plates, abbreviated heterocercal tail, and needle-like teeth. They are found in chiefly in riverine and estuarine waters and considered very rare in the marine environment. In the marine environment, they typically occur at the surface or in the water column in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems. Gars have some recreational game fishery importance. They are broadcast spawners and fertilized eggs attach to submerged aquatic vegetation until hatching. Juveniles prey upon plankton, invertebrates, and amphibians, while adults eat blue crabs, fishes, birds, reptiles, and small mammals. Gars are preyed upon by fishes as juveniles and alligators as adults.

3.6.2.3.8 Herrings (Order Clupeiformes)

Herring and allies (anchovies, herrings, sardines, and shad) are bony fishes with a silvery body with the lateral line and fin spines absent, and usually scutes along ventral profile. They are found only in the marine environment in the water column, and seafloor habitats in the West Greenland Shelf, Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, Gulf of Mexico and Caribbean Large Marine Ecosystems. Herring, menhaden, sardine, and anchovy species are well-known as valuable targets of commercial fisheries. Herring account for a large portion of the total worldwide fish catch (Food and Agriculture Organization of the United Nations, 2005, 2009). Herrings and allies are broadcast spawners. They are known to form schools to help conserve energy and minimize predation (Brehmer et al., 2007) which may facilitate some level of communication during predator avoidance (Marras et al., 2012). They feed on decaying organic matter and plankton while swimming in the water column (Moyle & Cech, 2004). Herring and allies support marine food webs as a forage fish and preyed upon by fish, birds, and marine mammals.

3.6.2.3.9 Tarpons (Orders Elopiformes and Albuliformes)

Tarpons and allies (bonefishes, halosaurs, ladyfish, and machete) are bony fishes with the body encased in silvery scales, a large mouth, a single dorsal fin (most), and a somewhat tapered tail with fin spines absent. They are associated with riverine, estuarine and marine environments on the surface, water column, and seafloor/bottom habitats in the Newfoundland-Labrador Shelf (halosaurs only), Northeast and Southeast U.S. Continental Shelves, Gulf of Mexico, and Caribbean Large Marine Ecosystems. Tarpon and allies are important game species, but are not considered edible. Tarpons and allies are broadcast spawners. Fertilized eggs float in the water column until hatching into a leptocephalus larva (ribbon-like, with no resemblance to the adult). During the change from larvae to juvenile, the body shrinks in length. Juveniles prey upon plankton and marine invertebrates, while adults feed on mid-water fishes. Tarpon and allies are nocturnal ambush predators (Wainwright & Richard, 1995) who prey on bottom-dwelling invertebrates and small fishes. Tarpons and allies are preyed upon by larger fishes, birds, and marine mammals.

3.6.2.3.10 Eels (Anguilliforms, Notacanthiformes, and Saccopharyngiformes)

Eels (conger, cutthroat, duckbill, false moray, morays, sawtooth, short-tailed, spiny, gulpers, and pelican eels) are bony fishes with a very elongate body, usually scaleless with pelvic fins, and without fin spines. They are associated with riverine, estuarine and marine environments in the water column, and seafloor/bottom habitats in the Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems. Eels and allies have little fishery importance. Some species are broadcast spawners, and fertilized eggs float in the water column until hatching into a leptocephalus larva. Juveniles prey upon plankton and marine invertebrates, while adults feed on small fishes. Depending on the species and its habitat, eels can be diurnal or nocturnal ambush predators and prey on bottom-dwelling invertebrates and small fishes. Eels are preyed upon mostly by larger fishes.

3.6.2.3.11 Salmonids (Orders Salmoniformes)

Salmon and allies (Arctic char, Atlantic salmon, and Atlantic whitefish) are bony fishes with silvery bodies with an adipose fin present and exhibit anadromy. They are found in riverine, estuarine, and marine environment in the water column, and seafloor habitats in the West Greenland Newfoundland-Labrador Shelf, and Northeast U.S. Continental Shelf Large Marine Ecosystems. Atlantic salmon is listed as endangered in the Study Area, as described in Section 3.6.2.2.1 (Atlantic salmon [*Salmo salar*]). Salmon have historic fishery importance. The native distribution of Salmoniformes is restricted to the cold waters of the Northern Hemisphere. Most salmon spawn in freshwater and live in the sea; they are among the most thoroughly studied and commercially valuable fish groups in the world. Juveniles prey upon insects, plankton, and small fishes while adults feed mainly on fishes. Salmon are preyed upon by sharks, birds, and marine mammals.

3.6.2.3.12 Argentines and Allies (Order Argentiniformes)

Argentines and allies (argentines, barreleyes, deep-sea smelts, slickheads, and tubeshoulders) are bony fishes with typically silvery, elongate bodies, adipose fin and extremely large mouths sometimes present, and pelvic fins and spines sometimes absent. They are found only in the marine environment in the water column, and seafloor habitats in the Newfoundland-Labrador Shelf, Northeast U.S. Continental Shelf, and Gulf of Mexico Large Marine Ecosystems. Argentines and allies have little fishery importance. Argentines and allies vary in their reproduction strategy. Some deep-sea species are capable of bioluminescence and release scents that may help to attract mates. Argentines are broadcast spawners and fertilized eggs float in the water column until hatching. Argentines and allies likely have few predators, but may be preyed upon by larger fishes.

3.6.2.3.13 Catfishes (Order Siluriformes)

Catfishes (sea catfishes) are bony fishes with barbels on head, spines on dorsal and pectoral fins, lack scale, with an adipose fin present. They are found in estuarine and marine environment on bottom and seafloor habitats in the Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems. These fishes do have recreational fishery importance. Catfishes prefer soft bottom habitats, and can tolerate salinities of wide ranges in the open ocean and nearshore fresh waters (Gulf

Coast Research Laboratory, 2016). Reproduction is external with males incubate eggs in their mouth. All ages of fishes eat benthic invertebrates. Predators are likely very limited (Moyle & Cech, 2004).

3.6.2.3.14 Bristlemouths and Allies (Order Stomiiformes)

Bristlemouths and allies (dragonfishes, fangjaws, hatchfishes, and lightfishes) are bony fishes with photophores and adipose fin present and chin barbels sometimes present. Bristlemouths and hatchetfishes are small in size and the most abundant fishes in many parts of the world's oceans. They are capable of eating large and small prey items and are known to engage in prey-related vertical migration patterns. Other species in this order prey largely on other fishes (Moyle & Cech, 2004).

3.6.2.3.15 Greeneyes and Allies (Order Aulopiformes)

Greeneyes and allies (barracudinas, daggertooth, lizardfishes, pearleyes, and waryfishes) are bony fishes with an upper protrusible jaw, an adipose fin and forked tail usually present with fin spines absent. Most greeneyes and allies are small (less than 50 cm) predators capable of devouring a wide range of species, including other fishes nearly their same size and pelagic invertebrates. Fishes in this order are preyed upon by salmon, tunas, and swordfishes. Reproduction is usually external, and includes the ability to change sex (Froese & Pauly, 2016).

3.6.2.3.16 Lanternfishes and Allies (Order Myctophiformes)

Lanternfishes and allies (headlight, lampfishes, and lancetfishes) are bony fishes that are usually small-sized, with an adipose fin, forked tail and photophores usually present. Lanternfishes can occur closer to the surface at night (10-100 m) and deeper during the day (300 to 1200 m) (Froese & Pauly, 2016), where they may become prey for marine mammals. These fishes often are an important part of the deep scattering layer (Moyle & Cech, 2004). Lanternfishes prey upon copepods and krill (Van Noord et al., 2016).

3.6.2.3.17 Hakes and Allies (Order Gadiformes).

Hakes and allies (cods, codlings, grenadiers, and whiptails) are bony fishes with long dorsal and anal fins, no true spines in fins, although spinous rays present in dorsal fin of most species, and chin barbels are often present. Hakes and allies account for approximately half of the global commercial landings (Food and Agriculture Organization of the United Nations, 2005). Prey items for fishes in this group include small crustaceans during juvenile phases and larger crustaceans, squid, and fishes as adults. Predators include striped bass, sharks, and cetaceans (Froese & Pauly, 2016).

3.6.2.3.18 Brotulas and Allies (Order Ophidiiformes)

Brotulas and allies (cusk-eels) are bony fishes with pelvic absent or far forward and filamentous, dorsal and anal fins joined to caudal fin, and spines absent. These fishes exhibit a variety of reproductive strategies including external fertilization and giving live birth. Prey items for fishes in this group include small crustaceans during juvenile phases and larger crustaceans, squid and fishes as adults. Predators include striped bass, sharks, and cetaceans (Froese & Pauly, 2016).

3.6.2.3.19 Toadfishes and Allies (Order Batrachoidiformes)

Toadfishes and allies (midshipman) are bony fishes with compressed bodies, large, depressed head and mouth usually with tentacles, and two dorsal fins with the first with spines. These fishes are known to build nests (Moyle & Cech, 2004).

3.6.2.3.20 Anglerfishes and Allies (Order Lophiiformes)

Anglerfishes and allies (footballfishes, frogfishes, goosefishes, and sea devils) are bony fishes with globulose bodies, a spine on the first dorsal fin and the pelvic fins usually absent. Anglerfish attract potential prey using their first dorsal fin (illicium) as a lure (Yasugi & Hori, 2016). Fishes in these orders are found occasionally on the surface, but most frequently in the water column and seafloor habitats in the West Greenland Shelf, Newfoundland-Labrador Shelf, Scotian Shelf Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems. Additional adaptations include large mouths, sharp teeth, and sensitive lateral line [sensory] systems (Haedrich, 1996; Koslow, 1996; Marshall, 1996; Rex & Etter, 1998; Warrant & Locket, 2004). These fishes are mostly generalist feeders. Reproduction is not well studied, but sexes are separate and some exhibit parasitism (Moyle & Cech, 2004). Fishes in this group generally have no fishery importance unless stated otherwise.

3.6.2.3.21 Flying Fishes (Order Beloniformes)

Flying fishes (halfbeaks, needlefishes, and sauries) are bony fishes with jaws extended into a beak; pelvic fins very large wing-like; spines absent. These fishes are associated with reefs, submerged aquatic vegetation, and open ocean habitat in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and open ocean areas (Froese & Pauly, 2016).

3.6.2.3.22 Killifishes (Order Cyprinodontiformes)

Killifishes (goldspotted, rivulus, and sheepshead minnows) are bony fishes with a protrusible upper jaw, fin spines rarely present, and a single dorsal fin. Killifishes are found in the water column of rivers and estuaries in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico and Caribbean Sea Large Marine Ecosystems. The mangrove rivulus (*Kleptolebias marmoratus*) is a species of concern in the Study Area, as listed in Table 3.6-1.

3.6.2.3.23 Silversides (Order Atheriniformes).

Silversides (Atlantic, beach, inland, and rough) are bony fishes with a silvery stripe on their sides, high pectoral fins, a dorsal fin, and the pelvic fin has a spine. These fishes are found on the surface and in the water column in the Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico and Caribbean Sea Large Marine Ecosystems. The Key silverside (*Menidia conchorum*) is a species of concern in the Study Area, as listed in Table 3.6-1.

3.6.2.3.24 Opahs and Allies (Order Lampriformes)

Opahs and allies (crestfishes, oarfishes, ribbonfishes, tapertails, and tube-eyes) are bony fishes with an upper protrusible jaw, pelvic fins located forward on body, below, or just behind insertion of pectoral fins. Toadfishes (midshipman) have compressed bodies, large, depressed head and mouth usually with tentacles, and two dorsal fins with the first with spines. These fishes are found in the water column and seafloor habitats in the Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and open ocean areas. Fishes in this group exhibit a variety of reproductive strategies including external fertilization and parasitism. Prey items for fishes in this group include crustaceans, squid, and fishes.

3.6.2.3.25 Squirrelfishes and Allies (Order Beryciformes)

Squirrelfishes and allies (bigscales, fangtooths, pricklefishes, slimeheads, and whalefishes) are bony fishes with round bodies, one dorsal fin often set far back, with pelvic fins absent, and fin spines often present. Squirrelfishes (family Holocentridae) are the largest and most widely distributed family in the order, with over 60 species found throughout tropical and subtropical marine habitats (Moyle & Cech, 2004). Most species in this group occupy shallow nearshore reef and rocky areas where they hide during the day and come out at night to feed on zooplankton in the water column.

3.6.2.3.26 Dories and Allies (Order Zeiformes)

Dories and allies (boarfishes, oreos, and tinselfishes) are bony fishes that have deeply compressed bodies, protrusible jaws, spines in dorsal fin, and pelvic fin spines sometimes present. There are seven species recorded in the Study Area (Froese & Pauly, 2016). These fishes are only found in marine habitats and most of are deep sea species. Fishes in this order typically have large heads with distensible jaws that allow them to capture larger-sized prey, including fishes and crustaceans.

3.6.2.3.27 Pipefishes and Allies (Order Syngnathiformes)

Pipefishes and allies (cornetfish, seahorses, and snipefishes) are bony fishes, which exhibit unique body shapes with snout tube-like, mouth small, and scales often modified bony plates. These fishes are associated with hard and soft bottom, submerged aquatic vegetation, reefs, and deep-sea habitats in the West Greenland, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Paxton & Eshmeyer, 1998). Some pipefishes and allies exhibit a high level of parental care by, brooding pouches (male seahorses), which results in relatively few young being produced (Helfman et al., 2009). Most fishes in this group are diurnal ambush predators and prey on zooplankton, marine invertebrates, and small fishes. Pipefishes and allies are preyed upon by larger fishes, and birds.

3.6.2.3.28 Sticklebacks (Order Gasterosteiformes)

Sticklebacks are small fishes comprised of only seven species that live in freshwater, saltwater, or brackish water (Helfman et al., 2009; Moyle & Cech, 2004). Species in this group are easily recognized by the presence of three to 16 isolated spines on their back in front of the dorsal fin, large eyes, and small upturned mouths. Most species in this group possess a row of bony plates on each side. Some sticklebacks display parental care through nest building. Fishes in this group are found in littoral marine waters and freshwater habitats in the Study Area.

3.6.2.3.29 Scorpionfishes (Order Scorpaeniformes)

Scorpionfishes and allies (poachers, sea robins, snailfishes, and sculpins) are bony fishes with usually strong spines on head and dorsal fin, cheeks with bony struts, and rounded pectoral fins. These fishes are associated with hard and soft bottom, reefs, and deep-sea habitats in the West Greenland, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and open ocean areas (Froese & Pauly, 2016; Paxton & Eshmeyer, 1998). Some scorpionfishes have commercial and recreation fishery importance (Moyle & Cech, 2004). Reproduction methods vary widely between species and include external fertilization and egg deposition (sculpins). Most fishes in this group are diurnal ambush predators and prey on bottom-dwelling invertebrates and small fishes. Scorpionfishes are allies are preyed upon by larger fishes, birds, and marine mammals.

3.6.2.3.30 Mullets (Order Mugiliformes)

Mullets (striped, white, fantail, mountain) are bony fishes with a streamline body, forked tail, hard angled mouth, large scales, high pectoral fins, and pelvic fins with one spine. Striped mullet is an important commercial fishery (Froese & Pauly, 2016). These fishes are associated with soft bottom, reefs, and nearshore open ocean habitats in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Mullets are catadromous; they spawn in saltwater but spend most of their lives in freshwater environments.

3.6.2.3.31 Order Perciformes

The Perciformes, with over 7,800 species, is the largest order of vertebrates. They are extremely diverse, but most species are adapted for life as predators in the shallow or surface waters of the ocean. Some of the characteristics include fin spines present, dorsal fins either double or made up of two distinct parts with the lead spiny, adipose fin absent, pelvic fins thoracic or jugular in position or absent, pectoral fins on side of body; ctenoid scales, and closed swim bladder. Nearly half of all species belong to four families: gobies, wrasses seabasses, or blennies (Moyle & Cech, 2004). Fish groupings in this section generally follow the classification in Nelson (2016).

3.6.2.3.31.1 Perches and Allies

Perches and allies (angelfishes, cardinal fishes, damselfishes, drums, grunts, jacks, remoras, groupers, sea basses, snappers, and striped bass) are bony fishes with deep to moderately elongate bodies, one to two dorsal fins, with large mouth and eyes and thoracic pelvic fins. These fishes are associated with hard and soft bottom, reefs, submerged aquatic vegetation, open ocean, and deep-sea habitats in the Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and open ocean areas (Froese & Pauly, 2016; Moyle & Cech, 2004).

3.6.2.3.31.2 Wrasses and Allies

Wrasses and allies (hogfishes, parrotfishes, wrasses, and damselfishes) are bony fishes with a compressed body, large scales, well-developed teeth, usually colorful coloring. Some wrasses and allies have recreational fishery and aquarium trade importance. Most of these fishes are associated with depths less than 30 m hard and soft bottom and reef habitats in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico and Caribbean Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Wrasses and allies can change sex, usually female-to-male and exhibit broadcast spawning, where the fertilized eggs float in the water column or attach to substrate until hatching into larvae. Most are diurnal opportunistic predators (Wainwright & Richard, 1995). Prey items include zooplankton, invertebrates, and small fishes. Predators of wrasses and allies include larger fishes and marine mammals.

3.6.2.3.31.3 Eelpouts and Allies

Eelpouts and allies (gunnels, ocean pout, pricklebacks, wolfeels) are bony fishes with an eel-like body, long dorsal and anal fins, and pelvic fins usually absent. These fishes are associated with soft bottom and deep-sea habitats in the West Greenland, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Eelpouts have been found to occur near deep-sea vents in the Atlantic Ocean's Mid-Atlantic Ridge (National Geographic, 2016).

3.6.2.3.31.4 Stargazers

Stargazers are bony fishes with an elongated body and eyes on top of their head and big oblique mouths. They are associated with soft bottom and deep-sea habitats in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016). This group of fishes ambush their prey from the sand.

3.6.2.3.31.5 Blennies, Gobies, and Allies

Blennies, gobies, and allies (barfin goby, freckled blenny, bridled goby, sleepers, and wormfishes) are bony fishes with an eel-like to sculpin-like body, pelvic fins reduced or fused. They are associated with hard and soft bottoms, reefs, and deep-sea habitats in the Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Caribbean Sea, and Gulf of Mexico Large Marine Ecosystems (Froese & Pauly, 2016).

3.6.2.3.31.6 Surgeonfishes

Surgeonfishes (doctorfish, Gulf surgeonfish, blue tang,) are bony fishes with bodies that are deeply compressed laterally, small mouth, small scales, and pelvic fins with spines. They are associated with reef habitats in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Caribbean Sea, and Gulf of Mexico Large Marine Ecosystems (Froese & Pauly, 2016). These fishes scrape algae from coral reefs with small, elongated mouths. These grazers provide an important function to the reef system by controlling the growth of algae on the reef (Goatley & Bellwood, 2009).

3.6.2.3.31.7 Tunas and Allies

Tuna and allies (barracudas, billfishes, swordfishes, and tunas) have a large mouth, keels usually present, pelvic fins often absent or reduced, and are fast swimmers. These fishes are associated with reefs, nearshore and offshore open ocean habitats in the Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico and Caribbean Large Marine Ecosystems (Froese & Pauly, 2016; Moyle & Cech, 2004). Most species have commercial and recreational importance. Tuna and allies are voracious open ocean predators (Estrada et al., 2003). They exhibit broadcast spawning and fertilized eggs float in the water column until hatching into larvae. Many feed nocturnally (Goatley & Bellwood, 2009) and in low-light conditions of twilight (Rickel & Genin, 2005). Many species in this group make large-scale migrations that allow for feeding in highly productive areas, which vary by season (Pitcher, 1995). Prey items include zooplankton for larvae and juvenile stages, while fishes and squid are consumed by subadults and adults. Predators of tuna and allies include other tuna species, billfishes, toothed whales, and some open ocean shark species. The Atlantic bluefin tuna is a NMFS Species of Concern that occurs in the Study Area, as presented in Table 3.6-1.

3.6.2.3.31.8 Butterfishes

Butterfishes (Ariommatids, driftfishes, and medusafishes) are bony fishes with a blunt and thick snout, teeth small, and a maxilla mostly covered by bone. They are associated with soft bottom and deep-sea habitats in the Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems (Froese & Pauly, 2016). Butterfishes form large schools over the continental shelf, except during winter months when it may descend to deeper waters. Juveniles are associated with jellies and floating vegetation. Adults feed mainly on jellies, squids, and crustaceans. Some species of butterfishes are also commercially harvested (Froese & Pauly, 2016).

3.6.2.3.32 Flatfishes (Order Pleuronectiformes)

Flatfishes (flounders, halibut, sand dabs, soles, and tonguefish) are bony fishes with a flattened body and eyes on one side of body (Table 3.6-2). These fishes occur on soft bottom habitat in inland waters, as well as in deep-sea habitats in the West Greenland Shelf, Newfoundland-Labrador Shelf, Scotian Shelf, Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems and are an important part of commercial fisheries in the Study Area. The Atlantic halibut (*Hippoglossus hippoglossus*) is a representative of this group and is also a Species of Concern. Flatfishes are broadcast spawners. They are ambush predators, and prey on other fishes and bottom-dwelling invertebrates. Some species in this group have been affected by overfishing (Drazen & Seibel, 2007; Froese & Pauly, 2010).

3.6.2.3.33 Pufferfishes (Order Tetraodontiformes)

Pufferfishes (boxfishes, filefishes, ocean sunfishes and triggerfishes) are bony fishes with thick or rough skin, sometimes with spines or scaly plates, pelvic fins absent or reduced, and a small mouth with strong teeth coalesced into a biting plate. They are associated with hard and soft bottom, reef, submerged aquatic vegetation, nearshore and offshore open-ocean, and deep-sea habitats in the Newfoundland-Labrador shelf, Northeast U.S. Continental Shelf, Scotian Shelf, Southeast U.S. Continental Shelf, Caribbean Sea, and Gulf of Mexico Large Marine Ecosystems. Pufferfishes are broadcast spawners. Predators vary by species, but due to spiny and rough exterior of this group, it is likely few are successful. Prey vary by species, but includes jellies, crustaceans, detritus, molluscs, and other bottom dwelling marine invertebrates (Froese & Pauly, 2016).

3.6.3 Environmental Consequences

This section evaluates how, and to what degree, the activities described in Chapter 2 (Description of Proposed Action and Alternatives) potentially impact fishes known to occur within the Study Area. Tables 2.6-2 through 2.6-5 present the proposed typical training and testing activity locations for each alternative (including number of events). General characteristics of all U.S. Department of the Navy (Navy) stressors were introduced in Section 3.0.3.3 (Identifying Stressors for Analysis), and living resources' general susceptibilities to stressors were introduced in Section 3.0.3.6 (Biological Resource Methods). The stressors vary in intensity, frequency, duration, and location within the Study Area. The stressors analyzed for fishes are:

- **Acoustic** (sonar and other transducers; air guns; pile driving; vessel noise; aircraft noise; and weapons noise)
- **Explosives** (explosive shock wave and sound; explosive fragments)
- **Energy** (in-water electromagnetic devices; in-air electromagnetic devices; high-energy lasers)
- **Physical disturbance and strikes** (vessels and in-water devices; aircraft and aerial targets, military expended materials, seafloor devices, pile driving)
- **Entanglement** (wires and cables, decelerators/parachutes, biodegradable polymers)
- **Ingestion** (military expended materials – munitions, military expended materials other than munitions)
- **Secondary stressors** (impacts to habitat and prey availability)

The analysis focuses on the fish groups and ESA-listed fish species discussed in Section 3.6.2 (Affected Environment). Largetooth sawfish, defined in Table 3.6-1 as extirpated, are not carried forward in the analysis as this species is unlikely to occur in the Study Area, and there would be no effect from training and testing activities. The analysis includes consideration of the mitigation that the Navy will implement to avoid potential impacts on fishes from explosives, and physical disturbance and strikes. Mitigation for fishes will be coordinated with NMFS through the consultation processes.

3.6.3.1 Acoustic Stressors

The following section analyzes potential impacts on fishes from proposed activities that involve acoustic stressors (i.e., sonar and other transducers; air guns; pile driving; vessel noise; aircraft noise; and weapons noise). It follows the outline and methodology for assessing potential impacts put forth in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities).

3.6.3.1.1 Background

Effects of human-generated sound on fishes have been examined in numerous publications (Hastings & Popper, 2005; Hawkins et al., 2015; Mann, 2016; National Research Council, 1994, 2003; Neenan et al., 2016; Popper, 2003; Popper et al., 2004; Popper, 2008; Popper & Hastings, 2009c; Popper et al., 2014; Popper et al., 2016). The potential impacts from Navy activities are based on the analysis of available literature related to each type of effect. In addition, a Working Group organized under the American National Standards Institute-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, developed sound exposure guidelines for fish and sea turtles (Popper et al., 2014), hereafter referred to as the ANSI Sound Exposure Guideline technical report. Where applicable, thresholds and relative risk factors presented in the ANSI Sound Exposure Guideline technical report were used to assist in the analysis of effects to fishes from Navy activities.

3.6.3.1.1.1 Injury

Injury refers to the direct effects on the tissues or organs of a fish. Research on injury in fish caused by exposure to high-intensity or long-duration sound from air guns, impact pile driving and some sonars is discussed below. Moderate- to low-level noise from vessels, aircraft, and weapons use is described in Section 3.0.3.3.1 (Acoustic Stressors) and lacks the amplitude and energy to cause any direct injury. Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on injury and the framework used to analyze this potential impact.

Injury due to Impulsive Sound Sources

Impulsive sounds, such as those produced by seismic air guns and impact pile driving, may cause injury or mortality in fishes. Mortality and potential damage to the cells of the lateral line have been observed in fish larvae, fry, and embryos after exposure to single shots from a seismic air gun within close proximity to the sound source (0.1 to 6 m) (Booman et al., 1996; Cox et al., 2012). However, exposure of adult fish to a single shot from an air gun array (four air guns) within similar ranges (6 m), has not resulted in any signs of mortality within seven days after exposure (Popper et al., 2016). Although injuries occurred in adult fishes, they were similar to injuries seen in control subjects (i.e., fishes that were not exposed to the air gun) so there is little evidence that the air gun exposure solely contributed to the observed effects.

In a pile driving study conducted by the California Department of Transportation, fish exposed to peak pressures up to 205–206 decibels referenced to 1 micropascal (dB re 1 µPa) exhibited no statistically significant differences in rates of injury compared to control fish (California Department of Transportation, 2004). Injuries, such as ruptured swim bladders, hematomas, and hemorrhaging of other gas-filled organs, have been reported in fish exposed to a large number of simulated impact pile driving strikes with cumulative sound exposure levels up to 219 decibels referenced to 1 micropascal squared seconds (dB re 1 µPa^2-s) under highly controlled settings where fish were unable to avoid the source (Casper et al., 2012b; Casper et al., 2013a; Casper et al., 2013b; Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). Halvorsen (2011) found that the equal energy hypothesis does not apply to effects of pile driving; rather, metrics relevant to injury could include, but not be limited to, cumulative sound exposure level, single strike sound exposure level, and number of strikes. Although single strike peak sound pressure levels were also measured during these experiments (207 dB re 1 µPa), the injuries were only observed during exposures to multiple strikes. These studies included species both with and without swim bladders. The majority of fish that exhibited injuries were those with swim bladders. Lake sturgeon (*Acipenser fulyescens*), a physostomous fish, was found to be less susceptible to injury from impulsive sources than Nile tilapia (*Oreochromis niloticus*), a physoclistous fish (Halvorsen et al., 2012a). The difference in results is likely due to the type of swim bladder in each fish. Physostomous fishes have an open duct connecting the swim bladder to their esophagus and may be able to quickly adjust the amount of gas in their body by gulping or releasing air. Physoclistous fishes do not have this duct and instead, gas pressure in the swim bladder is regulated by special tissues or glands. There were no mortalities reported during these experiments and in the studies where recovery was observed, the majority of exposure related injuries healed within a few days in a laboratory setting. In addition, limited experimental data suggests that fish larvae exposed to pile driving at cumulative sound exposure levels up to 206 dB re 1 µPa^2-s and peak sound pressure levels of 210 re 1 µPa are not susceptible to mortality (Bolle et al., 2012).

Debusschere et al. (2014) largely confirmed the results discussed in the paragraph above with caged juvenile European sea bass (Dicentrarchus labrax) exposed to actual pile driving operations. No differences in mortality were found between control and experimental groups at similar levels tested in the experiments described in the paragraph above (sound exposure levels up to 215–222 dB re 1 µPa^2-s) and many of the same types of injuries occurred. Fishes with injuries from impulsive sources such as these may not survive in the wild due to harsher conditions and risk of predation.

Other potential effects from exposure to impulsive sound sources include potential bubble formation and neurotrauma. It is speculated that high sound pressure levels may also cause bubbles to form from micronuclei in the blood stream or other tissues of animals, possibly causing embolism damage (Hastings & Popper, 2005). Fishes 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 take place in the eyes of fish due to potentially high gas saturation within the eye tissues (Popper & Hastings, 2009c). Additional research is necessary to verify if these speculations apply to exposures to non-impulsive sources such as sonars. These phenomena have not been well studied in fishes and are difficult to recreate under real-world conditions.

As summarized in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), exposure to high intensity and long duration impact pile driving or air gun shots did not cause mortality, and fishes typically recovered from injuries in controlled laboratory settings. Species tested to date can be used as viable surrogates for investigating injury in other species exposed to similar sources (Popper et al., 2014).

Injury due to Sonar and Other Transducers

Non-impulsive sound sources (e.g., sonar, acoustic modems, and sonobuoys) have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007). Potential direct injuries (e.g., barotrauma, hemorrhage or rupture of organs or tissue) from non-impulsive sound sources, such as sonar, are unlikely because of slow rise times[1], lack of a strong shock wave such as that associated with an explosive, and relatively low peak pressures. General categories and characteristics of Navy sonar systems are described in Section 3.0.3.3.1.1 (Sonar and Other Transducers).

The effects of mid-frequency sonar-like signals (1.5–6.5 kHz) on larval and juvenile Atlantic herring (*Clupea harengus*), Atlantic cod (*Gadus morhura*), saithe (*Pollachius virens*), and spotted wolffish (*Anarhichas minor*) were examined by Jørgensen et al. (2005). Researchers investigated potential effects on survival, development, and behavior in this study. Among fish kept in tanks and observed for one to four weeks after sound exposure, no significant differences in mortality or growth-related parameters between exposed and unexposed groups were observed. Examination of organs and tissues from selected herring experiments did not reveal obvious differences between unexposed and exposed groups. However, two (out of 42) of the herring groups exposed to sound pressure levels of 189 dB re 1 µPa and 179 dB re 1 µPa had a post-exposure mortality of 19 and 30 percent, respectively. It is not clear if this increased mortality was due to the received level or to other unknown factors, such as exposure to the resonance frequency of the swim bladder. Jørgensen et al. (2005) estimated a resonant frequency of 1.8 kHz for herring and saithe ranging in size from 6.3 to 7.0 cm, respectively, which lies within the range of frequencies used during sound exposures and therefore may explain some of the noted mortalities.

Individual juvenile fish with a swim bladder resonance in the frequency range of the operational sonars may be more susceptible to injury or mortality. Past research has demonstrated that fish species, size and depth influences resonant frequency (Løvik & Hovem, 1979; McCartney & Stubbs, 1971). At resonance, the swim bladder, which can amplify vibrations that reach the fishes hearing organs, may absorb much of the acoustic energy in the impinging sound wave. It is suspected that the resulting oscillations may cause mortality or harm the auditory organs or the swim bladder (Jørgensen et al., 2005; Kvadsheim & Sevaldsen, 2005). However, damage to the swim bladder and to tissues surrounding the swim bladder was not observed in fishes exposed to sonar at their presumed swim bladder resonant frequency (Jørgensen et al., 2005). The physiological effect of sonars on adult fish is expected to be less than for juvenile fish because adult fish are in a more robust stage of development, the swim bladder resonant frequencies would be lower than that of mid-frequency active sonar, and adult fish have more ability to move from an unpleasant stimulus (Kvadsheim & Sevaldsen, 2005). Lower frequencies (i.e., generally below 1 kHz) are expected to produce swim bladder resonance in adult fishes from about 10–100 cm (McCartney & Stubbs, 1971). Fish, especially larval and small juveniles, are more susceptible to injury from swim bladder resonance when exposed to continuous signals within the resonant frequency range.

Hastings (1995) found “acoustic stunning” (loss of consciousness) in blue gouramis (*Trichogaster trichopterus*), a freshwater species, following an 8-minute continuous exposure to a 150 Hz pure tone with a 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 (1991, 1995) also found that goldfish (*Carassius auratus*), also a freshwater species, exposed to a 250 Hz continuous wave sound with peak pressures of 204 dB re 1 µPa for two hours, and blue gourami exposed to a 150 Hz continuous wave sound at a sound pressure level of 198 dB re 1 µPa for 0.5 hours did not survive. These studies are examples of the highest known levels tested on fish and for relatively long durations.

[1] Rise time: the amount of time for a signal to change from static pressure (the ambient pressure without the added sound) to high pressure. Rise times for non-impulsive sound typically have relatively gradual increases in pressure where impulsive sound has near instantaneous rise to a high peak pressure. For more detail, see Appendix D (Acoustic and Explosives Primer).

Stunning and mortality due to exposure to non-impulsive sound exposure has not been observed in other studies.

Three freshwater species of fish, the rainbow trout (*Oncorhynchus mykiss*), channel catfish (*Ictalurus punctatus*), and the hybrid sunfish (*Lepomis* sp.), were exposed to both low- and mid-frequency sonar (Kane et al., 2010; Popper et al., 2007). Low-frequency exposures with received sound pressure levels of 193 dB re 1 µPa occurred for either 324 or 648 seconds. Mid-frequency exposures with received sound pressure levels of 210 dB re 1 µPa occurred for 15 seconds. No fish mortality resulted from either experiment and during necropsy after test exposures, both studies found that none of the subjects showed signs of tissue damage related to exposure (Kane et al., 2010; Popper et al., 2007).

As summarized in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), although fishes have been injured and killed due to intense, long-duration non-impulsive sound exposures, fish exposed under more realistic conditions have shown no signs of injury. Those species tested to date can be used as viable surrogates for estimating injury in other species exposed to similar sources.

3.6.3.1.1.2 Hearing Loss

Researchers have examined the effects on hearing in fishes from sonar-like signals, tones, and different continuous noise sources; however, studies from impulsive sources are limited to air gun and impact pile driving exposures. Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on hearing loss and the framework used to analyze this potential impact.

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, permanent loss of hair cells, or damage to auditory nerve fibers (Liberman, 2016), and can occur over a small range of frequencies related to the sound exposure. However, the sensory hair cells of the inner ear in fishes are regularly replaced over time when they are damaged, unlike in mammals where sensory hair cells loss is permanent (Lombarte et al., 1993; Popper et al., 2014; Smith et al., 2006). As a consequence, PTS has not been known to occur in fishes and 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 (Popper et al., 2005; Popper et al., 2014; Smith et al., 2006). It is not known if damage to auditory nerve fibers could occur, and if so, whether fibers would recover during this process. 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.

Hearing Loss due to Impulsive Sound Sources

Popper et al. (2005) examined the effects of a seismic air gun array on a fish with a swim bladder that is involved in hearing, the lake chub (*Couesius plumbeus*), and two species that have a swim bladder that is not involved in hearing, the northern pike (*Esox lucius*) and the broad whitefish (*Coregonus nasus*), a salmonid. In this study, the lowest received cumulative sound exposure level (5 shots with a mean sound pressure level of 177 dB re 1 µPa) at which effects were noted was 186 dB re 1 μPa^2-s. The results showed temporary hearing loss for both lake chub and northern pike to both 5 and 20 air gun shots, but not for the broad whitefish. Hearing loss was approximately 20 to 25 dB at some frequencies for both species, and full recovery of hearing took place within 18 hours after sound exposure. Examination of the sensory surfaces of the ears after allotted recovery times (one hour for 5 shot exposures, and up to 18 hours for 20 shot exposures) showed no damage to sensory hair cells in any of the fish from these exposures (Song et al., 2008).

McCauley et al. (2003) and McCauley and Kent (2012) showed loss of a small percent of sensory hair cells in the inner ear of caged fish exposed to a towed air gun array simulating a passing seismic vessel. Pink snapper (*Pargus auratus*), a species that has a swim bladder that is not involved in hearing, were exposed to multiple air gun shots for up to 1.5 hours (McCauley et al., 2003) where the maximum received sound exposure levels exceeded 180 dB re 1 µPa^2-s. 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. Gold band snapper (*Pristipomoides multidens*) and sea perch (*Lutjanis kasmira*), both fishes with a swim bladder involved in hearing, were also exposed to a towed air gun array simulating a passing seismic vessel (McCauley & Kent, 2012). Although received levels for these exposures have not been published, hair cell damage increased as the range of the exposure decreased. Again, the amount of damage was considered small in each case (McCauley & Kent, 2012). 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 and only a small portion were affected by the sound (Lombarte & Popper, 1994; Popper & Hoxter, 1984). The question remains as to why McCauley and Kent (2012) found damage to sensory hair cells while Popper et al. (Popper et al., 2005) did not; however, there are many differences between the studies, including species and the precise sound source characteristics.

Hastings et al. (2008) exposed a fish with a swim bladder that is involved in hearing, the pinecone soldierfish (*Myripristis murdjan*), and three species that have a swim bladder that is not involved in hearing, the blue green damselfish (*Chromis viridis*), the saber squirrelfish (*Sargocentron spiniferum*), and the bluestripe seaperch (*Lutjanus kasmira*), to an air gun array. Fish in cages were exposed to multiple air gun shots with a cumulative sound exposure level of 190 dB re 1 µPa^2-s. The authors found no hearing loss in any fish examined up to twelve hours after the exposures.

In an investigation of another impulsive source, Casper et al. (2013b) found that some fishes may actually be more susceptible to barotrauma (e.g., swim bladder ruptures, herniations, and hematomas) than hearing effects when exposed to simulated impact pile driving. Hybrid striped bass (white bass [*Morone chrysops*] x striped bass [*Morone saxatilis*]) and Mozambique tilapia (*Oreochromis mossambicus*), two species with a swim bladder not involved in hearing, were exposed to sound exposure levels between 213 and 216 dB re 1 µPa^2-s. The subjects exhibited barotrauma and although researchers began to observe signs of inner ear hair cell loss, these effects were small compared to the other non-auditory injuries incurred. Researchers speculated that injury might occur prior to signs of hearing loss or TTS. These sound exposure levels may present the lowest threshold at which hearing effects may begin to occur.

The lowest sound exposure level at which TTS has been observed in fishes with a swim bladder involved in hearing is 186 dB re 1 µPa^2-s. As reviewed in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), fishes without a swim bladder, or fishes with a swim bladder that is not involved in hearing, would be less susceptible to hearing loss (i.e., TTS) than fishes with swim bladders involved in hearing, even at higher levels and longer durations.

Hearing Loss due to Sonar and Other Transducers

Studies have examined the effects of the sound exposures from low-frequency sonar on fish hearing (Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). 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 648 seconds (a cumulative sound exposure level of 218 or 220 dB re 1 μPa^2-s, respectively) at frequencies ranging from 170 to 320 Hz (Kane et al., 2010; Popper et al., 2007) and 195 dB re 1 μPa for 324 seconds (a cumulative sound exposure level of 215 dB re 1 μPa^2-s) in a follow-on study (Halvorsen et al., 2013). Two species with a swim bladder not involved in hearing, the largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*), showed no loss in hearing sensitivity from sound exposure immediately after the test or 24 hours later. Channel catfish, a fish with a swim bladder involved in hearing, and some specimens of rainbow trout, a fish with a swim bladder not involved in hearing, showed a threshold shift (up to 10 to 20 dB of hearing loss) immediately after exposure to the low-frequency sonar when compared to baseline and control animals. Small thresholds shifts were detected for up to 24 hours after the experiment in some channel catfish. Although some rainbow trout showed signs of hearing loss, another group showed no hearing loss. The different results between rainbow trout test groups are difficult to understand, but may be due to development 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 sonar. Examination of the inner ears of the fish during necropsy revealed no differences from the control groups in ciliary bundles or other features indicative of hearing loss. The maximum time fish were held post exposure before sacrifice was 96 hours (Kane et al., 2010).

The same investigators examined the potential effects of mid-frequency active sonar on fish hearing and the inner ear (Halvorsen et al., 2012c; Kane et al., 2010). The maximum received sound pressure level was 210 dB re 1 μPa at a frequency of 2.8 to 3.8 kHz for a total duration of 15 seconds (cumulative sound exposure level of 220 dB re 1 μPa^2-s). Out of the species tested (rainbow trout and channel catfish), only one test group of channel catfish showed any hearing loss after exposure to mid-frequency active sonar. The investigators tested catfish during two different seasons and found that the group tested in October experienced TTS, which recovered within 24 hours, but fish tested in December showed no effect. It was speculated that the difference in hearing loss between catfish groups might have been due to the difference in water temperature during the testing period or due to differences between the two stocks of fish (Halvorsen et al., 2012c). Any effects on hearing in channel catfish due to sound exposure appeared to be short-term and non-permanent (Halvorsen et al., 2012c; Kane et al., 2010).

Some studies have suggested that there may be some loss of sensory hair cells due to high intensity sources, indicating a loss in hearing sensitivity; however, none of those studies concurrently investigated the subjects' actual hearing range after exposure to these sources. Enger (1981) found loss of ciliary bundles of the sensory cells in the inner ears of Atlantic cod following one to five 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 goldfish, a freshwater species with a swim bladder that is involved in hearing. Goldfish were exposed to 250 Hz and 500 Hz continuous tones with maximum peak sound pressure 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 observed one to four days following a one hour exposure to a pure tone at 300 Hz with a sound pressure level of 180 dB re 1 μPa but no damage to the lateral line was observed. Both studies found a relatively small percentage of total hair cell loss from hearing organs despite long duration exposures. Effects from long-duration noise exposure studies are generally informative; however, they are not necessarily a direct comparison to intermittent short-duration sounds generated during Navy activities involving sonar and other transducers.

As noted in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), some fish species with a swim bladder that is involved in hearing may be more susceptible to TTS from high intensity non-impulsive sound sources, such as sonar and other transducers, depending on the duration and frequency content of the exposure. Fishes with a swim bladder involved in hearing and fishes with high-frequency hearing may exhibit TTS from exposure to low- and mid-frequency sonar, specifically at cumulative sound exposure levels above 215 dB re 1 µPa^2-s. Fishes without a swim bladder and fishes with a swim bladder that is not involved in hearing would be unlikely to detect mid- or other higher-frequency sonars and would likely require a much higher sound exposure level to exhibit the same effect from exposure to low-frequency active sonar.

Hearing Loss due to Vessel Noise

Little data exist on the effects of vessel noise on hearing in fishes. However, TTS has been observed in fishes exposed to elevated background noise and continuous sources. Studies on pressure sensitive fishes show some hearing loss after several days or weeks of exposure to increased background sounds, although the hearing loss seems to recover (e.g., Scholik & Yan, 2002; Smith et al., 2004a; Smith et al., 2006). Smith et al. (2004a; 2006) exposed goldfish to noise with a sound pressure level of 170 dB re 1 µPa and found a clear relationship between the amount of hearing loss and the duration of exposure until maximum hearing loss occurred at about 24 hours of exposure. A 10-minute exposure resulted in 5 dB of TTS, whereas a three-week exposure resulted in a 28 dB TTS that took over two weeks to return to pre-exposure baseline levels (Smith et al., 2004a). Recovery times were not measured by investigators for shorter exposure durations. Scholik and Yan (2001) demonstrated TTS in fathead minnows (*Pimephales promelas*) after a 24-hour exposure to white noise (0.3 to 2.0 kHz) at 142 dB re 1 µPa, that took up to 14 days post-exposure to recover. This is the longest recorded time for a threshold shift to recover in a fish.

3.6.3.1.1.3 Masking

Masking refers to the presence of a noise that interferes with a fish's ability to hear biologically important sounds including those produced by prey, predators, or other fishes. Masking occurs in all vertebrate groups and can effectively limit the distance over which an animal can communicate and detect biologically relevant sounds. Human-generated continuous sounds (e.g., some sonar, vessel noise and vibratory pile driving) have the potential to mask sounds that are biologically important to fishes. Researchers have studied masking in fishes using continuous masking noise but masking due to intermittent, short duty cycle sounds has not been studied. Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on masking and the framework used to analyze this potential impact.

Masking is likely to occur in most fishes due to varying levels of ambient or natural noise in the environment such as wave action, precipitation, or other animal vocalizations (Popper et al., 2014). Ambient noise during higher sea states in the ocean has resulted in elevated thresholds in several fish species (Chapman & Hawkins, 1973; Ramcharitar & Popper, 2004). Masking may be most problematic in the frequency region near the signal but is also related to the overall level of the noise source (Buerkle, 1968, 1969; Popper et al., 2014; Tavolga, 1974).

Wysocki and Ladich (2005) investigated the influence of continuous white noise exposure on the auditory sensitivity of two freshwater fish with notable hearing specializations for sound pressure detection, the goldfish and the lined Raphael catfish (*Platydoras costatus*), and a freshwater fish without notable specializations, the pumpkinseed sunfish (*Lepomis gibbosus*). For the goldfish and catfish, baseline thresholds were lower than masked thresholds. Continuous white noise with a sound pressure level of approximately 130 dB re 1 µPa at 1 m resulted in an elevated threshold of 23 to 44 dB within the subjects' region of best sensitivity between 500 and 1000 Hz. There was less evidence of masking in the sunfish during the same exposures with only a shift of 11 dB. Wysocki and Ladich (2005) suggest that ambient sound regimes may limit acoustic communication and orientation, especially in animals with notable hearing specializations for sound pressure detection.

Masking could lead to potential fitness costs depending on the severity of the reaction (Radford et al., 2014; Slabbekoorn et al., 2010). For example, masking could result in changes in predator-prey relationships potentially inhibiting a fish's ability to detect predators and therefore increase its risk of predation (Astrup, 1999; Mann et al., 1998; Simpson et al., 2015; Simpson et al., 2016). Masking may also limit the distance over which fish can communicate or detect important signals (Codarin et al., 2009; Ramcharitar et al., 2001; Ramcharitar et al., 2006) including sounds emitted from a reef for navigating larvae (Higgs, 2005; Neenan et al., 2016). If the masking signal is brief (a few seconds or less), biologically important signals may still be detected resulting in little effect to the individual. If the signal is longer in duration (minutes or hours) or overlaps with important frequencies for a particular species, more severe consequences may occur such as the inability to attract a mate and reproduce. Holt et al. (2014) were the first to demonstrate the Lombard effect in one species of fish, a potentially compensatory behavior where an animal increases its vocalizations in response to elevated noise levels. The Lombard effect is currently understood to be a reflex which may be unnoticeable to the animal or may lead to increased energy expenditure during communication.

The ANSI Sound Exposure Guideline technical report (Popper et al., 2014) highlights a lack of data that exist for masking by sonar but suggests that the narrow bandwidth and intermittent nature of most sonar signals would result in only a limited probability of any masking effects. In addition, most sonars (mid-, high-, and very high-frequency) are above the hearing range of most marine fish species, eliminating the possibility of masking for these species. In most cases, the probability of masking would further decrease with increasing distance from the sound source.

In addition, no data are available on masking by impulsive signals (e.g., impact pile driving and air guns) (Popper et al., 2014). Impulsive sounds are typically brief, lasting only fractions of a second, where masking could occur only during that brief duration of sound. Biological sounds can typically be detected between pulses within close distances to the source unless those biological sounds are similar to the masking noise, such as impulsive or drumming vocalizations made by some fishes (e.g., cod or haddock). Masking could also indirectly occur because of repetitive impulsive signals where the repetitive sounds and reverberations over distance may create a more continuous noise exposure.

Although there is evidence of masking as a result of exposure to vessel noise, the ANSI Sound Exposure Guideline technical report (Popper et al., 2014) does not present numeric thresholds for this effect. Instead, relative risk factors are considered and it is assumed the probability of masking occurring is higher at near to moderate distances from the source (up to hundreds of meters) but decreases with increasing distance (Popper et al., 2014).

3.6.3.1.1.4 Physiological Stress

Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on physiological stress and the framework used to analyze this potential impact. A fish must first be able to detect a sound above its hearing threshold and above the ambient noise level before a physiological stress reaction can occur. The initial response to a 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 and animals, only a limited number of studies have measured biochemical responses by fishes to acoustic stress (e.g., Goetz et al., 2015; Madaro et al., 2015; Remage-Healey et al., 2006; Smith et al., 2004b; Wysocki et al., 2006; Wysocki et al., 2007) and the results have varied. Researchers have studied physiological stress in fishes using predator vocalizations, continuous and impulsive noise exposures.

A stress response that has been observed in fishes includes the production of cortisol (a stress hormone) when exposed to sounds such as boat noise, tones, or predator vocalizations. Nichols et al. (2015) found that giant kelpfish (*Heterostichus rostratus*) had increased levels of cortisol with increased sound level and intermittency of boat noise playbacks. Cod exposed to a short-duration upsweep (a tone that sweeps upward across multiple frequencies) across 100 to 1,000 Hz had increases in cortisol levels, which returned to normal within one hour post-exposure (Sierra-Flores et al., 2015). Remage-Healey et al. (2006) found elevated cortisol levels in Gulf toadfish (*Opsanus beta*) exposed to low-frequency bottlenose dolphin sounds. The researchers observed none of these effects in toadfish exposed to low-frequency snapping shrimp “pops.”

A sudden increase in sound pressure level or an increase in overall background noise levels can increase hormone levels and alter other metabolic rates indicative of a stress response, such as increased ventilation and oxygen consumption (Pickering, 1981; Popper & Hastings, 2009a; Simpson et al., 2015; Simpson et al., 2016; Smith et al., 2004a, 2004b). Although results have varied, it has been shown that chronic or long-term (days or weeks) exposures of continuous man-made sounds can lead to a reduction in embryo viability (Sierra-Flores et al., 2015) and slowed growth rates (Nedelec et al., 2015).

However not all species tested to date show these reactions. Smith et al. (2004b) found no increase in corticosteroid, a class of stress hormones, in goldfish exposed to a continuous, band-limited noise (0.1–10 kHz) with a sound pressure level of 170 dB re 1 µPa for one month. Wysocki et al. (2007) exposed rainbow trout to continuous band-limited noise with a sound pressure level of about 150 dB re 1 µPa for nine months with no observed stress effects. Growth rates and effects on the trout’s immune systems were not significantly different from control animals held at a sound pressure level of 110 dB re 1 µPa.

Fishes may have physiological stress reactions to sounds that they can hear. Generally, stress responses are more likely to occur in the presence of potentially threatening sound sources such as predator vocalizations or the sudden onset of impulsive signals. Stress responses are typically brief (a few seconds to minutes) if the exposure is short or if fishes habituate or learn to tolerate the noise that is being presented. However, exposure to chronic noise sources can lead to more severe impacts such as reduced growth rates, which may lead to reduced survivability for an individual. It is assumed that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

3.6.3.1.1.5 Behavioral Reactions

Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on behavioral reactions and the framework used to analyze this potential impact. Behavioral reactions in fishes have been observed due to a number of different types of sound sources. The majority of research has been performed using air guns (including large-scale seismic surveys), sonar, and vessel noise. Fewer observations have been made on behavioral reactions to impact pile driving noise; although fish are likely to show similar behavioral reactions to any impulsive noise within or outside the zone for hearing loss and injury.

As with masking, a fish must first be able to detect a sound above its hearing threshold and above the ambient noise level before a behavioral reaction can potentially occur. Most fishes can only detect low-frequency sounds with the exception of a few species that can detect some mid and high frequencies (above 1 kHz). 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. Studies of fishes have identified the following basic behavioral reactions to sound: alteration of natural behaviors (e.g., startle or alarm), and avoidance (McCauley et al., 2000; Pearson et al., 1992; Scripps Institution of Oceanography & National Science Foundation, 2008). In the context of this EIS/OEIS, and to remain consistent with available behavioral reaction literature, the terms startle and alarm response or reactions will be used synonymously. Changes in sound intensity may be more important to a fishes' behavior than the maximum sound level. Sounds that fluctuate in level or have intermittent pulse rates tend to elicit stronger responses from fish than even stronger sounds with a continuous level (Neo et al., 2014; Schwarz & Greer, 1984). Interpreting behavioral responses can be difficult due to species-specific behavioral tendencies, motivational state (e.g., feeding or mating), an individual's previous experience, and whether or not the fish are able to avoid the source (e.g., caged versus free-swimming subjects). Results from caged studies may not provide a clear understanding of how free-swimming fishes may react to the same or similar sound exposures (Hawkins et al., 2015).

Behavioral Reactions due to Impulsive Sound Sources

It is assumed that most species would react similarly to impulsive sources (i.e., air guns and impact pile driving). These reactions include startle or alarm responses at the onset of impulsive sounds (Fewtrell & McCauley, 2012; Pearson et al., 1992). Data on behavioral reactions in fishes exposed to impulsive sound sources is mostly limited to studies using caged fishes and the use of seismic air guns (Løkkeborg et al., 2012). Several species of rockfish (*Sebastes* species) in a caged environment exhibited startle or alarm reactions to seismic air gun pulses between peak-to-peak sound pressure levels of 180 dB re 1 µPa and 205 dB re 1 µPa (Pearson et al., 1992). More subtle behavioral changes were noted at lower sound pressure levels, including decreased swim speeds. At the presentation of the sound, some species of rockfish settled to the bottom of the experimental enclosure and reduced swim speed. Trevally (*Pseudocaranx dentex*) and pink snapper (*Pagrus auratus*) also exhibited alert responses as well as changes in swim depth, speed and schooling behaviors when exposed to air gun noise (Fewtrell & McCauley, 2012). Both trevally and pink snapper swam faster and closer to the bottom of the cage at the onset of the exposure. However, trevally swam in tightly cohesive groups at the bottom of the test cages while pink snapper exhibited much looser group cohesion. These behavioral responses were seen during sound exposure level s as low as 147 up to 161 dB re 1 μPa^2-s but habituation occurred in all cases, either within a few minutes or up to 30 minutes after the final air gun shot (Fewtrell & McCauley, 2012; Pearson et al., 1992).

Some studies have shown a lack of behavioral reactions to air gun noise. Herring exposed to an approaching air gun survey (from 27 to 2 km over 6 hours), resulting in single pulse sound exposure levels of 125 to 155 dB re 1 μPa^2-s, did not react by changing direction or swim speed (Pena et al., 2013). Although these levels are similar to those tested in other studies which exhibited responses (Fewtrell & McCauley, 2012), the distance of the exposure to the test enclosure, the slow onset of the sound source, and a strong motivation for feeding may have affected the observed response (Pena et al., 2013). In another study, Wardle et al. (2001) observed marine fish on an inshore reef before, during, and after an air gun survey at varying distances. The air guns were calibrated at a peak level of 210 dB re 1 µPa at 16 m and 195 dB re 1 µPa at 109 m from the source. Other than observed startle responses and small changes in position of pollack, when the air gun was located within close proximity to the test site (within 10 m), they found no substantial or permanent changes in the behavior of the fish on the reef throughout the course of the study. Behavioral responses to impulsive sources are more likely to occur within near and intermediate (tens to hundreds of meters) distances from the source as opposed to far distances (thousands of meters) (Popper et al., 2014).

Unlike the previous studies, Slotte et al. (2004) used fishing sonar (38 kHz echo sounder) to monitor behavior and depth of blue whiting (*Micromesistius poutassou*) and Norwegian spring herring (*Claupea harengus L.*) spawning schools exposed to air gun signals. They reported that fishes in the area of the air guns appeared to go to greater depths after the air gun exposure compared to their vertical position prior to the air gun usage. Moreover, the abundance of animals 30–50 km away from the air guns increased during seismic activity, suggesting that migrating fish left the zone of seismic activity and did not re-enter the area until the activity ceased. It is unlikely that either species was able to detect the fishing sonar, however, it should be noted that these behavior patterns may have also been influenced by other factors such as motivation for feeding, migration, or other environmental factors (e.g., temperature, salinity, etc.) (Slotte et al., 2004).

Alterations in natural behavior patterns due to exposure to pile driving noise have not been studied as thoroughly, but reactions noted thus far are similar to those seen in response to seismic surveys. These changes in behavior include startle responses, changes in depth (in both caged and free-swimming subjects), increased swim speeds, changes in ventilation rates, and avoidance (e.g., Hawkins et al., 2014; Mueller-Blenkle et al., 2010; Neo et al., 2015). The severity of response varied greatly by species and received sound pressure level of the exposure. For example, some minor behavioral reactions such as startle responses were observed during caged studies with a sound pressure level as low as 140 dB re 1 µPa (Neo et al., 2014). However, only some free-swimming fishes avoided pile driving noise at even higher sound pressure levels between 152 and 157 dB re 1 µPa (Iafrate et al., 2016). The repetition rate of pulses during an exposure may also have an effect on what behaviors were noted and how quickly these behaviors recovered as opposed to the overall sound pressure or exposure level. For example, Neo et al. (2014) observed slower recovery times in fishes exposed to intermittent sounds (similar to pile driving) compared to continuous exposures.

As summarized in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), species may react differently to the same sound source depending on a number of variables, such as the animal's life stage or behavioral state (e.g., feeding, mating). Without specific data, it is assumed that fishes react similarly to all impulsive sounds outside the zone for hearing loss and injury. Observations of fish reactions to large-scale air gun surveys are informative, but not necessarily directly applicable to analyzing impacts from the short-term, intermittent use of all impulsive sources. It is assumed that fish have a high probability of reacting to an impulsive sound source within near and intermediate distances (tens to hundreds of meters), and a decreasing probability of reaction at increasing distances (Popper et al., 2014).

Behavioral Reactions due to Sonar and Other Transducers

Behavioral reactions to sonar have been studied both in caged and free-living fish although results can often times be difficult to interpret depending on the species tested and the study environment. Jørgensen et al. (2005) showed that caged cod and spotted wolf fish lacked any response to simulated sonar between 1 and 8 kHz. However, within the same study, reactions were seen in juvenile herring. It is likely that the sonar signals were inaudible to the cod and wolf fish (species that lack notable hearing specializations), but audible to herring which do possess hearing capabilities in the frequency ranges tested.

Doksæter et al. (2009; 2012) and Sivle et al. (2012; 2014) studied the reactions of both wild and captive Atlantic herring to the Royal Netherlands Navy's experimental mid-frequency active sonar ranging from 1 to 7 kHz. The behavior of the fish was monitored in each study either using upward looking echosounders (for wild herring) or audio and video monitoring systems (for captive herring). The source levels used within each study varied across all studies and exposures with a maximum received sound pressure level of 181 dB re 1 µPa and maximum cumulative sound exposure level of 184 dB re 1 $µPa^2$·s. No avoidance or escape reactions were observed when herring were exposed to any sonar sources. Instead, significant reactions were noted at lower received sound levels of different non-sonar sound types. For example, dive responses (i.e., escape reactions) were observed when herring were exposed to killer whale feeding sounds at received sound pressure levels of approximately 150 dB re 1 µPa (Sivle et al., 2012). Startle responses were seen when the cages for captive herring were hit with a wooden stick and with the ignition of an outboard boat engine at a distance of 1 meter from the test pen (Doksaeter et al., 2012). It is possible that the herring were not disturbed by the sonar, were more motivated to continue other behaviors such as feeding, or did not associate the sound as a threatening stimulus. Based on these results (Doksaeter et al., 2009; Doksaeter et al., 2012; Sivle et al., 2012), Sivle et al. (2014) created a model in order to report on the possible population-level effects on Atlantic herring from active naval sonar. The authors concluded that the use of naval sonar poses little risk to populations of herring regardless of season, even when the herring populations are aggregated and directly exposed to sonar.

There is evidence that elasmobranchs also respond to human-generated sounds. Myrberg and colleagues did experiments in which they played back sounds (e.g., pulsed tones below 1 kHz) and attracted a number of different shark species to the sound source (e.g., Casper et al., 2012a; Myrberg et al., 1976; Myrberg et al., 1969; Myrberg et al., 1972; Nelson & Johnson, 1972). The results of these studies showed that sharks were attracted to irregularly pulsed 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 to continuous signals or higher frequencies that they presumably cannot hear (Casper & Mann, 2006, 2009).

Only a few species of marine fishes can detect sonars above 1 kHz (see Section 3.6.2.1.3, Hearing and Vocalization) meaning that most fishes would not detect most mid-, high-, or very high-frequency Navy sonars. The few marine species that can detect above 1 kHz and have some hearing specializations may be able to better detect the sound and would therefore be more likely to react. However, researchers have found little reaction by adult fish in the wild to sonars within the animals' hearing range (Doksaeter et al., 2009; Doksaeter et al., 2012; Sivle et al., 2012). The ANSI Sound Exposure Guideline technical report (Popper et al., 2014) suggests that fish able to hear sonars would have a low probability of reacting to the source within near or intermediate distances (within tens to hundreds of meters) and a decreasing probability of reacting at increasing distances.

Behavioral Reactions due to Vessel Noise

Vessel traffic also contributes to the amount of noise in the ocean and has the potential to affect fishes. Several studies have demonstrated and reviewed avoidance responses by fishes (e.g., herring and cod) to the low-frequency sounds of vessels (De Robertis & Handegard, 2013; Engås et al., 1995; Handegard et al., 2003). Misund (1997) found fish ahead of a ship that showed avoidance reactions did so at ranges of 50 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.

As mentioned in Section 3.6.3.1.1.5 (Behavioral Reactions), behavioral reactions are quite variable depending on a number of factors such as the type of fish, its life history stage, behavior, time of day, and the sound propagation characteristics of the water column (Popper et al., 2014; Schwarz & Greer, 1984). Reactions to playbacks of continuous noise or passing vessels noted, in addition to the basic startle and avoidance responses, increased group cohesion, changes in vertical distribution in the water column, changes in swim speeds, and changes in feeding efficacy such as reduced foraging attempts and increased mistakes (i.e., lowered discrimination between food and non-food items) (e.g., Bracciali et al., 2012; De Robertis & Handegard, 2013; Handegard et al., 2015; Nedelec et al., 2015; Neo et al., 2015; Payne et al., 2015; Purser & Radford, 2011; Sabet et al., 2016; Simpson et al., 2015; Simpson et al., 2016; Voellmy et al., 2014a; Voellmy et al., 2014b). Changes in anti-predator response have also been observed but vary by species. During exposures to vessel noise, juvenile Ambon damselfish (*Pomacentrus amboinensis*) and European eels showed slower reaction times and lacked startle responses to predatory attacks which subsequently increased their risk of predation during both simulated and actual predation experiments (Simpson et al., 2015; Simpson et al., 2016). In contrast, larval Atlantic cod showed a stronger anti-predator response and were more difficult to capture during simulated predator attacks (Nedelec et al., 2015). Although behavioral responses such as these were often noted during the onset of most sound presentations, these behaviors did not last long and animals quickly returned to baseline behavior patterns. In fact, in one study, when given the chance to move from a noisy tank (with sound pressure levels reaching 120–140 dB re 1 µPa) to a quieter tank (sound pressure levels of 110 dB re 1 µPa), there was no evidence of avoidance. The fish did not seem to prefer the quieter environment and continued to swim between the two tanks comparable to control sessions (Neo et al., 2015). However, many of these reactions are difficult to extrapolate to real world conditions due to the captive environment in which testing occurred.

Most fish species should be able to detect vessel noise due to its low-frequency content and their hearing capabilities (see Section 3.6.2.1.3, Hearing and Vocalization). The ANSI Sound Exposure Guideline technical report (Popper et al., 2014) suggests that fishes have a high to moderate probability of reacting to nearby vessel noise (i.e., within tens of meters) with decreasing probability of reactions with increasing distance from the source (hundreds or more meters).

3.6.3.1.1.6 Long-Term Consequences

Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) provides additional information on potential pathways for long-term consequences. Mortality removes an individual fish from the population and injury reduces the fitness of an individual. Few studies have been conducted on any long-term consequences from repeated hearing loss, stress, or behavioral reactions in fishes due to exposure to loud sounds (Hawkins et al., 2014; Popper & Hastings, 2009a; Popper et al., 2014). Repeated exposures of an individual to multiple sound-producing activities over a season, year, or life stage could cause reactions with costs that can accumulate over time to cause long-term consequences for the individual. These long-term consequences may affect the survivability of the individual or if impacting enough individuals, may have population-level effects including: alteration from migration paths, avoidance of important habitat, or even cessation of foraging or reproductive behavior (Hawkins et al., 2014). Conversely, some animals habituate to or become tolerant of repeated exposures over time, learning to ignore a stimulus that in the past has not accompanied any overt threat. In fact, Sivle et al. (2016) predicted that exposures to sonar at the maximum levels tested would only result in short-term disturbance and would not likely affect the overall population in sensitive fishes such as herring. More research is needed to understand better the long-term consequences of human-made noise on fishes.

3.6.3.1.2 Impacts from Sonar and Other Transducers

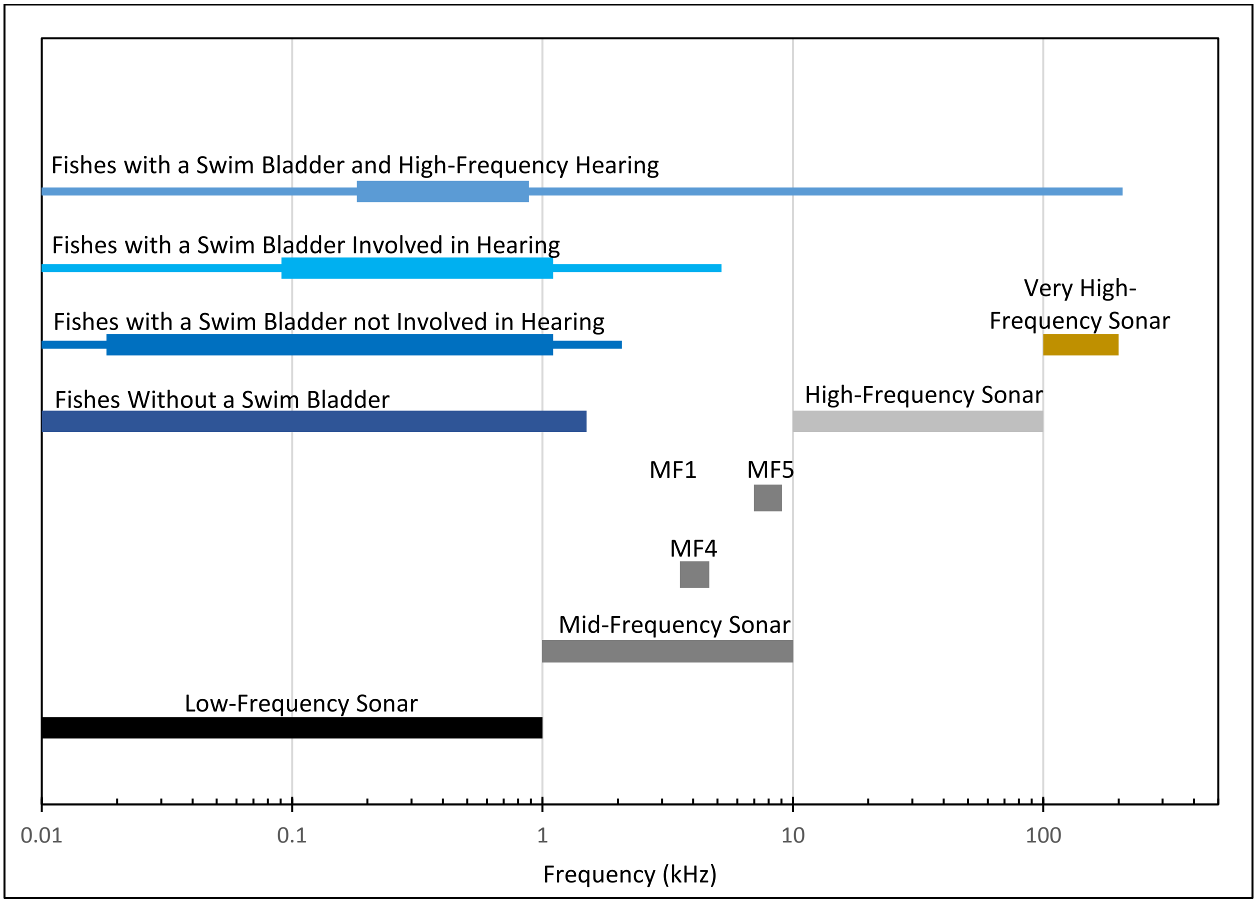
Sonar and other transducers proposed for use are transient in most locations because activities that involve sonar and other transducers take place at different locations throughout the Study Area. A few activities involving sonar and other transducers occur in inshore waters (within bays and estuaries), including at pierside locations where they reoccur. Sonar and other transducers emit sound waves into the water to detect objects, safely navigate, and communicate. General categories and characteristics of these systems and the number of hours these sonars will be operated are described in Section 3.0.3.3 (Identifying Stressors for Analysis). The activities analyzed in the EIS/OEIS that use sonar and other transducers are described in Appendix A (Navy Activity Descriptions).

As described under Section 3.6.3.1.1.1 (Injury due to Sonar and Other Transducers), direct injury from sonar and other transducers is highly unlikely because injury has not been documented in fish exposed to sonar (Halvorsen et al., 2012c; Halvorsen et al., 2013; Popper et al., 2007) and therefore is not considered further in this analysis.

Fishes are not equally sensitive to noise at all frequencies. Fishes must first be able to hear a sound in order to be affected by it. As discussed in Section 3.6.2.1.3 (Hearing and Vocalization), many marine fish species tested to date hear primarily below 1 kHz. For the purposes of this analysis, fish species were grouped into one of four fish hearing groups based on either their known hearing ranges (i.e., audiograms) or physiological features that may be linked to overall hearing capabilities (i.e., swim bladder with connection to, or in close proximity to, the inner ear). Figure 3.6-6 provides a summary of hearing threshold data from available literature (e.g., Casper & Mann, 2006; Deng et al., 2013; Kéver et al., 2014; Mann et al., 2001; Ramcharitar et al., 2006) to demonstrate the potential overall range of frequency detection for each hearing group. Due to data limitations, these estimated hearing ranges may be overly conservative in that they may extend beyond what some species within a given fish hearing group may actually detect. The upper bounds of each fish hearing groups frequency range is outside of the range of best sensitivity for all fishes within that group. As a result, fishes within each group would only be able to detect those upper frequencies from sources with relatively high source levels. Figure 3.6-6 is not intended as a composite audiogram, but rather displays the basic overlap in potential frequency content for each hearing group with Navy defined sonar classes (i.e., low-, mid-, high- and very high-frequency) as discussed under Section 3.0.3.3.1.1 (Sonar and Other Transducers – Classification of Sonar and Other Transducers).

Systems within the low-frequency sonar class presents the greatest potential for overlap with fish hearing. Some mid-frequency sonars and other transducers may also overlap some species' hearing ranges, but to a lesser extent than low-frequency sonars. For example, the only hearing groups that would be able to detect mid-frequency sources within bins MF3, MF4 and MF5 are fishes with a swim bladder involved in hearing and with high-frequency hearing. It is anticipated that most marine fishes would not hear or be affected by mid-frequency Navy sonars or other transducers with operating frequencies greater than about 1–4 kHz. Only a few fish species (i.e., fish with a swim bladder and high-frequency hearing specializations) can detect and therefore be potentially affected by high- and very high-frequency sonars and other transducers.

The most probable impacts from exposure to sonar and other transducers are TTS (for more detail see Section 3.6.3.1.1.2, Hearing Loss), masking (for more detail see Section 3.6.3.1.1.3, Masking), physiological stress (for more detail see Section 3.6.3.1.1.4, Physiological Stress), and behavioral reactions (for more detail see Section 3.6.3.1.1.5, Behavioral Reactions). Analysis of these effects is provided below.



Notes: kHz = kilohertz, MF1 = 3.5 kHz, MF4 = 4 kHz, MF5 = 8 kHz.

Thin blue lines represent the estimated minimum and maximum range of frequency detection for each group. All hearing groups are assumed to hear down to 0.01 kHz regardless of available data. Thicker portions of each blue line represent the estimated range of best sensitivity for that group. Currently, no data are available to estimate the range of best sensitivity for fishes without a swim bladder. Although each sonar class is represented graphically by the horizontal black, grey and brown bars, not all sources within each class would operate at all the displayed frequencies. Example mid-frequency sources are provided to further demonstrate this.

Figure 3.6-6: Fish Hearing Group and Navy Sonar Frequency Ranges

3.6.3.1.2.1 Methods for Analyzing Impacts from Sonar and Other Transducers

The Navy performed a quantitative analysis to estimate the range to TTS for fishes exposed to sonar and other transducers used during Navy training and testing activities. Inputs to the quantitative analysis included sound propagation modeling in the Navy's Acoustic Effects Model to the sound exposure criteria and thresholds presented below. Although ranges to effect are predicted, density data for fish species within the Study Area are not available; therefore, it is not possible to estimate the total number of individuals that may be affected by sound produced by sonar and other transducers.

Criteria and thresholds to estimate impacts from sonar and other transducers are presented below in Table 3.6-3. Thresholds for hearing loss are typically reported in cumulative sound exposure level so as to account for the duration of the exposure. Therefore, thresholds reported in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014) that were presented in other metrics were converted to sound exposure level based on the signal duration reported in the original studies (see Halvorsen et al., 2012c; Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). General research findings from these studies can be reviewed in Section 3.6.3.1.1.2 (Hearing Loss).

Table 3.6-3: Sound Exposure Criteria for TTS from Sonar

Fish Hearing Group	*TTS from Low-Frequency Sonar (SEL_{cum})*	*TTS from Mid-Frequency Sonar (SEL_{cum})*
Fishes without a swim bladder	NC	NC
Fishes with a swim bladder not involved in hearing	> 210	NC
Fishes with a swim bladder involved in hearing	210	220
Fishes with a swim bladder and high-frequency hearing	210	220

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), NC = effects from exposure to sonar is considered to be unlikely, therefore no criteria are reported, > indicates that the given effect would occur above the reported threshold.

For mid-frequency sonars, fishes with a swim bladder involved in hearing have shown signs of hearing loss because of mid-frequency sonar exposure at a maximum received sound pressure level of 210 dB re 1 μPa for a total duration of 15 seconds. To account for the total duration of the exposure, the threshold for TTS is a cumulative sound exposure level of 220 dB re 1 μPa^2-s (Halvorsen et al., 2012c; Kane et al., 2010). The same threshold is used for fishes with a swim bladder and high frequency hearing as a conservative measure although fishes in this hearing group have not been tested for the same impact. TTS has not been observed in fishes with a swim bladder that is not involved in hearing exposed to mid-frequency sonar. Fishes within this hearing group do not sense pressure well and typically cannot hear at frequencies above 1 kHz (Halvorsen et al., 2012c; Popper et al., 2014). Therefore, no criteria were proposed for fishes with a swim bladder that is not involved in hearing from exposure to mid-frequency sonars as it is considered unlikely for TTS to occur. Fishes without a swim bladder are even less susceptible to noise exposure; therefore TTS is unlikely to occur and no criteria are proposed for this group either.

For low-frequency sonar, as described in Section 3.6.3.1.1.2 (Hearing Loss), exposure of fishes with a swim bladder has resulted in TTS (Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). Specifically, fishes with a swim bladder not involved in hearing showed signs of hearing loss after exposure to a maximum received sound pressure level of 193 dB re 1 μPa for 324 and 648 seconds (cumulative sound exposure level of 218 and 220 dB re 1 μPa^2-s, respectively) (Kane et al., 2010; Popper et al., 2007). In addition, exposure of fishes with a swim bladder involved in hearing to low-frequency sonar at a sound pressure level of 195 dB re 1 μPa for 324 seconds (cumulative sound exposure level of 215 dB re 1 μPa^2-s) resulted in TTS (Halvorsen et al., 2013). Although the results were variable, it can be assumed that TTS may occur in fishes within the same hearing groups at similar exposure levels. As a conservative measure, the threshold for TTS from exposure to low-frequency sonar for all fish hearing groups with a swim bladder was rounded down to a cumulative sound exposure level of 210 dB re 1 μPa^2-s.

Criteria for high- and very high-frequency sonar were not available in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014); however, only species with a swim bladder involved in hearing and with high-frequency specializations such as shad could potentially be affected. The majority of fish species within the Study Area are unlikely to be able to detect these sounds. There is little data available on hearing loss from exposure of fishes to these high-frequency sonars. Due to the lack of available data, and as a conservative measure, effects to these hearing groups from high-frequency sonars would utilize the lowest threshold available for other hearing groups (a cumulative sound exposure level of 210 dB re 1 μPa^2-s) but effects would largely be analyzed qualitatively.

3.6.3.1.2.2 Impact Ranges from Sonar and Other Transducers

The following section provides ranges to specific effects from sonar and other transducers. Ranges are calculated using criteria from Table 3.6-4 and the Navy Acoustic Effects Model. Only ranges to TTS were predicted based on available data. Sonar durations of 1, 30, 60 and 120 seconds were used to calculate the ranges below. However, despite the variation in exposure duration, ranges were almost identical across these durations and therefore were combined and summarized by bin in the table below. General source levels, durations and other characteristics of these systems are described in Section 3.0.3.3.1 (Acoustic Stressors).

Table 3.6-4: Ranges to Temporary Threshold Shift from Four Representative Sonar Bins

Fish Hearing Group	*Range to Effects (meters)*			
	Sonar Bin LF5 Low-frequency	*Sonar Bin MF1 Hull-mounted surface ship sonars (e.g., AN/SQS-53C and AN/SQS-61)*	*Sonar Bin MF4 Helicopter-deployed dipping sonars (e.g., AN/AQS-22)*	*Sonar Bin MF5 Active acoustic sonobuoys (e.g., DICASS)*
Fishes without a swim bladder	NR	NR	NR	NR
Fishes with a swim bladder not involved in hearing	0	NR	NR	NR
Fishes with a swim bladder involved in hearing	0	7 (5 - 10)	0	0
Fishes with a swim bladder and high-frequency hearing	0	7 (5 - 10)	0	0

Notes: NR = no criteria are available and therefore no range to effects are estimated.

Ranges to TTS represent modeled predictions in different areas and seasons within the Study Area. The average range to TTS is provided as well as the minimum to the maximum range to TTS in parenthesis. Where only one number is provided the average, minimum, and maximum ranges to TTS are the same.

Ranges to TTS for mid-frequency sonar bins are only estimated for fishes with a swim bladder involved in hearing and fishes with high-frequency hearing. The maximum range to TTS is up to 10 m for these most sensitive hearing groups, but only for the most powerful sonar bins (e.g., MF1).

3.6.3.1.2.3 Impacts from Sonar and Other Transducers Under Alternative 1

Impacts from Sonar and Other Transducers Under Alternative 1 for Training Activities

Sonar and other transducers emit sound waves into the water to detect objects, safely navigate, and communicate. Use of sonar and other transducers would typically be transient and temporary. General categories and characteristics of sonar systems and the number of hours these sonars would be operated during training under Alternative 1 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 1, the number of Major Training Exercises, Integrated/Coordinated Training activities, and Civilian Port Defense Activities would fluctuate annually. In addition, a portion of Anti-Submarine Warfare Tracking Exercise –Ship unit-level training activities would be conducted using synthetic means (e.g., simulators) or in conjunction with other training exercises. Training activities using sonar and other transducers could occur throughout the Study Area.

Only a few species of shad within the Clupeidae family, subfamily Alosinae, are known to be able to detect high-frequency sonar and other transducers (greater than 10 kHz) and are considered a part of the fish hearing group for species with a swim bladder that have high-frequency hearing. Other marine fishes would probably not detect these sounds and therefore would not experience masking, physiological stress, or behavioral disturbance. 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 masking during these events. 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 due to lower source levels and higher frequencies that do not propagate as far as other sonars. Behavioral reactions and masking, if they occurred for some shad and herring species, are expected to be transient and long-term consequences for populations would not be expected.

Most marine fish species are not expected to detect sounds in the mid-frequency range (above a few kHz) of most operational sonars. The fish species that are known to detect mid-frequencies (i.e., those with swim bladders including some sciaenids [drum], most clupeids [herring, shad], and potentially deep-water fish such as myctophids [lanternfish]) do not have their best sensitivities in the range of the operational sonars (see Figure 3.6-6). Thus, fishes 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. Fishes with a swim bladder involved in hearing and with high-frequency hearing are more susceptible to hearing loss due to exposure to mid-frequency sonars. However, as shown in Table 3.6-4, the maximum estimated range to TTS for these fish hearing groups is equal to or less than 10 m for only the most powerful sonar bins. Fishes within these hearing groups would have to be very close to the source in order to experience this effect.

Most mid-frequency active sonars used in the Study Area would not have the potential to substantially mask key environmental sounds or produce sustained physiological stress or behavioral reactions due to the limited time of exposure due to the moving sound sources and variable duty cycles. However, it is important to note that some mid-frequency sonars have a high duty cycle or are operated continuously. This may increase the risk of masking but only for important biological sounds that overlap with the frequency of the sonar being operated. Furthermore, although some species may be able to produce sound at higher frequencies (greater than 1 kHz), vocal marine fishes, such as sciaenids, largely communicate below the range of mid-frequency levels used by most sonars. Any such effects would be temporary and infrequent as a vessel operating mid-frequency sonar transits an area. As such, mid-frequency sonar use is unlikely to impact individuals. Long-term consequences for fish populations due to exposure to mid-frequency sonar and other transducers are not expected.

The majority of marine fish species can likely detect low-frequency sonars and other transducers. However, low-frequency active sonar use is rare and most low-frequency active operations are typically conducted in deeper, offshore areas. The majority of fish species, including those that are the most highly vocal, exist on the continental shelf and within nearshore, estuarine areas. However, some species may still be present in areas where low-frequency sonar and other transducers are used, including some coastal areas. As shown in Table 3.6-4, it is not likely that fishes exposed to low-frequency sonars, with relatively low source levels, would result in TTS. Sonars with higher source levels may lead to TTS in some fishes but these ranges would not likely exceed a few tens of meters, similar to other ranges shown in Table 3.6-4. Fishes that experience hearing loss may have reduced ability to detect biologically important sounds until their hearing recovers. Recovery from hearing loss begins almost immediately after the noise exposure ceases and can take a few minutes to a few days to fully recover, depending on the magnitude of the initial threshold shift.

Fishes 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, due to the transient nature of most sonar operations, overall effects would be localized and infrequent, only lasting a few seconds or minutes. Based on the low level and short duration of potential exposure to low-frequency sonar and other transducers, long-term consequences for fish populations are not expected.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization) and as shown in Figure 3.6-6, all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting sound produced by low-frequency sonars and other transducers. Scalloped hammerhead sharks, smalltooth sawfish, giant manta ray, and oceanic whitetip sharks do not have a swim bladder and generally are not sensitive to frequencies above 1 kHz. It is assumed that fishes without a swim bladder cannot detect high-frequency sonars and may only detect mid-frequency sources below 2 kHz, with high source levels, and within close proximity to the source (a few tens of meters). Although Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon and Nassau groupers have a swim bladder not involved in hearing and may be able to detect some mid-frequency sources up to 2 kHz, they are not particularly sensitive to these frequencies. Therefore, effects from sound produced by mid- and high-frequency sonars and other transducers are not expected for any ESA-listed species.

All ESA-listed and proposed threatened species that occur in the Study Area may be exposed to low-frequency sonar or other transducers associated with training activities. Because most low-frequency sonar is typically operated in deeper offshore areas, ESA-listed shortnose sturgeon would be less likely to be exposed to low-frequency sonar due to their occurrence in nearshore areas. Atlantic sturgeon, Gulf sturgeon, and smalltooth sawfish typically occur in nearshore areas as well but can also occur farther offshore. Despite their occurrence in nearshore areas, each of these species may still be present in areas where low-frequency sonar and other transducers are used. The Central and Southwest Atlantic Distinct Population Segment of scalloped hammerhead only occur in the southeastern part of the Study Area in the eastern portion of the Key West Range Complex and in the vicinity of Puerto Rico. Nassau groupers are also limited to these southern portions of the Study Area, specifically around Florida, Key West and Puerto Rico. These species would only have the potential to be impacted by activities in these areas. Proposed threatened giant manta ray and oceanic whitetip sharks could be exposed to low-frequency sonar throughout the Study Area.

Overall, impacts to ESA-listed species that encounter sonar or other transducers within their hearing range would be similar to those discussed above for impacts to fishes in general. Based on the small ranges provided in Table 3.6-4, TTS in ESA-listed species would only occur within a maximum of 10 m from any sonar source. TTS may result in a reduction in detection of biologically significant sounds but would likely recover within a few minutes to days. Most ESA species within the Study Area could experience masking, physiological stress, and behavioral reactions; however, these impacts would be short-term (seconds to minutes) for individuals and minor for the population. Multiple exposures for individuals within a short period (seconds to minutes) are unlikely due to the transient nature of sonar activities. Although some shark species have shown attraction to irregularly pulsed low-frequency sounds (below several hundred Hz), they are not known to be attracted to continuous signals or higher frequencies that they presumably cannot hear (Casper & Mann, 2006, 2009; Casper et al., 2012a).

Proposed training activities involving the use of sonar overlap proposed critical habitat for Atlantic sturgeon in the James River at Naval Station Norfolk in Norfolk, VA. However, low-frequency sonars are not operated in these areas under training activities and although some mid-frequency sonars are used in these areas, most sources contain frequencies outside of the theorized hearing range for Atlantic sturgeon (above 2 kHz). While highly unlikely, the use of sonar and other transducers within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Proposed training activities involving the use of sonar overlap designated critical habitat for Gulf sturgeon in the Panama City OPAREA. A map of critical habitat is available in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. However, part of the physical and biological features for Gulf sturgeon critical habitat includes migratory corridors from winter feeding grounds to spring and summer spawning rivers. While highly unlikely, the use of sonar and other transducers within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. The use of sonar during training activities is not anticipated to overlap with designated critical habitat for Atlantic salmon or smalltooth sawfish.

Pursuant to the ESA, the use of sonar and other transducers during training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish. The use of sonar and other transducers during training activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, critical habitat designated for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Sonar and Other Transducers Under Alternative 1 for Testing Activities

General categories and characteristics of sonar systems and the number of hours these sonars would be operated during testing under Alternative 1 are described in Section 3.0.3.3.1 (Acoustic Stressors).

Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 1, the number of testing activities would fluctuate annually. Testing activities using sonar and other transducers could occur throughout the Study Area, although use would generally occur within Navy range complexes, on Navy testing ranges, or around inshore locations identified in Chapter 2 (Description of Proposed Action and Alternatives).

Hearing loss in fishes from exposure to sonar and other transducers is unlikely. If hearing loss is to occur, it would occur within tens of meters of the source. The majority of fish species exposed to sonar and other transducers may experience mild physiological stress, brief masking or behavioral reactions, such as startle or avoidance responses, or no reaction. Long-term consequences for individual fish are unlikely in most cases because acoustic exposures are intermittent, transient and unlikely to repeat over short periods. Since long-term consequences for most individuals are unlikely, long-term consequences for populations are not expected.

All ESA-listed and proposed threatened fish species that occur in the Study Area have the potential to be exposed to high- and mid-frequency sonar or other transducer use during testing activities, as activities involving these sources may occur in all range complexes, testing ranges, and at numerous inshore locations. As discussed above, all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting sound produced by low-frequency sonars and other transducers but may only detect mid-frequency sources below 2 kHz, with high source levels, and within close proximity to the source (a few tens of meters). Therefore, effects from sound produced by mid- and high-frequency sonars and other transducers are not expected for any ESA-listed species.

Most ESA-listed and proposed threatened fish species that occur in the Study Area may be exposed to low-frequency sonar or other transducers associated with testing activities. In particular, low-frequency sources occur in some coastal waters such as Newport, RI; the Naval Undersea Warfare Center Division, Newport Testing Range; offshore of Fort Pierce, FL; South Florida Ocean Measurement Facility; Naval Surface Warfare Center, Panama City Division Testing Range; as well as in any of the range complexes, with the exception of the Key West Range Complex, throughout the Study Area. The use of sonar in these coastal areas may increase the likelihood of exposure for Atlantic salmon, Atlantic sturgeon, shortnose surgeon, smalltooth sawfish and Gulf sturgeon. The Central and Southwest Atlantic Distinct Population Segment of scalloped hammerhead only occur in the southeastern part of the Study Area in the eastern portion of the Key West Range Complex and in the vicinity of Puerto Rico and would, therefore, not be exposed to low-frequency sonar use during testing activities. Nassau groupers are also limited to these southern portions of the Study Area, specifically around Florida, Key West and Puerto Rico and, as such, the species would only likely be exposed to low-frequency sonar during its use at the South Florida Ocean Measurement Facility and offshore of Fort Pierce, FL. Proposed threatened giant manta ray and oceanic whitetip sharks could be exposed to low-frequency sonar throughout the Study Area.

General impacts on ESA-listed species would be similar to those discussed for other fishes that occur in the Study Area. TTS in ESA-listed species would only occur within a maximum of 10 m from any sonar source and may result in a reduction in detection of biologically significant sounds but would likely recover within a few minutes to days. Most ESA species within the Study Area could experience masking, physiological stress, and behavioral reactions; however, these impacts would be short-term (seconds to minutes) for individuals and minor for the population. Multiple exposures for individuals within a short period (seconds to minutes) throughout most of the range complexes are unlikely due to the transient nature of sonar activities. Testing activities in coastal waters may increase the likelihood of repeated exposures. However, repeated exposures would likely involve short-term (seconds to minutes) and minor behavioral impacts, which, repeated a few times per year, would still likely be short-term (seconds to minutes) for individuals and minor for the population.

Proposed testing activities involving the use of sonar overlap proposed critical habitat for Atlantic sturgeon in the Kennebec River at Bath Iron Works in Bath, ME; in the Piscataqua River at Portsmouth Naval Shipyard in Portsmouth, NH; and in the James River at Naval Station Norfolk in Norfolk, VA. However, low-frequency sonars are not operated in these areas under testing activities and although some mid-frequency sonars are used in these areas, most sources contain frequencies outside of the theorized hearing range for Atlantic sturgeon (above 2 kHz). While highly unlikely, the use of sonar and other transducers within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Proposed testing activities involving the use of sonar overlap designated critical habitat for Gulf sturgeon in the Naval Surface Warfare Center Panama City Division Testing Range and the Panama City OPAREA. A map of critical habitat is available in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. However, part of the physical and biological features for Gulf sturgeon critical habitat includes migratory corridors from winter feeding grounds to spring and summer spawning rivers. While highly unlikely, the use of sonar and other transducers within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Proposed testing activities involving the use of sonar overlap proposed critical habitat for Atlantic salmon in the Kennebec River near Bath Iron Works in Bath, ME. While the waters immediately surrounding Bath Iron Works are excluded from the critical habitat designation, sound produced by the sonars or other transducers may travel beyond the boundaries of the exclusion area. However, low-frequency sonars are not operated in this area under testing activities and although some mid-frequency sonars are used in this area, most sources contain frequencies outside of the theorized hearing range for Atlantic salmon (above 2 kHz). While highly unlikely, the use of sonar and other transducers near the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida (see Figure 3.6-4). The use of sonar during testing activities is not anticipated to overlap designated critical habitat for smalltooth sawfish.

Pursuant to the ESA, the use of sonar and other transducers during testing activities, as described under Alternative 1, will have no effect on ESA-listed Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark and designated critical habitat for smalltooth sawfish. The use of sonar and other transducers during testing activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon and Atlantic salmon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.1.2.4 Impacts from Sonar and Other Transducers Under Alternative 2

Impacts from Sonar and Other Transducers Under Alternative 2 for Training Activities

Sonar and other transducers emit sound waves into the water to detect objects, safely navigate, and communicate. Use of sonar and other transducers would typically be transient and temporary. General categories and characteristics of sonar systems and the number of hours these sonars would be operated during training under Alternative 2 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 2, the maximum number of training activities could occur every year and all unit level training requirements would be completed at sea rather than synthetically. In addition, all unit level surface ship ASW training requirements would be completed through individual events conducted at sea, rather than through leveraging other ASW training exercises or the use of synthetic trainers. This would result in an increase of sonar use compared to Alternative 1. Training activities using sonar and other transducers could occur throughout the Study Area.

Impacts on fishes due to sonar and other transducers are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking for individuals; long-term consequences for individuals and therefore populations would not be expected. Predicted impacts on ESA-listed fish species and designated critical habitat would not be discernible from those described above in 3.6.3.1.2.3 (Impacts from sonar and Other Transducers under Alternative 1).

Pursuant to the ESA, the use of sonar and other transducers during training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish. The use of sonar and other transducers during training activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon.

Impacts from Sonar and Other Transducers Under Alternative 2 for Testing Activities

General categories and characteristics of sonar systems and the number of hours these sonars would be operated during testing under Alternative 2 are described in Section 3.0.3.3.1 (Acoustic Stressors). Activities using sonars and other transducers would be conducted as described in Chapter 2 (Description of Proposed Action and Alternatives) and Appendix A (Navy Activity Descriptions).

Under Alternative 2, the maximum number of nearly all testing activities would occur every year. This would result in an increase of sonar use compared to Alternative 1. Testing activities using sonar and other transducers could occur throughout the Study Area, although use would generally occur within Navy range complexes, on Navy testing ranges, or around inshore locations identified in Chapter 2 (Description of Proposed Action and Alternatives).

Impacts on fishes due to sonar and other transducers are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking for individuals; long-term consequences for individuals and therefore populations would not be expected. Predicted impacts on ESA-listed fish species and designated critical habitat would not be discernible from those described above in Section 3.6.3.1.2.3 (Impacts from sonar and Other Transducers under Alternative 1 – Testing Activities).

Pursuant to the ESA, the use of sonar and other transducers during testing activities, as described under Alternative 2, will have no effect on ESA-listed Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark and critical habitat designated for smalltooth sawfish. The use of sonar and other transducers during testing activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon and Atlantic salmon, and proposed critical habitat for Atlantic sturgeon.

3.6.3.1.2.5 Impacts from Sonar and Other Transducers Under the No Action Alternative

Impacts from Sonar and Other Transducers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., sonar and other transducers) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.3 Impacts from Air Guns

Fishes could be exposed to sounds from air guns during testing activities. General categories and characteristics of air guns and the number of hours these air guns will be operated are described in Section 3.0.3.3 (Identifying Stressors for Analysis). The activities analyzed in the EIS/OEIS that use air guns are also described in Appendix A (Navy Activity Descriptions).

As discussed in Section 3.6.2.1.3 (Hearing and Vocalization), most marine fish species hear primarily below 1 kHz. Fish species within each of the four fish hearing groups would likely be able to detect sounds produced by air guns. Exposure of fishes to air guns could result in direct injury, hearing loss, masking, physiological stress or behavioral reactions.

3.6.3.1.3.1 Methods for Analyzing Impacts for Air Guns

The Navy performed a quantitative analysis to estimate ranges to effect for fishes exposed to air guns during Navy testing activities. Inputs to the quantitative analysis included sound propagation modeling in the Navy's Acoustic Effects Model to the sound exposure criteria and thresholds presented below. Although ranges to effects are predicted, density data for fish species within the Study Area are not available; therefore, it is not possible to estimate the total number of individuals that may be affected by sound produced by air guns.

Criteria and Thresholds Used to Estimate Impacts from Air Guns

Mortality and Injury from Air Guns

Criteria and thresholds to estimate impacts from sound produced by air gun activities are presented below in Table 3.6-5. Consistent with the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), dual metric sound exposure criteria are utilized to estimate mortality and injury from exposure to air guns. For purposes of this analysis, it is assumed that a specified effect will occur when either metric (cumulative sound exposure level or peak sound pressure level) is met or exceeded. Due to the lack of detailed data on injury thresholds in fishes exposed to air guns, thresholds form impact pile driving exposures are used as a proxy for this analysis (Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). General research findings regarding mortality and injury in fishes are discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Acoustic Sources).

Table 3.6-5: Sound Exposure Criteria for Mortality and Injury from Air Guns

Fish Hearing Group	Onset of Mortality		Onset of Injury	
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}
Fishes without a swim bladder	> 219	> 213	> 216	> 213
Fishes with a swim bladder not involved in hearing	210	> 207	203	> 207
Fishes with a swim bladder involved in hearing	207	> 207	203	> 207
Fishes with a swim bladder and high-frequency hearing	207	> 207	203	> 207

Notes: SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 µPa²-s]), SPL_{peak} = Peak sound pressure level (decibel referenced to 1 micropascal [dB re 1 µPa]), > indicates that the given effect would occur above the reported threshold.

As discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Acoustic Sources), injury and mortality in fishes exposed to impulsive sources may vary depending on the presence or absence of, and type of swim bladder. Injury and mortal injury has not been observed in fishes without a swim bladder because of exposure to impulsive sources (Halvorsen et al., 2011; Halvorsen et al., 2012a). Therefore, these effects would likely occur above the given thresholds in Table 3.6-5. Cumulative sound exposure thresholds for mortality and injury in fishes with a swim bladder were measured by investigators (Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). However, only the single strike peak sound pressure level was measured during these experiments; therefore, mortality and injury thresholds are assumed to be the same across all hearing groups with a swim bladder (Popper et al., 2014).

Hearing Loss from Air Guns

Criteria and thresholds to estimate TTS in fishes exposed to sound produced by air guns are presented below in Table 3.6-6. Sound exposure thresholds are available in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014). General research findings regarding hearing loss in fishes are discussed under Section 3.6.3.1.1.2 (Hearing Loss due to Impulsive Sound Sources).

As discussed in Section 3.6.3.1.1.2 (Hearing Loss), exposure to sound produced from an air gun at a cumulative sound exposure level of 186 dB re 1 µPa²-s has resulted in TTS in fishes (Popper et al., 2005). TTS is not likely to occur in fishes without a swim bladder and would likely occur above the given threshold in Table 3.6-6 for fishes with a swim bladder not involved in hearing.

Table 3.6-6: Sound Exposure Criteria for TTS from Air Guns

Fish Hearing Group	TTS (SEL_{cum})
Fishes without a swim bladder	NC
Fishes with a swim bladder not involved in hearing	> 186
Fishes with a swim bladder involved in hearing	186
Fishes with a swim bladder and high-frequency hearing	186

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), NC = effects from exposure to sound produced by air guns is considered to be unlikely, therefore no criteria are reported, > indicates that the given effect would occur above the reported threshold.

Impact Ranges for Air Guns

The following section provides to range to effects for fishes exposed to air gun activities. Table 3.6-7 present the approximate ranges in meters to mortality, onset of injury and TTS for air guns for 100 pulses. Ranges are calculated using criteria (shown in Table 3.6-5 and Table 3.6-6) and the Navy Acoustic Effects Model and are specific to the AFTT Study Area and to each fish hearing group. Ranges to effect for each hearing group may vary depending on the available criteria or other factors such as location of the activity, season the activity occurs, or depth of the activity.

Table 3.6-7: Range to Effect for Fishes Exposed to 100 Air Gun Shots

Fish Hearing Group	Rang to Effects (meters)				
	Onset of Mortality		Onset of Injury		TTS
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}	SEL_{cum}
Fishes without swim bladders	0	5 (4 - 13)	0 (0 - 2)	5 (4 - 13)	NR
Fishes with swim bladders not involved in hearing	0	9 (8 - 21)	1 (0 - 30)	9 (8 - 21)	14 (4 - 190)
Fishes with swim bladders involved in hearing	1 (0 - 1)	9 (8 - 21)	1 (0 - 30)	9 (8 - 21)	14 (4 - 190)
Fishes with high-frequency hearing	1 (0 - 1)	9 (8 - 21)	1 (0 - 30)	9 (8 - 21)	14 (4 - 190)

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated.
Range to effects represent modeled predictions in different areas and seasons within the Study Area. Each cell contains the estimated average, minimum and maximum range to the specified effect.

Mortality or injury could occur in all fishes with a swim bladder from exposure to air guns within a maximum of 21 or 30 m, respectively. These effects would only occur in fishes without a swim bladder out to a maximum of 13 m. Hearing loss may occur in fishes with a swim bladder from exposure to air gun activities out to an average of 14 m. In some cases, these effects may occur out to a maximum of 190 m. The probability of these effects would decrease with increasing distance from the pile.

3.6.3.1.3.2 Impacts from Air Guns Under Alternative 1

Impacts from Air Guns Under Alternative 1 for Training Activities

Air gun activities would not occur during training activities under Alternative 1.

Impacts from Air Guns Under Alternative 1 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3 (Identifying Stressors for Analysis) and Appendix A (Navy Activity Descriptions), testing activities under Alternative 1 would include the use of single air guns pierside at the Naval Undersea Warfare Center Division, Newport Testing Range, and at off-shore locations typically in the Northeast, Virginia Capes, and Gulf of Mexico Range Complexes.

Impulses from air guns lack the strong shock wave and rapid pressure increases known to cause primary blast injury or barotrauma during explosive events and (to a lesser degree) impact pile driving. Although data from impact pile driving are often used as a proxy to estimate effects to fish from air guns, this may be overly conservative metric due to the differences in rise times between the two types of impulsive sources. Typically, impact pile driving signals have a much steeper rise time and higher peak pressure than air gun signals. However, there is evidence that air guns may cause direct injury to small juvenile or larval fish nearby (approximately 5 m). Therefore, larval and small juvenile fish within a few meters of the air gun may be injured or killed. While mortality, injury, or TTS may occur at the individual level because of air gun activities, considering the small footprint of the mortality/injury zone and the isolated and infrequent use of air guns, population-level consequences would not be expected.

Air guns produce broadband sounds; however, the duration of an individual impulse is about 1/10th of a second. Masking could potentially occur as a result of exposure to sound produced by air guns. However, due to the brief nature of each pulse, it is unlikely that fishes within relatively close distance of the source (tens to hundreds of meters) to experience these effects. It is more likely that masking would occur at farther distances from the source where signals may sound continuous. This may result in brief periods where fishes are unable to detect vocalizations from other fish and predators. Fishes may also respond by altering their vocalizations to compensate for the noise. However, these effects would only occur if air gun signals are detectable over the existing ambient noise.

In addition, fish that are able to detect the air gun impulses may exhibit signs of physiological stress or alterations in natural behavior. 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 events. Due to the limited use and relatively small footprint of air guns, impacts on fish are expected to be minor. Population consequences would not be expected.

As discussed previously in 3.6.2.1.3 (Hearing and Vocalization), all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting sound produced by air guns. Air gun activities associated with testing under Alternative 1 do not overlap the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark or Nassau grouper habitat. Therefore, in-water sound associated with air guns would not affect scalloped hammerhead sharks or Nassau grouper.

Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, and proposed threatened giant manta ray and oceanic whitetip sharks could be exposed to sound from air guns associated with testing activities. Salmon, sturgeon and sawfish exposures would only occur in the Northeast, Virginia Capes, and Gulf of Mexico Range Complexes, and in Newport, RI. However, based on the low annual number of activities to occur in the Study Area and the short period of time (spring months) during the year that Atlantic salmon are present, the likelihood of exposure to testing activities is expected to be infrequent throughout a given year. Only subadult and adult life phase Atlantic and Gulf sturgeon occur near air gun activity locations. All ESA-listed or proposed fishes that are present within a maximum of 30 m of an air gun could potentially suffer mortality or injury with the probability and severity increasing closer to the air gun. Although there are estimated ranges to mortality and injury, on average, these ranges are relatively short (under 10 m) across all fish hearing groups, further reducing the likelihood that mortality or injury would occur due to exposure to air gun activities.

ESA-listed fishes near air gun activities may also exhibit impacts such as behavioral reactions or physiological stress depending on their proximity to the activity. Masking effects would not be anticipated at close distances (likely within hundreds of meters) from the source due to the short duration of the signal pulse. If masking occurs, it would likely be at greater distances if sound from air guns could be detected above existing background noise levels.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. The majority of proposed Atlantic sturgeon critical habitat are within estuarine and river systems. Although Gulf designated critical habitat overlaps with portions of the study area, specifically in the Naval Surface Warfare Center Panama City Testing Range and the Panama City OPAREA, air gun activities do not occur in these areas. The use of air guns during training activities is not anticipated to overlap with Atlantic salmon, smalltooth sawfish, Gulf sturgeon critical habitat or proposed Atlantic sturgeon critical habitat.

Pursuant to the ESA, the use of air guns during testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon. The use of air guns during testing activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwestern Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.1.3.3 Impacts from Air Guns Under Alternative 2

Impacts from Air Guns Under Alternative 2 for Training Activities

Air gun activities would not occur under training activities under Alternative 2.

Impacts from Air Guns Under Alternative 2 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3 (Identifying Stressors for Analysis) and Appendix A (Navy Activity Descriptions), testing activities under Alternative 2 would include activities that produce in-water noise from the use of air guns. Testing activities under Alternative 2 would be identical to those described under Alternative 1; therefore, the locations, types, and severity of predicted impacts would be identical to those described above under 3.6.3.1.3.2 (Impacts from Air Guns under Alternative 1).

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. The majority of proposed Atlantic sturgeon critical habitat are within estuarine and river systems. Although Gulf designated critical habitat overlaps with portions of the study area, specifically in the Naval Surface Warfare Center Panama City Testing Range and the Panama City OPAREA, air gun activities do not occur in these areas. The use of air guns during training activities is not anticipated to overlap with Atlantic salmon, smalltooth sawfish, Gulf sturgeon critical habitat or proposed Atlantic sturgeon critical habitat.

Pursuant to the ESA, the use of air guns during testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon. The use of air guns during testing activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwestern Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon.

3.6.3.1.3.4 Impacts from Air Guns Under the No Action Alternative

<u>Impacts from Air Guns Under the No Action Alternative for Training and Testing Activities</u>

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (i.e., air guns) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.4 Impacts from Pile Driving

Fishes could be exposed to sounds produced by impact pile driving and vibratory pile extraction activities during the construction and removal phases of the Elevated Causeway System described in Chapter 2 (Description of Proposed Action and Alternatives), and Appendix A (Navy Activity Descriptions). The training involves the use of an impact hammer to drive the 24-inch steel piles into the sediment and a vibratory hammer to remove later the piles that support the causeway structure. The impulses can produce a shock wave that is transmitted to the sediment and water column (Reinhall & Dahl, 2011). Elevated Causeway System pile installation and removal within the project area would result in a short-term increase in underwater noise levels (approximately one month out of a year). Section 3.0.3.3.1.3 (Pile Driving) provides additional details on pile driving and noise levels measured from similar operations. Pile driving activities produce broadband sound, therefore it is anticipated that all fishes within each fish hearing group discussed in Section 3.6.2.1.3 (Hearing and Vocalization) would likely be able to detect sound produced by impact pile driving and vibratory pile extraction activities. Exposure of fishes to pile driving activities could result in direct injury, hearing loss, masking, physiological stress or behavioral reactions.

3.6.3.1.4.1 Methods for Analyzing Impact from Pile Driving

The Navy performed a quantitative analysis to estimate the range to effect for fishes exposed to impact pile driving during Navy training activities. Inputs to the quantitative analysis included basic sound propagation modeling and sound exposure criteria and thresholds presented below. Although ranges to effect are predicted, density data for fish species within the Study Area are not available; therefore, it is not possible to estimate the total number of individuals that may be affected by sound produced by impact pile driving.

Currently, there are no proposed criteria for vibratory pile extraction activities and therefore these activities are analyzed based on available literature and other observed reactions.

Criteria and Thresholds Used to Estimate Impacts from Pile Driving

Mortality and Injury from Pile Driving

Criteria and thresholds to estimate impacts from sound produced by impact pile driving activities are presented below in Table 3.6-8. Consistent with the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), dual metric sound exposure criteria are utilized to estimate mortality and injury from exposure to air guns. For purposes of this analysis, it is assumed that a specified effect will occur when either metric (cumulative sound exposure level or peak sound pressure level) is met or exceeded. General research findings regarding mortality and injury in fishes as well as findings specific to exposure to other impulsive sound sources are discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Acoustic Sources).

Table 3.6-8: Sound Exposure Criteria for Mortality and Injury from Impact Pile Driving

	Onset of Mortality		*Onset of Injury*	
Fish Hearing Group	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}
Fishes without a swim bladder	> 219	> 213	> 216	> 213
Fishes with a swim bladder not involved in hearing	210	> 207	203	> 207
Fishes with a swim bladder involved in hearing	207	> 207	203	> 207
Fishes with a swim bladder and high-frequency hearing	207	> 207	203	> 207

Notes: SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 μPa^2-s]), SPL_{peak} = Peak sound pressure level (decibel referenced to 1 micropascal [dB re 1 μPa]), > indicates that the given effect would occur above the reported threshold.

An explanation of mortality and injury criteria are also available under Section 3.6.3.1.3.1 (Methods for Analyzing Impacts from Air Guns – Mortality and Injury from Air Guns).

Hearing Loss from Pile Driving

Criteria and thresholds to estimate TTS in fishes exposed to sound produced by impact pile driving activities are presented below in Table 3.6-9. Sound exposure thresholds are available in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014) and inform the TTS thresholds presented here. Due to the lack of data on hearing loss in fishes exposed to impact pile driving, data from air gun studies were used as a proxy for this analysis (Popper et al., 2005). General research findings regarding hearing loss in fishes are discussed under Section 3.6.3.1.1.2 (Hearing Loss due to Impulsive Sound Sources).

Table 3.6-9: Sound Exposure Criteria for TTS from Impact Pile Driving

Fish Hearing Group	*TTS (SEL_{cum})*
Fishes without a swim bladder	NC
Fishes with a swim bladder not involved in hearing	> 186
Fishes with a swim bladder involved in hearing	186
Fishes with a swim bladder and high-frequency hearing	186

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 µPa²-s]), NC = effects from exposure to sound produced by impact pile driving is considered to be unlikely, therefore no criteria are reported, > indicates that the given effect would occur above the reported threshold.

An explanation of hearing loss criteria is also available under Section 3.6.3.1.3.1 (Methods for Analyzing Impacts from Air Guns – Hearing Loss from Air Guns).

Modeling of Pile Driving Noise

Underwater noise effects from pile driving and vibratory pile extraction were modeled using actual measures of impact pile driving and vibratory removal during construction of an elevated causeway (Illingworth and Rodkin, 2015, 2016). A conservative estimate of spreading loss of sound in shallow coastal waters (i.e., transmission loss = 16.5*Log10[radius]) was applied based on spreading loss observed in actual measurements. Inputs used in the model are provided in Section 3.0.3.3.1.3 (Pile Driving), including source levels; the number of strikes required to drive a pile and the duration of vibratory removal per pile; the number of piles driven or removed per day; and the number of days of pile driving and removal.

Assumptions made for this analysis are:

- The event is equally likely to occur in any season.
- Impact pile driving would occur over 20 days. On average, 6 piles would be driven per day, at an average of 35 strikes per minute for a total of 15 minutes per pile.
- Vibratory pile removal would occur over 10 days. On average, 12 piles would be removed per day, at 6 minutes effort per pile.

3.6.3.1.4.2 Impact Ranges for Pile Driving

The following section provides range to effects for fishes exposed to impact pile driving to specific criteria determined using the calculations and modeling described above. Fishes within these ranges would be predicted to receive the associated effect. Where effects are anticipated to occur above the designated criteria (see Table 3.6-10), the estimated ranges to that effect would be less than those displayed in the table.

Because of the static nature of pile driving activities, two different exposure times were used when calculating ranges to effect for different types of fish (e.g., pelagic vs. demersal). It is assumed that some transient or pelagic species would likely move through the area during pile driving activities, resulting in less time exposed. Therefore, ranges to effect for these species are estimated based on 35 strikes per minute, for a cumulative exposure time of one minute (see Table 3.6-10). In addition, it is assumed that ranges to mortality or injury would actually be less than the ranges shown in the table due to the criteria, which informed the range calculations.

Table 3.6-10: Impact Ranges for Transient or Pelagic Fishes from Impact Pile Driving for 35 Strikes (1 minute)

Fish Hearing Group	Range to Effects (meters)				
	Onset of Mortality		Onset of Injury		TTS
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}	SEL_{cum}
Fishes without a swim bladder	1	< 8	1	< 8	NR
Fishes with a swim bladder not involved in hearing	2	< 17	5	< 17	< 57
Fishes with a swim bladder involved in hearing	3	< 17	5	< 17	57
Fishes with a swim bladder and high-frequency hearing	3	< 17	5	< 17	57

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, < indicates that effects would occur below the provided range.

Based on the measured sound levels for pile driving, mortality or injury could occur in transient or pelagic fishes from exposure to impact pile driving within 17 m of the source. In addition, it is assumed that these fishes may also experience signs of hearing loss out to 57 m. The probability of these effects would decrease with increasing distance from the pile. Fishes without a swim bladder would not likely experience TTS and would only have the potential for mortality or injury effects within 8 m of the source.

In contrast, it is assumed that demersal species, or those with high site fidelity, may stay in the area during pile driving activities and therefore may receive a longer exposure. As a conservative measure, ranges in Table 3.6-11 were calculated based on an estimated 3,150 strikes over the course of an entire day.

Table 3.6-11: Impact Ranges for Demersal Fishes from Impact Pile Driving for 3,150 strikes (1 Day)

Fish Hearing Group	Range to Effects (meters)				
	Onset of Mortality		Onset of Injury		TTS
	SEL_{cum}	SPL_{peak}	SEL_{cum}	SPL_{peak}	SEL_{cum}
Fishes without a swim bladder	9	< 8	13	< 8	NR
Fishes with a swim bladder not involved in hearing	30	< 17	81	< 17	< 868
Fishes with a swim bladder involved in hearing	46	< 17	81	< 17	868
Fishes with a swim bladder and high-frequency hearing	46	< 17	81	< 17	868

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, < indicates that effects would occur below the provided range.

Mortality and injury could occur in demersal fishes from exposure to impact pile driving within 46 m and potentially out to 81 m from the source, respectively, for species within the most sensitive hearing groups (i.e., fishes with a swim bladder involved in hearing and fishes with high-frequency hearing). In addition, fishes with a swim bladder may also experience signs of hearing loss out to 868 m. The probability of these effects would decrease with increasing distance from the pile. Fishes without a swim bladder would not likely experience TTS and would only have the potential for mortality or injury effects within 9 or 13 m of the source, respectively.

3.6.3.1.4.3 Impacts from Pile Driving Under Alternative 1

Impacts from Pile Driving Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.6-1, Section 3.0.3.3 (Identifying Stressors for Analysis), and Appendix A (Navy Activity Descriptions), training activities under Alternative 1 include pile driving associated with construction and removal the Elevated Causeway System. This activity would take place nearshore and within the surf zone for up to 30 days (20 days for construction and 10 days for removal). Specifically, pile driving activities would only occur once at Joint Expeditionary Base Little Creek-Fort Story, Virginia, and once at Marine Corps Base Camp Lejeune, North Carolina, per year. The pile driving locations are within coastal areas that tend to have high ambient noise levels due to natural and anthropogenic sources.

Impulses from the impact hammer are broadband and carry most of their energy in the lower frequencies. The impulses are within the hearing range of all fish, and in close proximity exhibit an overpressure shock front in the water due to the high-speed travel of the impact pressure wave down and back up the steel pile (Reinhall & Dahl, 2011). The impulse can also travel through the bottom sediment. Fishes may be exposed to sound or energy from impact and vibratory pile driving associated with training activities throughout the year.

Range to effects for demersal fishes are generally longer than those reported for transient or pelagic fishes due to the differences in cumulative exposure time (see Table 3.6-11). However, it is not likely that either demersal or pelagic fishes would remain close enough to a pile driving source for an entire day to result in mortality or injury. Fishes would be more likely to startle or avoid the source prior to receiving these higher order effects. Signs of hearing loss however may occur in fishes exposed to initial pile driving activities. Fishes that experience hearing loss may have reduced ability to detect biologically important sounds until their hearing recovers. Recovery from hearing loss begins almost immediately after the noise exposure ceases and can take a few minutes to a few days to fully recover, depending on the magnitude of the initial threshold shift. As discussed in Section 2.3.3.13 (Pile Driving Safety), as a standard operating procedure, the Navy performs soft starts at reduced energy during an initial set of strikes from an impact hammer. Soft starts may “warn” fish and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Considering the small footprint of this injury zone and standard operating procedure for soft starts, long-term consequences to transient individuals, and therefore population consequences, would not be expected. Fishes with high site fidelity would be at more risk to experience effects from impact pile driving, but these effects would also not be likely to result in population level consequences.

Fishes exposed to vibratory extraction would not likely result in mortality, injury, or TTS based on the low source level and limited duration of these activities as discussed in Section 3.0.3.3.1.3 (Pile Driving). Based on the predicted impact pile driving and vibratory extraction noise levels, fishes may also exhibit other responses such as masking, physiological stress, or behavioral responses. Masking only occurs when the interfering signal is present; however, impact pile driving activities are intermittent, with actual pile driving occurring for only about 60 minutes per 24-hour period. Therefore, masking would be localized and of limited duration during impact pile driving. Fishes may habituate, or choose to tolerate pile driving sound after multiple strikes, returning to normal behavior patterns during the pile driving activities. Vibratory pile extraction is more likely than impact pile driving to cause masking of environmental sounds; however, due to its low source level, the masking effect would only be relevant in a small area around the vibratory pile extraction activity. Fishes may also react to pile driving and vibratory pile extraction sound by increasing their swimming speed, moving away from the source, or not responding at all.

As discussed previously (Section 3.6.2.1.3, Hearing and Vocalization), all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting sound produced by pile driving activities. Pile driving activities associated with training under Alternative 1 do not overlap Atlantic salmon, smalltooth sawfish, shortnose sturgeon, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of scalloped hammerhead shark, Nassau grouper or oceanic whitetip habitat. Atlantic sturgeon and giant manta ray could be exposed to sound or substrate vibration from pile driving associated with training activities. These exposures would only occur in either Joint Expeditionary Base Little Creek-Fort Story, Virginia, or Marine Corps Base Camp Lejeune, North Carolina. Atlantic sturgeon, and giant manta ray, if close enough to pile driving, could potentially suffer mortality, injury or hearing loss with the probability and severity increasing closer to the pile driving activity. Masking, physiological stress or behavioral reactions are also possible due to pile driving or vibratory pile extraction, although these impacts would be expected to be short-term, infrequent, and localized based on the low annual number of activities and short duration of the actual event (maximum of 60 minutes of impact pile driving per day) to occur in the training area. All ESA-listed species that could be exposed to pile driving activities may habituate, or choose to tolerate the sound after multiple strikes or after multiple pile removals, returning to normal behavior patterns during the pile driving activities. Although Atlantic sturgeon, and giant manta ray may be affected, long-term consequences for populations would not be expected.

As discussed in Section 3.6.2.2 (Endangered Species Act-Listed Species) critical habitat designated for Atlantic salmon, Atlantic sturgeon, smalltooth sawfish, and Gulf sturgeon does not overlap with areas where pile driving activities will occur therefore, there would be no impact on critical habitat.

Pursuant to the ESA, the use of pile driving during training activities, as described under Alternative 1, will have no effect on ESA-listed Atlantic salmon, smalltooth sawfish, shortnose sturgeon, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, or proposed oceanic whitetip sharks, or designated critical habitat for Atlantic salmon, Atlantic sturgeon, smalltooth sawfish, and Gulf sturgeon. The use of pile driving during training activities, as described under Alternative 1, may affect ESA-listed Atlantic sturgeon and proposed giant manta rays. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Pile Driving Under Alternative 1 for Testing Activities

Pile driving (impact and vibratory) would not occur under testing activities under Alternative 1.

3.6.3.1.4.4 Impacts from Pile Driving Under Alternative 2

Impacts from Pile Driving Under Alternative 2 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3 (Identifying Stressors for Analysis), and Appendix A (Navy Activity Descriptions), training activities under Alternative 2 include activities that produce in-water sound from the pile driving. Training activities under Alternative 2 would be identical to those described under Alternative 1; therefore, the locations, types, and severity of predicted impacts would be identical to those described above in Section 3.6.3.1.4.3 (Impacts from Pile Driving Under Alternative 1 – Training Activities).

Pursuant to the ESA, the use of pile driving during training activities, as described under Alternative 2, will have no effect on ESA-listed Atlantic salmon, smalltooth sawfish, shortnose sturgeon, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, or proposed oceanic whitetip sharks, or designated critical habitat for Atlantic salmon, Atlantic sturgeon, smalltooth sawfish, and Gulf sturgeon. The use of pile driving during training activities, as described under Alternative 2, may affect ESA-listed Atlantic sturgeon and proposed giant manta rays.

Impacts from Pile Driving Under Alternative 2 for Testing Activities

Pile driving (impact and vibratory) would not occur under testing activities under Alternative 2.

3.6.3.1.4.5 Impacts from Pile Driving Under the No Action Alternative

Impacts from Pile Driving Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., impact pile driving and vibratory pile extraction) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.5 Impacts from Vessel Noise

Fishes may be exposed to sound from vessel movement. A detailed description of the acoustic characteristics and typical sound produced by vessels is in Section 3.0.3.3 (Identifying Stressors for Analysis). Vessel movements involve transits to and from ports to various locations within the Study Area. 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), as well as unmanned vehicles. Moderate- to low-level passive sound sources including vessel noise are unlikely to cause any direct injury or trauma due to characteristics of the sounds and the moderate source levels as discussed in Section 3.0.3.3.1 (Acoustic Stressors). Furthermore, although hearing loss because of continuous noise exposure has occurred, vessels are transient and would result in only brief periods of exposure. Injury and hearing loss because of exposure to vessel noise is not discussed further in this analysis.

As discussed in Section 3.6.2.1.3 (Hearing and Vocalization), all fish species should be able to detect vessel noise due to its low-frequency content and their hearing capabilities. Exposure to vessel noise could result in short-term behavioral or physiological responses (e.g., avoidance, stress) as discussed in Section 3.6.3.1.1.3 (Masking), Section 3.6.3.1.1.4 (Physiological Stress), and Section 3.6.3.1.1.5 (Behavioral Reactions).

Training and testing events 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. The exception is for pierside activities, although these areas are located inshore, these are industrialized areas that are already exposed to high levels of anthropogenic noise due to numerous waterfront users (e.g., commercial properties, ports, marinas). Ships would produce low-frequency, broadband underwater sound below 1 kHz while smaller vessels would emit higher-frequency sound between 1 kHz to 50 kHz, though the exact level of sound produced varies by vessel type. Navy vessels make up a very small percentage of the overall traffic (Mintz, 2012), and the rise of ambient noise levels in the Study Area is a problem related to all ocean users, including commercial and recreational vessels and shoreline development and industrialization. Fishes could be exposed to a range of impacts depending on the source of vessel noise and context of the exposure. Specifically, impacts from exposure to vessel noise may include temporary hearing loss, auditory masking, physiological stress, or changes in behavior.

3.6.3.1.5.1 Methods for Analyzing Impacts from Vessel Noise

The impacts on fishes due to exposure to vessel noise are analyzed qualitatively by comparing reported observations under specific conditions as discussed in Section 3.6.3.1.1 (Background) to the conditions which fishes may be exposed to during proposed Navy activities.

3.6.3.1.5.2 Impacts from Vessel Noise Under Alternative 1

Impacts from Vessel Noise Under Alternative 1 for Training Activities

As discussed in Chapter 2 (Description of Proposed Action and Alternatives) and Section 3.0.3.3.1.4 (Vessel Noise), training activities under Alternative 1 include vessel movement in many events. Navy vessel traffic could occur anywhere within the Study Area, but would be concentrated near the Norfolk and Mayport Navy ports and within the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. A study of Navy vessel traffic found that traffic was heaviest just offshore between the mouth of the Chesapeake Bay and Jacksonville, FL, with very little Navy vessel traffic in the Northeast or Gulf of Mexico Range Complexes (Mintz, 2012).

As described in Section 3.6.2.1.3 (Hearing and Vocalization), an increase in background noise levels from training and testing activities have the potential to expose fishes to sound and general disturbance, potentially resulting in short-term physiological stress, masking, or behavioral reactions. Fishes are more likely to react to nearby vessel noise (i.e., within tens of meters) than to vessel noise emanating from a distance. Fishes may have physiological stress reactions to sounds they can hear but typically, responses would be brief and would not affect the overall fitness of the animal. Auditory masking due to vessel noise can potentially mask vocalizations and other biologically important sounds (e.g., sounds of prey or predators) that fish may rely on. The low-frequency sounds of large vessels or accelerating small vessels can cause avoidance responses by fishes. However, impacts from vessel noise would be temporary and localized, and such responses would not be expected to compromise the general health or condition of individual fish. Therefore, long-term consequences for populations are not expected.

All ESA-listed species that occur in the Study Area are likely capable of detecting vessel noise as discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization). Atlantic salmon may be exposed to vessel sound from training activities throughout the year in the Northeast Range Complexes. Atlantic sturgeon exposures could occur at any inshore training area in the Northeast, Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes, particularly in the Chesapeake Bay and in the St. Marys River near Naval Submarine Base Kings Bay, GA. Shortnose sturgeon, which primarily inhabit rivers and estuaries, are not expected to occur in the off shore portions of the Study Area (Dadswell, 2006; National Marine Fisheries Service, 1998b). However, exposures could occur in the Northeast, Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. Smalltooth sawfish and Gulf sturgeon exposures could occur in the Gulf of Mexico Range Complexes. Smalltooth sawfish could also be exposed to vessel noise in the Jacksonville and Key West Range Complexes. The Central and SW Atlantic distinct population segment of scalloped hammerhead sharks and Nassau grouper may be exposed to vessel noise associated with training activities throughout the year in the Key West Range Complex and in waters in the vicinity of Puerto Rico and the U.S. Virgin Islands. In addition, Nassau grouper may also be exposed to vessel noise associated with training activities throughout the year in the Jacksonville Range Complex. Giant manta ray and oceanic whitetip sharks may also be exposed throughout the Study Area. If exposure to vessel noise did occur, ESA-listed species could experience behavioral reactions, physiological stress, and masking, although these impacts would be expected to be short-term and infrequent based on the low probability of co-occurrence between vessel activity and species. Long-term consequences for populations would not be expected.

Proposed training activities that produce vessel noise overlap proposed critical habitat for Atlantic sturgeon in a number of areas including; Kennebec River, ME; James River at Naval Station Norfolk in Norfolk, VA; York River in the Chesapeake Bay, VA; Coopers, River, SC; and the St. Mary's River near Naval Submarine Base Kings Bay, GA. As discussed above, Atlantic sturgeon can detect vessel noise and may experience brief behavioral reactions, physiological stress, or periods of masking. While highly unlikely, sound produced by vessel movement within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Proposed training activities that produce vessel noise overlap designated critical habitat for Gulf sturgeon in the Panama City OPAREA. A map of critical habitat is available in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. However, part of the physical and biological features for Gulf sturgeon critical habitat includes migratory corridors from winter feeding grounds to spring and summer spawning rivers. As discussed above, Atlantic sturgeon can detect vessel noise and may experience brief behavioral reactions, physiological stress, or periods of masking. While highly unlikely, sound from vessel movement within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. All of the biological and physical features required by Atlantic salmon are only applicable to freshwater areas. However, while highly unlikely, sound from vessel movement within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. Training activities that produce vessel noise is not anticipated to overlap with smalltooth sawfish critical habitat.

Pursuant to the ESA, sound produced by vessel movement during training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish. Sound produced by vessel movement during training activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Vessel Noise Under Alternative 1 for Testing Activities

As discussed in Chapter 2 (Description of the Proposed Action and Alternatives) and Section 3.0.3.3.1.8 (Vessel Noise), proposed testing activities under Alternative 1 include vessel movements in many events. Testing activities within the Study Area typically consist of a single vessel involved in unit-level activity for a few hours, one or two small boats conducting testing, or during a larger training event.

Navy vessel traffic could occur anywhere within the Study Area, primarily concentrated within the Jacksonville and Virginia Capes Range Complexes; the Northeast Range Complexes and adjacent inland waters, especially near the Naval Underwater Warfare Center Newport Testing Range; and in the Gulf of Mexico, especially in areas near Naval Surface Warfare Center, Panama City Division Testing Range (Mintz, 2012).

Impacts on fishes due to vessel noise sound are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking; and, long-term consequences for populations would not be expected. Predicted impacts on ESA-listed fish species and designated critical habitat would not be discernible from those described above under Section 3.6.3.1.5.2 (Impacts from Vessel Noise under Alternative 1 for Training Activities).

Proposed training activities that produce vessel noise overlap proposed critical habitat for Atlantic sturgeon in a number of areas including; Kennebec River, ME; James River at Naval Station Norfolk in Norfolk, VA; York River in the Chesapeake Bay, VA; Coopers, River, SC; and the St. Mary's River near Naval Submarine Base Kings Bay, GA. As discussed above, Atlantic sturgeon can detect vessel noise and may experience brief behavioral reactions, physiological stress, or periods of masking. While highly unlikely, sound produced by vessel movement within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Proposed training activities that produce vessel noise overlap designated critical habitat for Gulf sturgeon in the Panama City OPAREA. A map of critical habitat is available in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. However, part of the physical and biological features for Gulf sturgeon critical habitat includes migratory corridors from winter feeding grounds to spring and summer spawning rivers. As discussed above, Atlantic sturgeon can detect vessel noise and may experience brief behavioral reactions, physiological stress, or periods of masking. While highly unlikely, sound from vessel movement within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. All of the biological and physical features required by Atlantic salmon are only applicable to freshwater areas. However, while highly unlikely, sound from vessel movement within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. Training activities that produce vessel noise is not anticipated to overlap with smalltooth sawfish critical habitat.

Pursuant to the ESA, sound produced by vessel movement during testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish. Sound produced by vessel movement during training activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.1.5.3 Impacts from Vessel Noise Under Alternative 2

Impacts from Vessel Noise Under Alternative 2 for Training Activities

Proposed Training Activities under Alternative 2 that involve vessel movement slightly increase from Training Activities proposed under Alternative 1, but the locations, types, and severity of impacts would not be discernible from those described above in Section 3.6.3.1.5.2 (Impacts from Vessel Noise under Alternative 1 for Training Activities).

Pursuant to the ESA, sound produced by vessel movement during training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish. Sound produced by vessel movement during training activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Vessel Noise Under Alternative 2 for Testing Activities

Proposed Testing Activities under Alternative 2 that involve vessel movement slightly increase from Testing Activities proposed under Alternative 1, but the locations, types, and severity of impacts would not be discernible from those described above Section 3.6.3.1.5.2 (Impacts from Vessel Noise under Alternative 1 for Testing Activities).

Pursuant to the ESA, sound produced by vessel movement during testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish. Sound produced by vessel movement during training activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.1.5.4 Impacts from Vessel Noise Under the No Action Alternative

Impacts from Vessel Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., vessel noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.6 Impacts from Aircraft Noise

Fishes may be exposed to aircraft-generated overflight noise throughout the Study Area. A detailed description of the acoustic characteristics and typical sound produced by aircraft overflights are in Section 3.0.3.3 (Identifying Stressors for Analysis). Most of these sounds would be concentrated around airbases and fixed ranges within each of the range complexes. 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). Aircraft would pass quickly overhead and rotary-wing aircraft (e.g., helicopters) may hover for a few minutes at a time over the ocean. Aircraft overflights have the potential to affect surface waters and, therefore, to expose fish occupying those upper portions of the water column to sound. Fish may be exposed to fixed-wing or rotary-wing aircraft-generated noise wherever aircraft overflights occur; however, sound is primarily transferred into the water from air in a narrow cone under the aircraft. Fish would have to be at or near the surface at the time of an overflight to be exposed to appreciable sound levels. Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors. These factors are discussed in detail in Appendix D (Acoustic and Explosives Primer).

As discussed in Section 3.6.3.1.1.1 (Injury) and Section 3.6.3.1.1.2 (Hearing Loss), direct injury and hearing loss in fishes because of exposure to aircraft overflight noise is highly unlikely to occur. Sounds from aircraft noise, including occasional sonic booms, lack the amplitude or duration to cause injury or hearing loss in fishes underwater (see Section 3.6.3.1, Acoustic Stressors). Due to the brief and dispersed nature of aircraft overflights, masking is also unlikely and not discussed further in this analysis.

Fixed- and rotary-wing aircraft are used for a variety of training and testing activities throughout the Study Area. Fishes within close proximity to the activity and closer to the surface would have a higher probability of detecting these sounds although exposure to aircraft overflight noise would likely only last while the object is directly overhead. Training and testing events involving overflight noise are widely dispersed throughout the Study Area.

3.6.3.1.6.1 Methods for Analyzing Impacts from Aircraft Noise

The impacts on fishes due to exposure to aircraft noise are analyzed qualitatively by comparing reported observations under specific conditions as discussed in section 3.6.3.1.1 (Background) to the conditions which fish may be exposed to during proposed Navy activities.

3.6.3.1.6.2 Impacts from Aircraft Noise Under Alternative 1

Impacts from Aircraft Noise Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives) and Section 3.0.3.3.1.5 (Aircraft Overflight Noise), training activities under Alternative 1 include fixed- and rotary-wing aircraft overflights. Certain portions of the Study Area such as areas near fleet concentration areas where planes are based are used more heavily by Navy aircraft than other portions. A detailed description of aircraft noise as a stressor is provided in Section 3.0.3.3.1.5 (Aircraft Overflight Noise). If fish were to respond to aircraft noise, only short-term behavioral or physiological reactions (e.g., avoidance and increased heart rate) would be expected. Therefore, long-term consequences for individuals would be unlikely and long-term consequences for populations are not expected.

Each ESA-listed species within the Study Area could be exposed to aircraft overflight noise. However, due to the small area within which sound could potentially enter the water and the extremely brief window the sound could be present, exposures of ESA-listed fishes to aircraft noise would be extremely rare and in the event that they did occur, would be very brief (seconds). Likewise, although some portions of the Study Area overlap designated critical habitat for Atlantic salmon, Gulf sturgeon, smalltooth sawfish, and proposed critical habitat for Atlantic sturgeon, aircraft noise would not affect critical habitat or any of the physical or biological features.

Pursuant to the ESA, sound produced by aircraft overflights during training activities, as described under Alternative 1, will have no effect on ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, or proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Atlantic salmon, smalltooth sawfish, Gulf sturgeon, or proposed critical habitat for Atlantic sturgeon.

Impacts from Aircraft Noise Under Alternative 1 for Testing Activities

As discussed in Chapter 2 (Description of the Proposed Action and Alternatives) and Section 3.0.3.3.1.9 (Aircraft Noise), testing activities under Alternative 1 include fixed- and rotary-wing aircraft overflights. Certain portions of the Study Area such as areas near fleet concentration areas and testing facilities where planes are based are used more heavily by Navy aircraft than other portions. Proposed testing activities under Alternative 1 that involve aircraft differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.6.2 (Impacts from Aircraft Noise under Alternative 1 for Training Activities).

Each ESA-listed species within the Study Area could be exposed to aircraft overflight noise. However, due to the small area within which sound could potentially enter the water and the extremely brief window the sound could be present, exposures of ESA-listed fishes to aircraft noise would be rare and in the event that they did occur, would be very brief (seconds). Likewise, although some portions of the Study Area overlap designated critical habitat for Atlantic salmon, Gulf sturgeon, smalltooth sawfish, and proposed critical habitat for Atlantic sturgeon, aircraft noise would not affect critical habitat or any of the physical or biological features.

Pursuant to the ESA, sound produced by aircraft overflights during testing activities, as described under Alternative 1, will have no effect on ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, or proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Atlantic salmon, smalltooth sawfish, Gulf sturgeon, or proposed critical habitat for Atlantic sturgeon.

3.6.3.1.6.3 Impacts from Aircraft Noise Under Alternative 2

Impacts from Aircraft Noise Under Alternative 2 for Training Activities

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), and Section 3.0.3.3.1.5 (Aircraft Overflight Noise), training activities under Alternative 2 include a minor increase in the number of events that involve aircraft as compared to Alternative 1; however, the training locations, types of aircraft, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.1.6.2 (Impacts from Aircraft Noise under Alternative 1 for Training Activities).

Pursuant to the ESA, sound produced by aircraft overflights during training activities, as described under Alternative 2, will have no effect on ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, or proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Atlantic salmon, smalltooth sawfish, Gulf sturgeon, or proposed critical habitat for Atlantic sturgeon.

Impacts from Aircraft Noise Under Alternative 2 for Testing Activities

As discussed in Chapter 2 (Description of Proposed Action and Alternatives), and Section 3.0.3.3.1.9 (Aircraft Noise), testing activities under Alternative 2 include a minor increase in the number of events that involve aircraft noise as compared to Alternative 1; however, the testing locations, types of aircraft, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.1.6.2 (Impacts from Aircraft Noise under Alternative 1 for Testing Activities).

Pursuant to the ESA, sound produced by aircraft overflights during testing activities, as described under Alternative 2, will have no effect on ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, or proposed giant manta rays and oceanic whitetip sharks, designated critical habitat for Atlantic salmon, smalltooth sawfish, Gulf sturgeon, or proposed critical habitat for Atlantic sturgeon.

3.6.3.1.6.4 Impacts from Aircraft Noise Under the No Action Alternative

Impacts from Aircraft Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., aircraft overflight noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.1.7 Impacts from Weapons Noise

Fishes could be exposed to noise from weapons firing, launch, flight downrange, and from the impact of non-explosive munitions on the water's surface. A detailed description of the acoustic characteristics of weapons noise is in Section 3.0.3.3.1.6 (Weapons Noise). Reactions by fishes to these specific stressors have not been recorded; however, fishes would be expected to react to weapons noise, as they would other transient sounds (Section 3.6.3.1.1.5, Behavioral Reactions).

3.6.3.1.7.1 Methods for Analyzing Impacts from Weapons Noise

The impacts on fishes due to exposure to weapons noise are analyzed qualitatively by comparing reported observations under specific conditions as discussed in section 3.6.3.1.1 (Background) to the conditions which fish may be exposed to during proposed Navy activities.

3.6.3.1.7.2 Impacts from Weapons Noise Under Alternative 1

Impacts from Weapons Noise Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), training activities under Alternative 1 include activities that produce in-water sound from weapons firing, launch, flight downrange, and non-explosive practice munitions impact with the water's surface. Training activities could occur throughout the Study Area but would be concentrated in the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes, with fewer events in the Northeast, Key West, and Gulf of Mexico Range Complexes. Most activities involving large-caliber naval gunfire or the launching of targets, missiles, bombs, or other munitions are conducted more than 12 NM from shore. Impacts from training activities would be highly localized and concentrated in space and duration.

Mortality, injury, hearing loss and masking in fishes because of exposure to weapons noise is highly unlikely to occur. Sound from these sources lack the duration and high intensity to cause injury or hearing loss. Therefore, injury and hearing loss is not discussed further in this analysis. Due to the brief and dispersed nature of weapons noise, masking is also unlikely and not discussed further in this analysis. However, potential impacts considered are short-term behavioral or physiological reactions (e.g., swimming away and increased heart rate).

Animals at the surface of the water, in a narrow footprint under a weapons trajectory, could be exposed to naval gunfire sound and may exhibit brief behavioral reactions such as startle reactions or avoidance, or no reaction at all. Due to the short-term, transient nature of gunfire activities, animals may be exposed to multiple shots within a few seconds, but are unlikely to be exposed multiple times within a short period (minutes or hours). Behavioral reactions would likely be short-term (minutes) and are unlikely to lead to substantial costs or long-term consequences for individuals or populations.

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 sound in the water due to the altitude of the aircraft at launch. Behavioral reactions would likely be short-term (minutes) and are unlikely to lead to long-term consequences for individuals or populations.

As discussed in Section 3.0.3.3.1.6 (Weapons Noise), any objects that are dropped and impact the water with great force could produce a loud broadband sound at the water's surface. Large-caliber non-explosive projectiles, non-explosive bombs, and intact missiles and targets could produce a large impulse upon impact with the water surface (McLennan, 1997). Fishes within a few meters could experience some temporary hearing loss, although the probability is low of the non-explosive munitions landing within this range while a fish is near the surface. Animals within the area may hear the impact of object on the surface of the water and would likely alert, dive, or avoid the immediate area. Impact noise would not be expected to induce significant behavioral reactions from fishes, and long-term consequences for individuals and populations are unlikely.

As discussed previously (Section 3.6.2.1.3, Hearing and Vocalization), all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting weapons noise but not all species occur in areas where weapons noise is present. Shortnose sturgeon, smalltooth sawfish, and Nassau grouper would not likely encounter weapon noise as smalltooth sawfish and Nassau grouper typically are found along the seafloor and shortnose sturgeon are largely confined to rivers and estuaries. Scalloped hammerhead sharks, and Gulf and Atlantic sturgeon could occur in areas associated with weapons noise however, these species don't typically swim near the surface at sea, therefore decreasing the likelihood of exposure. Atlantic salmon, giant manta ray and oceanic white tip sharks could be exposed to weapons noise. In particular, oceanic whitetip sharks in deeper waters spend much of their time at the surface, potentially increasing the risk of exposure. However, most species that occur within 12 NM of the shore would have a lower probability of encountering these activities. ESA listed fishes that are exposed to weapons noise may exhibit minor behavioral reactions, brief physiological stress, or short periods of masking. Due to the short-term, transient nature of weapons noise, animals are unlikely to be exposed multiple times within a short period. Physiological stress and behavioral reactions would likely be short-term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected.

Proposed training activities that produce weapons largely occur 12 NM from shore but could potentially occur in the Panama City OPAREA and may overlap designated critical habitat for Gulf sturgeon. A map of critical habitat is available in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. However, part of the physical and biological features for Gulf sturgeon critical habitat includes migratory corridors from winter feeding grounds to spring and summer spawning rivers. While highly unlikely, activities that produce weapons noise within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. Weapons noise produced during training activities is not anticipated to overlap with Atlantic salmon or smalltooth sawfish critical habitat. In addition, proposed training activities that produce weapons noise largely occur 12 NM from shore and would not overlap proposed critical habitat for Atlantic sturgeon.

Pursuant to the ESA, weapons noise produced during training activities, as described under Alternative 1, will have no effect on ESA-listed shortnose sturgeon, smalltooth sawfish or Nassau grouper, designated critical habitat for Atlantic salmon, smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. Weapons noise produced during training activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Gulf and Atlantic sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, proposed giant manta rays, oceanic whitetip sharks, and designated critical habitat for Gulf sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Weapons Noise Under Alternative 1 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), testing activities under Alternative 1 include activities that produce weapons noise. Testing activities could occur in the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes, with fewer events in the Northeast, Key West, and Gulf of Mexico Range Complexes. Activities could also occur in the Naval Surface Warfare Center Panama Canal Testing Range. Most activities involving large-caliber naval gunfire or the launching of targets, missiles, bombs, or other munitions are conducted more than 12 NM from shore. Proposed testing activities under Alternative 1 differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above for Impacts from Weapons Noise under Alternative 1 for Training Activities. Impacts on fish due to weapons noise are expected to be limited to short-term, minor behavioral responses, physiological stress, and short periods of masking; and, long-term consequences for an individual, and therefore populations, would not be expected.

As discussed previously (Section 3.6.2.1.3, Hearing and Vocalization), all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting weapons noise but not all species occur in areas where weapons noise is present. Shortnose sturgeon, smalltooth sawfish, and Nassau grouper would not likely encounter weapon noise. Scalloped hammerhead sharks, and Gulf and Atlantic sturgeon could occur in areas associated with weapons noise however, these species don't typically swim near the surface at sea, therefore decreasing the likelihood of exposure. Atlantic salmon, giant manta ray and oceanic white tip sharks could be exposed to weapons noise. Most species that occur within 12 NM of the shore would have a lower probability of encountering these activities. ESA listed fishes that are exposed to weapons noise may exhibit minor behavioral reactions, brief physiological stress, or short periods of masking. Due to the short-term, transient nature of weapons noise, animals are unlikely to be exposed multiple times within a short period. Physiological stress and behavioral reactions would likely be short-term (minutes) and substantive costs or long-term consequences for individuals or populations would not be expected.

Proposed training activities that produce weapons largely occur 12 NM from shore but could potentially occur in the Naval Surface Warfare Center Panama City Testing Range and the Panama City OPAREA and may overlap designated critical habitat for Gulf sturgeon. A map of critical habitat is available in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. However, part of the physical and biological features for Gulf sturgeon critical habitat includes migratory corridors from winter feeding grounds to spring and summer spawning rivers. While highly unlikely, activities that produce weapons noise within the critical habitat may affect migratory passage corridors within the vicinity of the sound source.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida. Weapons noise produced during training activities is not anticipated to overlap with Atlantic salmon or smalltooth sawfish critical habitat. In addition, proposed training activities that produce weapons noise largely occur 12 NM from shore and would not overlap proposed critical habitat for Atlantic sturgeon.

Pursuant to the ESA, weapons noise produced during testing activities, as described under Alternative 1, will have no effect on ESA-listed shortnose sturgeon, smalltooth sawfish, Nassau grouper, designated critical habitat for Atlantic salmon, smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. Weapons noise produced during testing activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Gulf and Atlantic sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, proposed giant manta rays, oceanic whitetip sharks and designated critical habitat for Gulf sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.1.7.3 Impacts from Weapons Noise Under Alternative 2

Impacts from Weapons Noise Under Alternative 2 for Training Activities

Proposed training activities under Alternative 2 that produce weapons noise differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.7.2 (Impacts from Weapons Noise under Alternative 1 for Training Activities). Impacts on fishes due to weapons noise are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking; furthermore, long-term consequences for an individual, and therefore populations, would not be expected.

Pursuant to the ESA, weapons noise produced during training activities, as described under Alternative 2, will have no effect on ESA-listed shortnose sturgeon, smalltooth sawfish or Nassau grouper, designated critical habitat for Atlantic salmon, smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. Weapons noise produced during training activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Gulf and Atlantic sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, proposed giant manta rays, oceanic whitetip sharks, and designated critical habitat for Gulf sturgeon.

Impacts from Weapons Noise Under Alternative 2 for Testing Activities

Proposed testing activities under Alternative 2 that produce weapons noise differ in number and location from testing activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.1.7.2 (Impacts from Weapons Noise under Alternative 1 for Training Activities). Impacts on fishes due to weapons noise are expected to be limited to minor behavioral responses, short-term physiological stress, and short periods of masking; and, long-term consequences for an individual, and therefore populations, would not be expected.

Pursuant to the ESA, weapons noise produced during testing activities, as described under Alternative 2, will have no effect on ESA-listed shortnose sturgeon, smalltooth sawfish, Nassau grouper, designated critical habitat Atlantic salmon, smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. Weapons noise produced during testing activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Gulf and Atlantic sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, proposed giant manta rays, oceanic whitetip sharks and designated critical habitat for Gulf sturgeon.

3.6.3.1.7.4 Impacts from Weapons Noise Under the No Action Alternative

Impacts from Weapons Noise Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various acoustic stressors (e.g., weapons noise) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.2 Explosive Stressors

Explosions in the water or near the water surface can introduce loud, impulsive, broadband sounds into the marine environment. However, unlike acoustic stressors, explosives release energy at a high rate producing a shock wave that can be injurious and even deadly. Therefore, explosive impacts on fishes are discussed separately from other acoustic stressors, even though the analysis of explosive impacts will in part rely on data from fishes exposed to impulsive sources where appropriate.

Explosives are usually described by their net explosive weight, which accounts for the weight and type of explosive material. Additional explanation of the acoustic and explosive terms and sound energy concepts used in this section is found in Appendix D (Acoustic and Explosives Concepts).

The ways in which an explosive exposure could result in immediate effects or lead to long-term consequences for an animal are explained in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) and the below background section follows that framework. The following Background section discusses what is currently known about effects of explosives on fishes.

3.6.3.2.1 Background

The effects of explosions on fishes have been studied and reviewed by numerous authors (Keevin & Hempen, 1997; O'Keeffe, 1984; O'Keeffe & Young, 1984; Popper et al., 2014). A summary of the literature related to each type of effect forms the basis for analyzing the potential effects from Navy activities. The sections below include a survey and synthesis of best-available-science published in peer-reviewed journals, technical reports, and other scientific sources pertinent to impacts on fishes potentially resulting from Navy training and testing activities. Fishes could be exposed to a range of impacts depending on the explosive source and context of the exposure. In addition to acoustic impacts including temporary or permanent hearing loss, auditory masking, physiological stress, or changes in behavior, potential impacts from an explosive exposure can include non-lethal injury and mortality.

3.6.3.2.1.1 Injury

The blast wave from an underwater explosion is lethal to fishes at close range, causing massive organ and tissue damage (Keevin & 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, depth, physical condition of the fish, and perhaps most importantly, the presence of a swim bladder (Keevin & Hempen, 1997; Wright, 1982; Yelverton et al., 1975; Yelverton & Richmond, 1981). At the same distance from the source, larger fishes 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 fishes oriented sideways to the blast suffer the greatest impact (Edds-Walton & Finneran, 2006; O'Keeffe, 1984; O'Keeffe & Young, 1984; Wiley et al., 1981; Yelverton et al., 1975). Species with a swim bladder are much more susceptible to blast injury from explosives than fishes without them (Gaspin, 1975; Gaspin et al., 1976; Goertner et al., 1994).

If a fish is close to an explosive detonation, the exposure to rapidly changing high pressure levels can cause barotrauma. Barotrauma is injury due to a sudden difference in pressure between an air space inside the body and the surrounding water and tissues. Rapid compression followed by rapid expansion of airspaces, such as the swim bladder, can damage surrounding tissues and result in the rupture of the airspace itself. The swim bladder is the primary site of damage from explosives (Wright, 1982; Yelverton et al., 1975). Gas-filled swim bladders resonate at different frequencies than surrounding tissue and can be torn by rapid oscillation between high- and low-pressure waves (Goertner, 1978). Swim bladders are a characteristic of most bony fishes with the notable exception of flatfishes (e.g., halibut). Sharks and rays are examples of fishes without a swim bladder. Small airspaces, such as micro-bubbles that may be present in gill structures, could also be susceptible to oscillation when exposed to the rapid pressure increases caused by an explosion. This may have caused the bleeding observed on gill structures of some fish exposed to explosions (Goertner et al., 1994). Sudden very high pressures can also cause damage at tissue interfaces due to the way pressure waves travel differently through tissues with different densities. Rapidly oscillating pressure waves might rupture the kidney, liver, spleen, and sinus and cause venous hemorrhaging (Keevin & Hempen, 1997).

Several studies have exposed fish to explosives and examined various metrics in relation to injury susceptibility. Sverdrup (1994) exposed Atlantic salmon (1 to 1.5 kg [2–3 lb.]) in a laboratory setting to repeated shock pressures of around 2 megapascals (300 pounds per square inch) without any immediate or delayed mortality after a week. Hubbs and Rechnitzer (1952) showed that fish with swim bladders exposed to explosive shock fronts (the near-instantaneous rise to peak pressure) were more susceptible to injury when several feet below the water surface than near the bottom. When near the surface, the fish began to exhibit injuries around peak pressure exposures of 40 to 70 pounds per square inch. However, near the bottom (all water depths were less than 100 ft.) fish exposed to pressures over twice as high exhibited no sign of injury. Yelverton et al. (1975) similarly found that peak pressure was not correlated to injury susceptibility. Yelverton et al. (1975) instead found that injury susceptibility of swim bladder fish at shallow depths (10 ft. or less) was correlated to the metric of positive impulse (Pa-s), which takes into account both the positive peak pressure and the duration of the positive pressure exposure, and the fish mass, with smaller fish being more susceptible.

Gaspin et al. (1976) exposed multiple species of fish with a swim bladder, placed at varying depths, to explosive blasts of varying size and depth. Goertner (1978) and Wiley (1981) developed a swim bladder oscillation model, which showed that the severity of injury observed in those tests could be correlated to the extent of swim bladder expansion and contraction predicted to have been induced by exposure to the explosive blasts. Per this model, the degree of swim bladder oscillation is affected by ambient pressure (i.e., depth of fish), peak pressure of the explosive, duration of the pressure exposure, and exposure to surface rarefaction (negative pressure) waves. The maximum potential for injury is predicted to occur where the surface reflected rarefaction (negative) pressure wave arrives coincident with the moment of maximum compression of the swim bladder caused by exposure to the direct positive blast pressure wave, resulting in a subsequent maximum expansion of the swim bladder. Goertner (1978) and Wiley et al. (1981) found that their swim bladder oscillation model explained the injury data in the Yelverton et al. (1975) exposure study and their impulse parameter was applicable only to fishes at shallow enough depths to experience less than one swim bladder oscillation before being exposed to the following surface rarefaction wave.

O'Keeffe (1984) provides calculations and contour plots that allow estimation of the range to potential effects of underwater explosions on fish possessing swim bladders using the damage prediction model developed by Goertner (1978). O'Keeffe's (1984) parameters include the charge weight, depth of burst, and the size and depth of the fish, but the estimated ranges do not take into account unique propagation environments that could reduce or increase the range to effect. The 10 percent mortality range shown below in Table 3.6-12 is the maximum horizontal range predicted by O'Keeffe (1984) for 10 percent of fish suffering injuries that are expected to not be survivable (e.g., damaged swim bladder or severe hemorrhaging). Fish at greater depths and near the surface are predicted to be less likely to be injured because geometries of the exposures would limit the amplitude of swim bladder oscillations.

Table 3.6-12: Range to Effect from Underwater Explosions for Fishes with a Swim Bladder

Weight of Pentolite (lb.) [NEW, lb.][1]	*Depth of Explosion (ft.) [m]*	*10% Mortality Maximum Range (ft.) [m]*		
		1 oz. Fish	*1 lb. Fish*	*30 lb. Fish*
10 [13]	10 [3]	530 [162]	315 [96]	165 [50]
	50 [15]	705 [214]	425 [130]	260 [79]
	200 [61]	905 [276]	505 [154]	290 [88]
100 [130]	10 [3]	985 [300]	600 [183]	330 [101]
	50 [15]	1,235 [376]	865 [264]	590 [180]
	200 [61]	1,340 [408]	1,225 [373]	725 [221]
1,000 [1,300]	10 [3]	1,465 [447]	1,130 [344]	630 [192]
	50 [15]	2,255 [687]	1,655 [504]	1,130 [344]
	200 [61]	2,870 [875]	2,390 [728]	1,555 [474]

Table 3.6-12: Range to Effect from Underwater Explosions for Fishes with a Swim Bladder (continued)

Weight of Pentolite (lb.) [NEW, lb.][1]	*Depth of Explosion (ft.) [m]*	*10% Mortality Maximum Range (ft.) [m]*		
		1 oz. Fish	*1 lb. Fish*	*30 lb. Fish*
10,000 [13,000]	10 [3]	2,490 [759]	1,920 [585]	1,155 [352]
	50 [15]	4,090 [1,247]	2,885 [879]	2,350 [716]
	200 [61]	5,555 [1,693]	4,153 [1,266]	3,090 [942]

[1]Explosive weights of pentolite converted to net explosive weight using the peak pressure parameters in Swisdak (1978).lb. = pounds, NEW = net explosive weight, oz. = ounce.
Source: O'Keeffe (1984)

In contrast to fish with swim bladders, fishes without swim bladders have been shown to be more resilient to explosives (Gaspin, 1975; Gaspin et al., 1976; Goertner et al., 1994). For example, some small (average 116 mm length; approximately 1 oz.) hogchokers (*Trinectes maculatus*) exposed less than 5 ft. from a 10-lb. pentolite charge immediately survived the exposure with slight to moderate injuries and only a small number of fish were immediately killed; however, most of the fish at this close range did suffer moderate to severe injuries, typically of the gills or around the otolithic structures (Goertner et al., 1994).

Studies that have documented caged fishes killed during planned underwater explosions indicate that most fish that die do so within one to four hours, and almost all die within a day (Yelverton et al., 1975). Mortality in free-swimming (uncaged) fishes may be higher due to increased susceptibility to predation. Fitch and Young (1948) found that the type of free-swimming fish killed changed when blasting was repeated at the same 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.

Fitch and Young (1948) also investigated whether a significant portion of fish killed would have sunk and not been observed at the surface. Comparisons of the numbers of fish observed dead at the surface and at the bottom in the same affected area after an explosion showed that fish found dead on the bottom comprised less than 10 percent of the total observed mortality. Gitschlag et al. (2001) conducted a more detailed study of both floating fishes and those that were sinking or lying on the bottom after explosive removal of nine oil platforms in the northern Gulf of Mexico. Results were highly variable. They found that 3 to 87 percent (46 percent average) of the red snapper killed during a blast might float to the surface. Currents, winds, and predation by seabirds or other fishes may be some of the reasons that the magnitude of fish mortality may not have been accurately captured.

There have been few studies of the impact of underwater explosives on early life stages of fish (eggs, larvae, juveniles). Fitch and Young (1948) reported mortality of larval anchovies exposed to underwater blasts off California. Nix and Chapman (1985) found that anchovy and smelt larvae died following the detonation of buried charges. Similar to adult fishes, the presence of a swim bladder contributes to shock wave-induced internal damage in larval and juvenile fish (Settle et al., 2002). Explosive shock wave injury to internal organs of larval pinfish and spot exposed at shallow depths was documented by Govoni et al. (2003; 2008) at impulse levels similar to those predicted by Yelverton et al. (1975) for very small fish. Researchers (Faulkner et al., 2006; Faulkner et al., 2008; Jensen, 2003) have suggested that egg mortality may be correlated with peak particle velocity exposure (i.e., the localized movement or shaking of water particles, as opposed to the velocity of the blast wave), although sufficient data from direct explosive exposures is not available.

Rapid pressure changes could cause mechanical damage to sensitive ear structures due to differential movements of the otolithic structures. Bleeding near otolithic structures was the most commonly observed injury in non-swim bladder fish exposed to a close explosive charge (Goertner et al., 1994). General research findings regarding injury in fishes due to exposure to other impulsive sound sources are discussed in Section 3.6.3.1.1.1 (Injury Due to Impulsive Sources). Results from other impulsive sound exposure studies, such as those for seismic air guns and impact pile driving, may be useful in interpreting effects where data are lacking for explosive sources.

As summarized by the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), exposure to explosive energy poses the greatest potential threat for injury and mortality in marine fishes. Fishes with a swim bladder are more susceptible to injury than fishes without a swim bladder. The susceptibility also probably varies with size and depth of both the detonation and the fish. Fish larvae or juvenile fish may be more susceptible to injury from exposure to explosives.

3.6.3.2.1.2 Hearing Loss

There are no direct measurements of hearing loss in fishes due to exposure to explosive sources. The sound resulting from an explosive detonation is considered an impulsive sound and shares important qualities (i.e., short duration and fast rise time) with other impulsive sounds such as those produced by air guns. PTS in fish has not been known to occur in species tested to date and 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 (Popper et al., 2005; Popper et al., 2014; Smith et al., 2006).

As reviewed in Popper et al. (2014), fishes without a swim bladder, or fishes with a swim bladder not involved in hearing, would be less susceptible to hearing loss (i.e., TTS), even at higher level exposures. Fish with a swim bladder involved in hearing may be susceptible to TTS within very close ranges to an explosive. General research findings regarding TTS in fishes as well as findings specific to exposure to other impulsive sound sources are discussed in Section 3.6.3.2.1.2 (Hearing Loss).

3.6.3.2.1.3 Masking

Masking refers to the presence of a noise that interferes with a fish's ability to hear biologically important sounds including those produced by prey, predators, or other fish in the same species (Myrberg, 1980; Popper et al., 2003). This can take place whenever the noise level heard by a fish exceeds the level of a biologically relevant sound. As discussed in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities) masking only occurs in the presence of the masking noise and does not persist after the cessation of the noise. Masking may lead to a change in vocalizations or a change in behavior (e.g., cessation of foraging, leaving an area).

There are no direct observations of masking in fishes due to exposure to explosives. Popper et al. (2014) highlights a lack of data that exist for masking by explosives but suggests that the intermittent nature of explosions would result in very limited probability of any masking effects and if masking were to occur it would only occur during the duration of the sound. General research findings regarding masking in fishes due to exposure to sound are discussed in detail in Section 3.6.3.1.1.3 (Masking). Potential masking from explosives is likely to be similar to masking studied for other impulsive sounds such as air guns.

3.6.3.2.1.4 Physiological Stress

Fishes naturally experience stress within their environment and as part of their life histories. The stress response is a suite of physiological changes that are meant to help an organism mitigate the impact of a stressor. However, if the magnitude and duration of the stress response is too great or too long, then it can have negative consequences to the organism (e.g., decreased immune function, decreased reproduction). Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Stressors) provides additional information on physiological stress and the framework used to analyze this potential impact.

Research on physiological stress in fishes due to exposure to explosive sources is limited. Sverdrup et al. (1994) studied levels of stress hormones in Atlantic salmon after exposure to multiple detonations in a laboratory setting. Increases in cortisol and adrenaline were observed following the exposure, with adrenaline values returning to within normal range within 24 hours. General research findings regarding physiological stress in fishes due to exposure to impulsive sources are discussed in detail in Section 3.6.3.1.1.4 (Physiological Stress). Generally, stress responses are more likely to occur in the presence of potentially threatening sound sources such as predator vocalizations or the sudden onset of impulsive signals. Stress responses may be brief (a few seconds to minutes) if the exposure is short or if fishes habituate or learn to tolerate the noise. It is assumed that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

3.6.3.2.1.5 Behavioral Reactions

As discussed in Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities), any stimuli in the environment can cause a behavioral response in fishes, including sound produced by explosions. Wright (1982) observed changes in fish behavior as a result of the sound produced by an explosion, with effects intensified in areas of hard substrate, but there are no other data available on the behavioral reactions of fish to explosives (Popper et al., 2014). Behavioral reactions from explosive sounds are likely to be similar to reactions studied for other impulsive sounds such as those produced by air guns. Impulsive signals, particularly at close range, have a rapid rise time and higher instantaneous peak pressure than other signal types, making them more likely to cause startle or avoidance responses. General research findings regarding behavioral reactions from fishes due to exposure to impulsive sounds, such as those associated with explosions, are discussed in detail in Section 3.6.3.1.1.5 (Behavioral Reactions).

As summarized by the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), species may react differently to the same sound source depending on a number of variables, such as the animal's life stage or behavioral state (e.g., feeding, mating). Without data that are more specific it is assumed that fishes with similar hearing capabilities react similarly to all impulsive sounds outside or within the zone for hearing loss and injury. Observations of fish reactions to large-scale air gun surveys are informative, but not necessarily directly applicable to analyzing impacts from the short-term, intermittent use of all impulsive sources. Fish have a higher probability of reacting when closer to an impulsive sound source (within tens of meters), and a decreasing probability of reaction at increasing distances (Popper et al., 2014).

3.6.3.2.1.6 Long-term Consequences

Long-term consequences to a population are determined by examining changes in the population growth rate. For additional information on the determination of long-term consequences, see Section 3.0.3.6.1 (Conceptual Framework for Assessing Effects from Acoustic and Explosive Stressors). Physical effects from explosive sources that could lead to a reduction in the population growth rate include mortality or injury, which could remove animals from the reproductive pool, and permanent hearing impairment or chronic masking, which could affect navigation, foraging, predator avoidance, or communication. The long-term consequences due to individual behavioral reactions, masking and short-term instances of physiological stress are especially difficult to predict because individual experience over time can create complex contingencies, especially for fish species that live for multiple seasons or years. For example, a lost reproductive opportunity could be a measurable cost to the individual; however, short-term costs may be recouped during the life of an otherwise healthy individual. These factors are taken into consideration when assessing risk of long-term consequences.

3.6.3.2.2 Impacts from Explosives

Fishes could be exposed to energy and sound from underwater and in-air explosions associated with proposed activities. General categories and characteristics of explosives and the numbers and sizes of detonations proposed are described in Section 3.0.3.3.2 (Explosive Stressors). The activities analyzed in the EIS/OEIS that use explosives are also described in Appendix A (Navy Activity Descriptions).

As discussed throughout Section 3.6.3.2.1 (Background), sound and energy from underwater explosions are capable of causing mortality, injury, hearing loss, a behavioral response, masking, or physiological stress, depending on the level and duration of exposure. The death of an animal would eliminate future reproductive potential, which is considered in the analysis of potential long-term consequences to the population. Exposures that result in non-auditory injuries may limit an animal's ability to find food, communicate with other animals, or interpret the surrounding environment. Impairment of these abilities can decrease an individual's chance of survival or affect its ability to reproduce. Temporary threshold shift can also impair an animal's abilities, although the individual may recover quickly with little significant effect.

3.6.3.2.2.1 Methods for Analyzing Impacts from Explosives

The Navy performed a quantitative analysis to estimate ranges to effect for fishes exposed to underwater explosions during Navy training and testing activities. Inputs to the quantitative analysis included sound propagation modeling in the Navy's Acoustic Effects Model to the sound exposure criteria and thresholds presented below. Density data for fish species within the Study Area are not currently available; therefore, it is not possible to estimate the total number of individuals that may be affected by explosive activities.

<u>Criteria and Thresholds used to Estimate Impacts on Fishes from Explosives</u>

Mortality and Injury from Explosives

Criteria and thresholds to estimate impacts from sound and energy produced by explosive activities are presented below in Table 3.6-13. In order to estimate the longest range at which a fish may be killed or mortally injured, the Navy based the threshold for mortal injury on the lowest pressure that caused mortalities in the study by Hubbs and Rechnitzer (1952), consistent with the recommendation in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014). As shown in Section 3.6.3.2.1.1 (Injury), this threshold likely over-estimates the potential for mortal injury. The potential for mortal injury has been shown to be correlated to fish size, depth, and geometry of exposure, which are not accounted for by using a peak pressure threshold. However, until fish mortality models are developed that can reasonably consider these factors across multiple environments, use of the peak pressure threshold allows for a conservative estimate of maximum impact ranges.

Due to the lack of detailed data for onset of injury in fishes exposed to explosives, thresholds from impact pile driving exposures are used as a proxy for this analysis (Halvorsen et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b). Consistent with the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), dual metric sound exposure criteria are utilized to estimate injury from exposure to explosives, as shown in Table 3.6-13. For purposes of this analysis, it is assumed that a specified effect will occur when either metric (cumulative sound exposure level or peak sound pressure level) is met or exceeded. General research findings regarding mortality and injury in fishes due to exposure to impact pile driving (or simulated impact pile driving sources) are discussed under Section 3.6.3.1.1.1 (Injury due to Impulsive Acoustic Sources) and Section 3.6.3.2.1.1 (Injury).

Table 3.6-13: Sound Exposure Criteria for Mortality and Injury from Explosives

Fish Hearing Group	*Onset of Mortality*	*Onset of Injury*	
	SPL_{peak}	SEL_{cum}	SPL_{peak}
Fishes without a swim bladder	229	> 216	> 213
Fishes with a swim bladder not involved in hearing	229	203	> 207
Fishes with a swim bladder involved in hearing	229	203	> 207
Fishes with a swim bladder and high-frequency hearing	229	203	> 207

Notes: SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 µPa2-s]), SPL_{peak} = Peak sound pressure level (decibel referenced to 1 micropascal [dB re 1 µPa]), > indicates that the given effect would occur above the reported threshold.

The number of fish killed by an underwater explosion would depend on the population density near the blast, as well as factors discussed Section 3.6.3.2.1.1 (Injury) 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 menhaden, herring, or other schooling fish, a large number of fish could be killed. However, the probability of this occurring is low based on the patchy distribution of dense schooling fish. Stunning from pressure waves could also temporarily immobilize fish, making them more susceptible to predation.

Fragments produced by exploding munitions at or near the surface may present a high-speed strike hazard for an animal at or near the surface. In water, however, fragmentation velocities decrease rapidly due to drag (Swisdak & Montanaro, 1992). Because blast waves propagate efficiently through water, the range to injury from the blast wave would likely extend beyond the range of fragmentation risk.

Hearing Loss from Explosives

Criteria and thresholds to estimate TTS from sound produced by explosive activities are presented below in Table 3.6-14. Direct (measured) TTS data from explosives are not available. Criteria used to define TTS from explosives is derived from data on fishes exposed to seismic air gun signals (Popper et al., 2005) as summarized in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014). TTS has not been documented in fishes without a swim bladder from exposure to other impulsive sources (pile driving and air guns). Although it is possible that fishes without a swim bladder could receive TTS from exposure to explosives, fishes without a swim bladder are typically less susceptible to hearing impairment than fishes with a swim bladder. If TTS occurs in fishes without a swim bladder, it would likely occur within the range of injury, therefore no threshold for TTS are proposed. General research findings regarding hearing loss in fishes as well as findings specific to exposure to other impulsive sound sources are discussed in Section 3.6.3.1.1.2 (Hearing Loss Due to Impulsive Sound Sources).

Table 3.6-14: Sound Exposure Criteria for Hearing Loss from Explosives

Fish Hearing Group	*TTS (SEL_{cum})*
Fishes with a swim bladder not involved in hearing	> 186
Fishes with a swim bladder involved in hearing	186
Fishes with a swim bladder and high-frequency hearing	186

Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micropascal squared seconds [dB re 1 µPa2-s]), > indicates that the given effect would occur above the reported threshold.

As discussed in Section 3.6.3.2.1.2 (Hearing Loss), exposure to sound produced from seismic air guns at a cumulative sound exposure level of 186 dB re 1 µPa2-s has resulted in TTS in fishes with a swim bladder involved in hearing (Popper et al., 2005). TTS has not occurred in fishes with a swim bladder not involved in hearing and would likely occur above the given threshold in Table 3.6-14.

3.6.3.2.2.2 Impact Ranges for Explosives

The following section provides estimated range to effects for fishes exposed to sound and energy produced by explosives. Ranges are calculated using criteria from Table 3.6-13 and Table 3.6-14 and the Navy Acoustic Effects Model. Fishes within these ranges would be predicted to receive the associated effect. Ranges may vary greatly depending on factors such as the cluster size, location, depth, and season of the activity. Table 3.6-15 provides ranges to effect for all fishes without a swim bladder. Only one table (Table 3.6-16) is provided for ranges to effect for all fishes with a swim bladder due to identical numeric thresholds across each hearing group. However, ranges to TTS for fishes with a swim bladder not involved in hearing would be shorter than those reported because this effect has not been observed from the designated threshold in Table 3.6-14.

Table 3.6-15: Range to Effect for Fishes without a Swim Bladder from Explosives

		Range to Effects (meters)		
		Onset of Mortality	*Onset of Injury*	
Bin	*Cluster Size*	*SPL_{peak}*	*SEL_{cum}*	*SPL_{peak}*
E1 (0.25 lb. NEW)	1	49 (40–80)	1 (0–2)	246 (100–1,025)
	100	49 (40–80)	17 (16–30)	246 (100–1,025)
E2 (0.5 lb. NEW)	1	57 (50–70)	3 (2–4)	247 (110–410)
E3 (2.5 lb. NEW)	1	105 (70–220)	4 (4–5)	543 (150–1,775)
	50	105 (70–220)	30 (25–40)	543 (150–1,775)

Table 3.6-15: Range to Effect for Fishes without a Swim Bladder from Explosives (continued)

Bin	Cluster Size	Range to Effects (meters)		
		Onset of Mortality	Onset of Injury	
		SPL_{peak}	SEL_{cum}	SPL_{peak}
E4 (5 lb. NEW)	1	151 (140–370)	11 (6–30)	1,027 (625–2,025)
E5 (10 lb. NEW)	1	163 (90–330)	8 (7–15)	688 (210–2,025)
	25	163 (90–330)	34 (25–85)	688 (210–2,025)
E6 (20 lb. NEW)	1	218 (120–1,275)	10 (9–18)	950 (370–3,025)
E7 (60 lb. NEW)	1	465 (380–525)	26 (25–30)	3,643 (3,025–4,525)
E8 (100 lb. NEW)	1	419 (160–1,275)	21 (15–30)	2,224 (525–7,025)
E9 (250 lb. NEW)	1	462 (280–550)	24 (20–35)	1,749 (775–5,025)
E10 (500 lb. NEW)	1	511 (240–925)	32 (25–55)	2,307 (725–11,525)
E11 (650 lb. NEW)	1	1,075 (625–2,775)	74 (65–120)	5,693 (2,275–15,525)
E12 (1,000 lb. NEW)	1	701 (360–1,025)	39 (30–70)	2,758 (1,025–17,275)
E16 (14,500 lb. NEW)	1	5,039 (1,775–8,025)	322 (320–330)	14,997 (9,025–31,525)
E17 (58,000 lb. NEW)	1	6,740 (2,775 –11,525)	705 (600 –1,000)	20,963 (11,775–46,525)

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift. Range to effects represents modeled predictions in different areas and seasons within the Study Area. Each cell contains the estimated average, minimum and maximum range to the specified effect.

Table 3.6-16: Range to Effect for all Fishes with a Swim Bladder from Explosives

Bin	Cluster Size	*Range to Effects (meters)*			
		Onset of Mortality	*Onset of Injury*		*TTS*
		SPL_{peak}	*SEL_{cum}*	*SPL_{peak}*	*SEL_{cum}*
E1 (0.25 lb. NEW)	1	49 (40–80)	8 (8–10)	453 (140 –1,025)	52 (45–85)
	100	49 (40–80)	73 (55–120)	453 (140–1,025)	471 (180–1,275)
E2 (0.5 lb. NEW)	1	57 (50–70)	13 (10–16)	467 (160 –1,275)	92 (55–170)
E3 (2.5 lb. NEW)	1	105 (70 –220)	20 (17–30)	962 (230–3,775)	129 (75–260)
	50	105 (70–220)	129 (75–260)	962 (230–3,775)	830 (240–2,525)
E4 (5 lb. NEW)	1	151 (140–370)	55 (25–180)	1,874 (850–5,275)	432 (150–1,275)
E5 (10 lb. NEW)	1	163 (90–330)	30 (25–75)	1,112 (330–4,025)	198 (100–490)
	25	163 (90–330)	139 (85–350)	1,112 (330–4,025)	755 (260–2,775)
E6 (20 lb. NEW)	1	218 (120–1,275)	43 (30–95)	1,569 (550–5,275)	339 (170–1,275)
E7 (60 lb. NEW)	1	465 (380–525)	147 (130–180)	5,338 (3,775–9,775)	1,504 (1,275–1,775)
E8 (100 lb. NEW)	1	419 (160–1,275)	99 (55–190)	3,951 (800 –13,025)	784 (240–2,525)
E9 (250 lb. NEW)	1	462 (280–550)	116 (75–230)	3,094 (1,025–17,275)	683 (340–1,275)
E10 (500 lb. NEW)	1	511 (240–925)	162 (95–350)	5,025 (975–30,525)	860 (370–7,775)
E11 (650 lb. NEW)	1	1,075 (625–2,775)	378 (290–875)	9,705 (2,525–25,775)	3,152 (1,525–8,525)
E12 (1,000 lb. NEW)	1	701 (360–1,025)	241 (120–460)	4,778 (1,525–40,775)	1,084 (525–7,525)
E16 (14,500 lb. NEW)	1	5,039 (1,775–8,025)	1,738 (1,275–2,275)	23,868 (16,025–51,775)	14,863 (11,525–21,775)
E17 (58,000 lb. NEW)	1	6,740 (2,775–11,525)	3,612 (2,775–4,525)	32,369 (12,775–85,275)	26,240 (13,775–51,775)

Notes: SEL_{cum} = Cumulative sound exposure level, SPL_{peak} = Peak sound pressure level, TTS = Temporary Threshold Shift.
Range to effects represent modeled predictions in different areas and seasons within the Study Area. Each cell contains the estimated average, minimum and maximum range to the specified effect.

3.6.3.2.2.3 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3.2 (Explosive Stressors), and Appendix A (Navy Activity Descriptions), training activities under Alternative 1 would use underwater detonations and explosive munitions. Training activities involving explosions would be concentrated in the Virginia Capes Range Complex, followed in descending order of numbers of activities by Jacksonville, Navy Cherry Point, Gulf of Mexico, Northeast, and Key West Range Complexes, and the lower Chesapeake Bay, although training activities could occur anywhere within the Study Area. Activities that involve underwater detonations and explosive munitions typically occur more than 3 NM from shore however, some mine warfare and demolition activities could also occur in shallow water close to shore. In addition, the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Seafloor Resource Mitigation Areas), which will consequently also help avoid potential impacts on fishes that shelter and feed on shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks.

Sound and energy from explosions could result in mortality and injury, on average, for hundreds to even thousands of meters from some of the largest explosions. Exposure to explosions could also result in hearing loss in nearby fishes. The estimated range to each of these effects based on explosive bin size is provided in Table 3.6-13. Generally, explosives that belong to larger bins (with large net explosive weights) produce longer ranges within each effect category. However, some ranges vary depending upon a number of other factors (e.g., number of explosions in a single activity, depth of the charge, etc.). Fishes without a swim bladder, adult fishes, and larger species would generally be less susceptible to injury and mortality from sound and energy associated with explosive activities than small, juvenile or larval fishes. Fishes that experience hearing loss could miss opportunities to detect predators or prey, or show a reduction in interspecific communication.

If an individual fish were repeatedly exposed to sound and energy 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. If detonations occurred close together (within a few seconds), there could be the potential for masking to occur but this would likely happen at farther distances from the source where individual detonations might sound more continuous. Training activities involving explosions are generally dispersed in space and time. Consequently, repeated exposure of individual fishes to sound and energy from underwater explosions over the course of a day or multiple days is not likely and most behavioral effects are expected to be short-term (seconds or minutes) and localized. Exposure to multiple detonations over the course of a day would most likely lead to an alteration of natural behavior or the avoidance of that specific area.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization), all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting sound produced by explosives. Atlantic salmon, Atlantic sturgeon, smalltooth sawfish, Gulf sturgeon, scalloped hammerhead sharks, Nassau grouper, giant manta rays and oceanic whitetip sharks may be exposed to sound and energy from explosives associated with training activities throughout the Study Area. Atlantic salmon occur in the Northeast Range Complex where relatively few explosive activities occur throughout a given year. Although they may be more likely to be exposed to detonations at the water's surface or throughout the water column, impacts, if they occur, would be infrequent due to the lack of overlap in habitat and activity areas. Atlantic sturgeon may be exposed throughout the year in the Northeast, Navy Cherry

Point, and Jacksonville Range Complexes but in particular, may be more likely to be exposed to activities that occur in the Virginia Capes Range Complex and the lower Chesapeake Bay. Shortnose sturgeon are primarily restricted to inshore waters with only infrequent excursions into the marine environment and therefore are not likely to be exposed to sound and energy from explosives. Smalltooth sawfish and Gulf sturgeon may be exposed to sound and energy from explosions associated with training activities throughout the year in the Gulf of Mexico Range complex. In addition, smalltooth sawfish could also occur in the Jacksonville and Key West Range Complexes and the Panama City OPAREA. Known habitat for the Central and Southwest Distinct Population Segment of scalloped hammerhead shark only overlaps with a small southern portion of the Study Area, so the likelihood of exposure would be rare. Nassau grouper may be exposed to training activities throughout the year in the Jacksonville and the Key West Range Complexes. Giant manta ray and oceanic whitetip sharks could be exposed throughout the Study Area.

Proposed training activities involving the use of explosives overlap designated critical habitat for Gulf sturgeon within one mile of the coastline in the eastern Gulf of Mexico as discussed in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. Explosives are typically detonated 3 NM offshore however, if the use of explosive sources overlapped Gulf sturgeon critical habitat, it is unlikely to interfere with the individuals' safe and unobstructed passage between riverine, estuarine, and marine habitats. However, part of the physical and biological features for Gulf sturgeon critical habitat includes abundant prey items (e.g., amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, molluscs, and crustaceans) within estuarine and marine habitats and substrates. The use of explosives within the critical habitat may affect the abundance of prey items.

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida and Atlantic sturgeon critical habitat are within estuarine and river systems. Explosives are typically detonated 3 NM offshore and are not anticipated to overlap with critical habitat designated for Atlantic salmon and smalltooth sawfish or proposed critical habitat for Atlantic sturgeon.

Pursuant to the ESA, the use of explosives during training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. The use of explosives during training activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, and designated critical habitat for Gulf sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Explosives Under Alternative 1 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3.2 (Explosive Stressors), and Appendix A (Navy Activity Descriptions), testing activities under Alternative1 would involve underwater detonations and explosive munitions. Testing activities would be conducted, in descending order, in the Virginia Capes, Jacksonville, Northeast, Gulf of Mexico, Key West, and Navy Cherry Point Range Complexes, as well as the Naval Surface Warfare Center, Panama City Testing Range. Small Ship Shock Trials could take place any season within the deep offshore water of the Virginia Capes Range Complex or in the Spring, Summer or Fall within the Jacksonville Range Complex and would occur up to three times over a 5-year period. The Large Ship Shock Trial could take place in the Jacksonville

Range Complex during the Spring, Summer, or Fall and during any season within the deep offshore water of the Virginia Capes Range Complex or within the Gulf of Mexico. The Large Ship Shock Trial would occur once over 5 years. Testing activities using explosives do not normally occur within 3 NM of shore; the exception is the designated underwater detonation area near Naval Surface Warfare Center, Panama City Division Testing Range, which is nearshore, partially within the surf zone. Although there is the potential for larger ranges to mortality or injury due to Ship Shock trials, proposed testing activities that involve explosives under Alternative 1 would differ in number and location from training activities under Alternative 1; however, the types and severity of impacts would not be discernible from those described above in Section 3.6.3.2.2.3 (Impacts from Explosives under Alternative 1 for Training Activities). To avoid potential impacts, the Navy will implement mitigation that includes ceasing ship shock trial explosive detonations if a large school of fish is observed in the mitigation zone, and seasonal mitigation for line charge testing specific to Gulf Sturgeon migrations in the Naval Surface Warfare Center, Panama City Division Testing Range, as discussed in Section 5.3.3, Explosive Stressors. In addition to procedural mitigation, the Navy will implement mitigation to avoid impacts from explosives on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Seafloor Resource Mitigation Areas). The mitigation areas will further avoid potential impacts on fishes that shelter and feed on shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks.

As discussed previously in Section 3.6.2.1.3 (Hearing and Vocalization), all ESA-listed and proposed fish species that occur in the Study Area are capable of detecting sound produced by explosives. Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, Nassau grouper, giant manta rays and oceanic whitetip sharks may be exposed to sound and energy from explosives associated with testing activities throughout the Study Area. Known habitat for the Central and Southwest Distinct Population Segment of scalloped hammerhead shark only overlaps with a small southern portion of the Study Area, but would not occur in range complexes where explosives are used during testing activities.

Atlantic salmon occur in the Northeast Range Complex where relatively few explosive activities occur throughout a given year. Although they may be more likely to be exposed to detonations at the water's surface or throughout the water column, impacts, if they occur, would be infrequent due to the lack of overlap in habitat and activity areas. Atlantic sturgeon may be exposed throughout the year in the Northeast, Navy Cherry Point, and Jacksonville Range Complexes and the Chesapeake Bay area but are more likely to be exposed to activities that occur in the Virginia Capes Range Complex and the lower Chesapeake Bay. Shortnose sturgeon are primarily restricted to inshore waters with only infrequent excursions into the marine environment and therefore may only be exposed to sound and energy from explosive activities in nearshore areas within the Northeast, Navy Cherry Point, and Jacksonville Range Complexes. Smalltooth sawfish and Gulf sturgeon, may be exposed to sound and energy from explosive activities associated with testing activities throughout the year in the Gulf of Mexico Range Complex. In addition, smalltooth sawfish could also occur in the Jacksonville and Key West Range Complexes and the Panama City OPAREA portion of the Gulf of Mexico Range Complex and the Naval Surface Warfare Center, Panama City Testing Range. Nassau grouper may be exposed to testing activities throughout the year in the Jacksonville and the Key West Range Complexes. Giant manta ray and oceanic whitetip sharks could be exposed throughout the Study Area.

To avoid potential impacts during one activity that occurs close to shore in Gulf sturgeon habitat (line charge testing), the Navy will implement mitigation that includes avoiding line charge testing in nearshore waters in the Naval Surface Warfare Center, Panama City Division Testing Range (except within the designated location on Santa Rosa Island) between October and March. The mitigation would help avoid impacts from explosives during Gulf sturgeon migrations from the Gulf of Mexico winter and feeding grounds to the spring and summer natal (hatching) rivers (the Yellow, Choctawhatchee, and Apalachicola Rivers).

Designated critical habitat for Atlantic salmon is restricted to rivers within Maine. Likewise, designated critical habitat for smalltooth sawfish is restricted to nearshore, shallow waters (less than 1 m) around the tip of Florida and Atlantic sturgeon critical habitat are within estuarine and river systems. Explosives are typically detonated 3 NM offshore and are not anticipated to overlap with critical habitat designated for Atlantic salmon and smalltooth sawfish or proposed critical habitat for Atlantic sturgeon.

Proposed testing activities overlap designated critical habitat for Gulf sturgeon within one mile of the coastline in the eastern Gulf of Mexico as discussed in Section 3.6.2.2.6.1 (Status and Management). Most of the physical and biological features are generally not applicable to the Study Area since they occur within the riverine habitat of the species. Explosives are typically detonated 3 NM offshore however, if the use of explosive sources overlapped Gulf sturgeon critical habitat, it is unlikely to interfere with the individuals' safe and unobstructed passage between riverine, estuarine, and marine habitats. However, part of the physical and biological features for Gulf sturgeon critical habitat includes abundant prey items (e.g., amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, molluscs, and crustaceans) within estuarine and marine habitats and substrates. The use of explosives within the critical habitat may affect the abundance of prey items within the vicinity of the explosion. Therefore, explosives used in proposed training activities may affect Gulf sturgeon designated critical habitat.

Pursuant to the ESA, the use of explosives during testing activities, as described under Alternative 1, will have no effect on ESA-listed Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, designated critical habitat for Atlantic salmon and smalltooth sawfish, and proposed critical habitat for Atlantic sturgeon. The use of explosives during testing activities, as described under Alternative 1, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, and designated critical habitat for Gulf sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.2.2.4 Impacts from Explosives Under Alternative 2

Impacts from Explosives Under Alternative 2 for Training Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), Section 3.0.3.3.2 (Explosive Stressors), and Appendix A (Navy Activity Descriptions), training activities under Alternative 2 would be almost identical to those described under Alternative 1. The differences in the number of activities within each range complex across a year is nominal with only slight increases in activities in the Virginia Capes Range Complex across a five year period; therefore, the locations, types, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.2.2.3 (Impacts from Explosives Under Alternative 1 – Training Activities).

Pursuant to the ESA, the use of explosives during training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. The use of explosives during training activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, and designated critical habitat for Gulf sturgeon.

Impacts from Explosives Under Alternative 2 for Testing Activities

As described in Chapter 2 (Description of Proposed Action and Alternatives), testing activities under Alternative 2 include activities that produce sound and energy from explosives. Testing activities under Alternative 2 would be almost identical to those described under Alternative 1. The differences in the number of activities across a year is nominal with only slight increases in activities in the Virginia Capes Range Complex and the Naval Surface Warfare Center, Panama City Testing Range across a five year period; therefore the locations, types, and severity of predicted impacts would not be discernible from those described above in Section 3.6.3.2.2.3 (Impacts from Explosives Under Alternative 1 – Testing Activities).

Pursuant to the ESA, the use of explosives during testing activities, as described under Alternative 2, will have no effect on ESA-listed Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, designated critical habitat for Atlantic salmon, smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon. The use of explosives during testing activities, as described under Alternative 2, may affect ESA-listed Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, smalltooth sawfish, Gulf sturgeon, Nassau grouper, proposed giant manta rays and oceanic whitetip sharks, and designated critical habitat for Gulf sturgeon.

3.6.3.2.2.5 Impacts from Explosives Under the No Action Alternative

Impacts from Explosives Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various explosive stressors (e.g., explosive shock wave and sound; explosive fragments) would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment either would remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.3 Energy Stressors

This section analyzes the potential impacts of the various types of energy stressors that can occur during training and testing activities within the Study Area. This section includes analysis of the potential impacts from (1) in-water and in-air electromagnetic devices and (2) high energy lasers.

3.6.3.3.1 Impacts from in-Water Electromagnetic Devices

Several different electromagnetic devices are used during training and testing activities. A discussion of the characteristics of energy introduced into the water through naval training and testing activities and the relative magnitude and location of these activities is presented in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), while Table B-1 (Appendix B) lists the activities in each alternative that use the devices.

A comprehensive review of information regarding the sensitivity of marine organisms to electric and magnetic impulses is presented in (Normandeau et al., 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 (Hore, 2012), further investigation is necessary to understand the physiological response and magnitude of the potential impacts. Most examinations of electromagnetic fields on marine fishes have focused on buried undersea cables associated with offshore wind farms in European waters (Boehlert & Gill, 2010; Gill, 2005; Ohman et al., 2007).

Many fish groups including lampreys, elasmobranchs, sturgeon, eels, marine catfish, salmonids, stargazers, tuna, and others, have an acute sensitivity to electrical fields, known as electroreception (Bullock et al., 1983; Helfman et al., 2009). Fishes likely use the same sensory organs (e.g., lateral line system particularly around the head) for electroreception and also for detecting sounds. Some species such as sharks such as the scalloped hammerhead have small pores near the nostrils, around the head and on the underside of the snout, or rostrum called ampullae of Lorenzini to detect the electromagnetic signature of their prey. Each ESA-listed fish has some level of electroreception, but elasmobranchs (including sawfishes) are more sensitive than the others. 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 per cm and behaviorally at 5 nanovolts per cm (Collin & Whitehead, 2004), while Kajiura & Holland (2002) showed juvenile scalloped hammerhead sharks detected and behaviorally responded to electric fields of less than 1 nanovolt per cm.

There are two general types of electroreceptor organs in fishes (Helfman et al., 2009). Ampullary receptors, located in recesses in the skin, are connected to the surface by a canal filled with a conductive gel and are sensitive to electric fields of low-frequency (<0.1 to 25 Hz). Tuberous receptors are located in depressions of the epidermis, are covered with loosely packed epithelial cells, and detect higher frequency electric fields (50 Hz to > 2 kHz). They are typically found in fishes that use electric organs to produce their own electric fields. The distribution of electroreceptors on the head of these fishes, especially around the mouth (e.g., along the rostrum of sawfishes), suggests that these sensory organs may be used in foraging. Additionally, some researchers hypothesize that the electroreceptors aid in social communication (Collin & Whitehead, 2004).

Electromagnetic sensitivities of the Gulf, Atlantic, and shortnose sturgeon have not been heavily studied; however, the presence of electroreceptive ampullae in all sturgeon strongly supports the assertion that they are sensitive to electromagnetic energy (Bouyoucos et al., 2014). The ampullae of some fishes are sensitive to low frequencies (less than 0.1–25 Hz) of electrical energy (Helfman et al., 2009), which may be of physical or biological origin, such as muscle contractions. A recent study on juvenile Atlantic sturgeon showed a behavioral avoidance of electropositive metals when food was present (Bouyoucos et al., 2014). (Zhang et al., 2012) studied electroreception on Siberian sturgeon (*Acipenser baerii*) and suggested that electroreception plays a role in the feeding behavior of most sturgeon species.

While elasmobranchs and other fishes can sense the level of the earth's electromagnetic field, the potential impacts on fishes 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 & Lowe, 2008). A recent study on cat sharks (*Scyliorhinus canicula*) demonstrated that sharks may show habituation to electrical fields over short-term exposures (Kimber et al., 2014). Other studies suggest that sharks are attracted to electromagnetic sources when conditions in the water hinder their other senses such as sight and hearing. This attraction to electromagnetic sources helps sharks to find prey when in these low sensory conditions (Fields, 2007).

The mechanism for direct sensing of magnetic fields is unknown; however, the presence of magnetite (a magnetic mineral) in the tissues of some fishes such as tunas and salmon, or other sensory systems such as the inner ear and the lateral line system may be responsible for electromagnetic reception (Helfman et al., 2009). Magnetite of biogenic origins has been documented in the lateral line of the European eel (*Anguilla anguilla*), a close relative of the American eel; both species occur in the Study Area (Moore & Riley, 2009). These species undergo long-distance migrations from natal waters of the Sargasso Sea (North Atlantic Subtropical Gyre) to freshwater habitats in Europe and North America (Helfman et al., 2009), where they mature and then return as adults to the Sargasso Sea to spawn. Some species of salmon, tuna, and stargazers have likewise been shown to respond to magnetic fields and may also contain magnetite in their tissues (Helfman et al., 2009).

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 & Hocutt, 1990). The observed 48-hour mortality of small estuarine fishes (e.g., sheepshead minnow, mummichog, Atlantic menhaden, striped bass, Atlantic silverside, fourspine stickleback, and rainwater killifish) exposed to electromagnetic pulses of 100–200 kilovolts per meter (10 nanoseconds per pulse) from distances greater than 50 m was not statistically different than the control group (Hartwell et al., 1991; Nemeth & 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 & Hocutt, 1990).

Electromagnetic sensitivity in some marine fishes (e.g., salmonids) is already well-developed at early life stages (Ohman et al., 2007); however, most of the limited research that has occurred focuses on adults. A laboratory study on Atlantic salmon showed no behavioral changes for adults and post-smolts passing through an area with a 50 Hz magnetic field activated (Armstrong et al., 2015). 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 nanovolt per cm) (Kajiura & Holland, 2002). In a test of sensitivity to fixed magnets, five Pacific sharks were shown to react to magnetic field strengths of 2,500–234,000 µT (microtesla) at distances ranging between 0.26 and 0.58 m and avoid the area (Rigg et al., 2009). A field trial in the Florida Keys demonstrated that southern stingrays (*Dasyatis americana*) and nurse sharks (*Ginglymostoma cirratum*) detected and avoided a fixed magnetic field producing a flux of 95,000 µT (O'Connell et al., 2010). A field study on white sharks (*Carcharodon carcharias*) in South Africa suggested behavioral changes in the sharks when approaching a towed prey item with an active electromagnetic field (Huveneers et al., 2013). No change was noticed in the sharks' behavior towards a static prey item. The maximum electromagnetic fields typically generated during Navy training and testing activities is approximately 2,300 µT.

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 lay on the bottom, while many neonate and adult sharks occur in the water column or near the water surface. Exposure of eggs and larvae (ichthyoplankton) to electromagnetic fields would be low since their distributions are extremely patchy. Early life history stages of ESA-listed sturgeon and Atlantic salmon occur in freshwater or estuarine habitats outside of the Study Area. Similarly, sawfish neonates and juveniles typically inhabit nearshore mangrove habitats, beyond the areas where in-water electromagnetic devices are used. For many sharks, skates, rays, and livebearers, the fecundity and natural mortality rates are much lower, and the exposure of the larger neonates and juveniles to electromagnetic energy would be similar across life stages for these species.

Based on current literature, only the fish groups identified above are capable of detecting electromagnetic fields (primarily elasmobranchs, sturgeon, salmonids, tuna, eels, and stargazers) and thus will be carried forward in this section. The remaining major fish groups (from Table 3.6-2) will not be presented further. Aspects of electromagnetic stressors that are applicable to marine organisms in general are described in Section 3.0.3.6.2 (Conceptual Framework for Assessing Effects from Energy-Producing Activities).

3.6.3.3.1.1 Impacts from In-Water Electromagnetic Devices Under Alternative 1

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Training Activities

Under Alternative 1, training activities involving in-water electromagnetic devices occur in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Caribbean Sea, and Gulf of Mexico Large Marine Ecosystems—specifically within the Virginia Capes Range Complex, Navy Cherry Point Range Complex, Jacksonville Range Complex, Gulf of Mexico Range Complex, and within inland waters in these areas. Activities that use in-water electromagnetic devices would remain concentrated within the Virginia Capes Range Complex, accounting for 63 percent of the annual activities. Fish species that do not occur within these specified areas—including the ESA-listed Atlantic salmon— would not be exposed to in-water electromagnetic devices. Species that do occur within the areas listed above—including the ESA-listed smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, Nassau grouper, and the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark would have the potential to be exposed to in-water electromagnetic devices.

Exposure is limited to those marine fish groups able to detect electromagnetic properties in the water column, as described in Section 3.6.2 (Affected Environment), such as elasmobranchs, sturgeon, tuna, salmon, eels, and stargazers (Bullock et al., 1983; Helfman et al., 2009). Fishes sensitive to electromagnetic fields (primarily elasmobranchs, sturgeon, salmonids, tuna, eels, and stargazers) may experience temporary disturbance of normal sensory perception during migratory or foraging movements, or they could experience avoidance or attraction reactions (Fields, 2007; Kalmijn, 2000), resulting in alterations of behavior and avoidance of normal foraging areas or migration routes. Exposure of electromagnetically sensitive fish species to electromagnetic activities has the potential to result in stress to the animal and may also elicit alterations in normal behavior patterns (e.g., swimming, feeding, resting, and spawning). Such effects may have the potential to disrupt long-term growth and survival of an individual. However, due to the temporary (hours) and isolated locations where in-water electromagnetic devices are used in the Study Area, the resulting stress on fishes is not likely to impact the health of resident or migratory populations. Likewise, some fish in the vicinity of training activities may react to in-water electromagnetic devices, but the signals are not widespread or frequent enough to alter behavior on a long-term basis. Any behavioral changes are not expected to have lasting effects on the survival, growth, recruitment, or reproduction of these marine fish groups at the population level.

Smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, oceanic whitetip sharks, and giant manta rays are the only ESA-listed fish species occurring in training areas that are known to be capable of detecting electromagnetic energy. Smalltooth sawfish could occur in the Jacksonville Range Complex, but any occurrences would be extremely rare (Florida Museum of Natural History, 2011). Atlantic sturgeon inhabit inland and coastal waters, and therefore may encounter in-water electromagnetic devices used in training activities in bays and estuaries, like the lower Chesapeake Bay. Other locations include portions of the range complexes that lie over the Continental Shelf, overlapping the normal distribution of Atlantic sturgeon, shortnose sturgeon, and smalltooth sawfish. Oceanic whitetip sharks and giant manta rays are found in offshore waters and may encounter in-water electromagnetic devices used in training activities in those areas. Any behavioral changes are not expected to have lasting effects on the survival, growth, recruitment, or reproduction of fishes at the population level.

The civilian port defense training activity could overlap with Gulf sturgeon critical habitat, if it were to occur in St. Andrew Bay in a given year. Food sources identified as biological and physical features of the critical habitat for Gulf sturgeon that occurs in St. Andrew Bay would not be impacted by this activity; but it is possible, though highly unlikely, that the use of electromagnetic devices may impact fish passage, which is another biological and physical feature of the critical habitat for this species. In addition, civilian port defense training activities in Wilmington, DE; Norfolk, VA; and Savannah, GA overlap with proposed Atlantic sturgeon critical habitat in the Delaware River, James River, and Savannah River, respectively. As with Gulf sturgeon critical habitat, while highly unlikely, electromagnetic activities could affect fish passage within these areas.

All of the biological and physical features required by Atlantic salmon are applicable to freshwater only and are outside the Study Area. Therefore, none of the electromagnetic stressors would affect Atlantic salmon critical habitat. The biological and physical features of critical habitat for smalltooth sawfish are red mangrove habitats and shallow marine waters of less than 1 m deep. Electromagnetic activities do not occur at these depths and thus would not overlap with smalltooth sawfish critical habitat.

The in-water electromagnetic devices used in training activities would not be anticipated to result in more than minimal impact on fishes as individuals or populations because of: (1) the relatively low intensity of the magnetic fields generated (0.2 microtesla at 200 m from the source), (2) the highly localized potential impact area, and (3) the limited and temporally distinct duration of the activities (hours). Some fishes could have a detectable response to electromagnetic exposure, but the fields generated are typically well below physiological and behavioral responses of magnetoreceptive fishes, and 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), or species recruitment, and are not expected to result in population-level impacts. Electromagnetic exposure of eggs and larvae of sensitive bony fishes would be low relative to their total ichthyoplankton biomass (Able & Fahay, 1998); therefore, potential impacts on recruitment would not be expected.

Pursuant to the ESA, the use of in-water electromagnetic devices during training activities, as described under Alternative 1, will have no effect on Atlantic salmon, Nassau grouper, and critical habitats designated for Atlantic salmon and smalltooth sawfish. Training activities under Alternative 1 involving the use of in-water electromagnetic devices may affect smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, proposed oceanic whitetip sharks and giant manta rays, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from In-Water Electromagnetic Devices Under Alternative 1 for Testing Activities

Under Alternative 1, testing activities involving in-water electromagnetic devices occur in a number of areas, including Virginia Capes Range Complex, Navy Cherry Point Range Complex, Jacksonville Range Complex, Gulf of Mexico Range Complex, Naval Undersea Warfare Center Newport Testing Range, South Florida Ocean Measurement Facility, Naval Surface Warfare Center Panama City Testing Range, and within inland waters (see Table 3.0-14). Atlantic salmon and scalloped hammerhead sharks belonging to the Central and Southwest Atlantic Distinct Population Segment do not occur within these specified areas and would not be exposed to in-water electromagnetic devices during testing activities.

ESA-listed species that occur within these areas, including Atlantic sturgeon, shortnose sturgeon smalltooth sawfish, Gulf sturgeon, Nassau grouper, scalloped hammerhead sharks, oceanic whitetip sharks, and giant manta rays would have the potential to be exposed to in-water electromagnetic devices.

Exposure is limited to those marine fish groups able to detect electromagnetic properties in the water column, as described in Section 3.6.2 (Affected Environment), such as elasmobranchs, sturgeon, tuna, salmon, eels, and stargazers (Bullock et al., 1983; Helfman et al., 2009). Two such species, the Atlantic torpedo ray (*Torpedo nobiliana*) and the lesser electric ray (*Narcine brasiliensis*) occur in the Naval Surface Warfare Center, Panama City Division Testing Range, where a portion of the electromagnetic activities will be concentrated.

All of the ESA-listed fish species occurring in areas where testing occurs are capable of detecting electromagnetic energy, with the exception of Nassau grouper. Potential exposure to electromagnetic testing activities may occur in the offshore portions of the testing ranges that lie within the continental shelf, overlapping the normal distribution of Gulf sturgeon, Atlantic sturgeon, shortnose sturgeon, and smalltooth sawfish. Oceanic whitetip sharks and giant manta rays are found in offshore waters and may encounter in-water electromagnetic devices used in testing activities in those areas. Behavioral changes are not expected to have lasting effects on the survival, growth, recruitment, or reproduction of fish species.

Testing activities in the Gulf of Mexico Range Complex could overlap with Gulf sturgeon critical habitat. Food sources identified as biological and physical features of the critical habitat for Gulf sturgeon that would not be impacted by this activity; but it is possible, though highly unlikely, that the use of electromagnetic devices may impact fish passage, which is another biological and physical feature of the critical habitat for this species. The use of electromagnetic devices during testing activities does not overlap with the proposed critical habitat for Atlantic sturgeon.

All of critical habitat biological and physical features required by Atlantic salmon are applicable to freshwater only and are outside the Study Area. Therefore, none of the electromagnetic stressors would affect Atlantic salmon critical habitat. The biological and physical features for smalltooth sawfish are red mangrove habitats and shallow marine waters of less than 1 m deep. Electromagnetic activities do not occur at these depths and thus would not overlap with smalltooth sawfish critical habitat.

The in-water electromagnetic devices used in testing activities would not cause any risk to fish because of the: (1) relatively low intensity of the magnetic fields generated (0.2 microtesla at 200 m from the source), (2) highly localized potential impact area, and (3) limited and temporally distinct duration of the activities (hours). Fishes may have a detectable response to electromagnetic exposure, but would likely recover completely. Potential impacts of exposure to electromagnetic stressors 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.

Pursuant to the ESA, the use of in-water electromagnetic devices during testing activities, as described under Alternative 1, will have no effect on Atlantic salmon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, designated critical habitat for Atlantic salmon and smalltooth sawfish, and proposed critical habitat for Atlantic sturgeon. Testing activities under Alternative 1 involving the use of in-water electromagnetic devices may affect smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, proposed oceanic whitetip sharks and giant manta rays, and designated critical habitat for Gulf sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.3.1.2 Impacts from In-Water Electromagnetic Devices Under Alternative 2

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Training Activities

Because the locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same Under Alternatives 1 and 2, impacts experienced by fishes from in-water electromagnetic devices use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of in-water electromagnetic devices during training activities, as described under Alternative 2, will have no effect on Atlantic salmon, Nassau grouper, and designated critical habitat for Atlantic salmon and smalltooth sawfish. Training activities under Alternative 2 involving the use of in-water electromagnetic devices may affect smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, proposed oceanic whitetip sharks and giant manta rays, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon.

Impacts from In-Water Electromagnetic Devices Under Alternative 2 for Testing Activities

Because the locations, number of events, and potential effects associated with in-water electromagnetic devices would be the same under Alternatives 1 and 2, impacts experienced by fishes from in-water electromagnetic devices use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of in-water electromagnetic devices during testing activities, as described under Alternative 2, will have no effect on Atlantic salmon, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, Nassau grouper, designated critical habitat for Atlantic salmon and smalltooth sawfish, and proposed critical habitat for Atlantic sturgeon. Testing activities under Alternative 2 involving the use of in-water electromagnetic devices may affect smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, proposed oceanic whitetip sharks and giant manta rays, and designated critical habitat for Gulf sturgeon.

3.6.3.3.1.3 Impacts from In-Water Electromagnetic Devices Under the No Action Alternative

Impacts from In-Water Electromagnetic Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Electromagnetic fields from towed devices or unmanned mine warfare systems would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.3.2 Impacts from In-Air Electromagnetic Devices

In-air electromagnetic stressors are not applicable to fishes because they are transmitted in the air and not underwater and will not be analyzed further in this section.

3.6.3.3.3 Impacts from High-Energy Lasers

This section analyzes the potential impacts of high energy lasers on fishes. As discussed in Section 3.0.3.3.3.3 (Lasers), high energy laser weapons are designed to disable surface targets, rendering them immobile. The primary impact from high-energy lasers would be from the laser beam striking the fish at or near the water's surface, which could result in injury or death.

Fish could be exposed to a laser only if the beam missed the target. Should the laser strike the sea surface, individual fish at or near the surface could be exposed. The potential for exposure to a high energy laser beam decreases as the water depth increases. Most fish are unlikely to be exposed to laser activities because they primarily occur more than a few meters below the sea surface.

3.6.3.3.3.1 Impacts from High-Energy Lasers Under Alternative 1

Impacts from High-Energy Lasers Under Alternative 1 for Training Activities

Under Alternative 1, training activities involving high-energy lasers only occur within the Virginia Capes and Jacksonville Range Complexes. Fish species in these areas that occur near the surface, such as oceanic whitetip sharks and giant manta rays, would have the potential to be exposed to high-energy lasers. Although occurring in areas of laser use, while in coastal and offshore waters, Atlantic sturgeon, shortnose sturgeon, and smalltooth sawfish typically occur in the lower depths of the water column or near the seafloor and would not be exposed. Atlantic salmon, Gulf sturgeon, Nassau grouper, and the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark do not occur in areas of laser use. In addition, the use of high energy lasers under Alternative 1 for training activities does not overlap with the designated critical habitat for any of the ESA-listed fish species.

Pursuant to the ESA, the use of high-energy lasers during training activities, as described under Alternative 1, would have no effect on Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, Nassau grouper, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The use of high-energy lasers during training activities under Alternative 1 may affect proposed oceanic whitetip sharks and giant manta rays. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from High-Energy Lasers Under Alternative 1 for Testing Activities

Under Alternative 1, high-energy laser weapons would be used for testing activities in the AFTT Study Area, the Northeast U.S. Continental Shelf and Southeast U.S. Continental Shelf Large Marine Ecosystems and Gulf Stream Open Ocean Area (see Table 3.0-15). High-energy laser testing occurs at the highest frequency within the Virginia Capes Range Complex, but would also occur at the Northeast Range Complexes, Navy Cherry Point Range Complex, Jacksonville Range Complex, Key West Range Complex, Gulf of Mexico Range Complex, Naval Undersea Warfare Center Newport Testing Range, South Florida Ocean Measurement Facility, and Naval Surface Warfare Center Panama City Testing Range. Species that occur near the surface at these locations within these areas would have the potential to be exposed.

Some ESA-listed species such as Atlantic salmon, as well as proposed species such as oceanic whitetip sharks and giant mantas that are found in offshore locations and occur near the surface of the water column may pose a higher risk of being exposed to high-energy lasers. Although occurring in areas of laser use, while in coastal and offshore waters, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, and Nassau grouper typically occur in the lower depths of the water column or near the seafloor and would not be exposed. Scalloped hammerheads belonging to the Central and Southwestern Atlantic Distinct Population Segment do not occur in the areas used for testing activities. High-energy laser weapons tests would not overlap with critical habitat for Atlantic salmon, Atlantic sturgeon, smalltooth sawfish, or Gulf sturgeon.

Fishes are unlikely to be exposed to high-energy lasers based on: (1) the relatively low number of events, (2) the very localized potential impact area of the laser beam, and (3) the temporary duration of potential impact (seconds).

Pursuant to the ESA, the use of high-energy lasers during testing activities, as described under Alternative 1, will have no effect on Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, Nassau grouper, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The use of high-energy lasers during testing activities under Alternative 1 may affect Atlantic salmon, proposed giant manta rays and oceanic whitetip sharks. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.3.3.2 Impacts from High-Energy Lasers Under Alternative 2

Impacts from High-Energy Lasers Under Alternative 2 for Training Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, impacts experienced by fishes from high-energy laser use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of high-energy lasers during training activities, as described under Alternative 2, would have no effect on Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, Nassau grouper, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The use of high-energy lasers during training activities under Alternative 2 may also affect proposed giant manta rays and oceanic whitetip sharks.

Impacts from High-Energy Lasers Under Alternative 2 for Testing Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, impacts experienced by fishes from high-energy laser use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of high-energy lasers during testing activities, as described under Alternative 2, will have no effect on Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, Nassau grouper, the Central and Southwest Atlantic Distinct Population Segment of the scalloped hammerhead shark, designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The use of high-energy lasers during testing activities under Alternative 2 may affect ESA-listed Atlantic salmon and proposed giant manta rays and oceanic whitetip sharks.

3.6.3.3.3.3 Impacts from High-Energy Lasers Under the No Action Alternative

Impacts from High-Energy Lasers Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area and fishes would not be exposed to high-energy lasers. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4 Physical Disturbance and Strike Stressors

This section analyzes the potential impacts of the various types of physical disturbance and potential for strike during training and testing activities within the Study Area from (1) vessels and in water devices, (2) military expended materials, including non-explosive practice munitions and fragments from high-explosive munitions, and (3) seafloor devices. A discussion of the relative magnitude and location of these activities is presented in Section 3.0.3.3.4 (Physical Disturbance and Strike Stressors), while Table B-1 (Appendix B) lists the activities in each alternative that use the devices.

How a physical strike impacts a fish depends on the relative size of the object potentially striking the fish and the location of the fish in the water column. Before being struck by an object, Atlantic salmon for example, would sense a pressure wave through the water (Hawkins & Johnstone, 1978) and have the ability to swim away from the oncoming object. The movement generated by a large object moving through the water would simply displace small fishes in open water, such as Atlantic herring. Some fish might have time to detect the approaching object and swim away; others could be struck before they become aware of the object. An open-ocean fish that is displaced a small distance by movements from an object falling into the water nearby would likely continue on its original path as if nothing had happened. However, a bottom-dwelling fish near a sinking object would likely be disturbed, and may exhibit a general stress response, as described in Section 3.0.3.6 (Biological Resource Methods). As in all vertebrates, the function of the stress response in fish is to rapidly alter blood chemistry levels or ratios 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). If the object hits the fish, direct injury (in addition to stress) or death may result.

The potential responses to a physical strike are varied, but include behavioral changes such as avoidance, altered swimming speed and direction, physiological stress, and physical injury or mortality. Despite their ability to detect approaching vessels using a combination of sensory cues (e.g., sight, hearing, and lateral line), larger slow-moving fishes (e.g., whale sharks [*Rhincodon typus*], basking sharks [*Cetorhinus maximus*], manta rays [*Manta* spp.), sturgeon [*Acipenser* spp.], and ocean sunfish) cannot avoid all collisions, with some collisions resulting in mortality (Balazik et al., 2012; Braun et al., 2015; Brown & Murphy, 2010; Couturier et al., 2012; Deakos et al., 2011; Foderaro, 2015; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016; Ramirez-Macias et al., 2012; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007). Many fishes respond by darting quickly away from the stimulus. Some other species may respond by freezing in place and adopting cryptic coloration, while still some other species may respond in an unpredictable manner. Regardless of the response, 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 a variety of factors. Some fish species are more tolerant of stressors than others and become re-acclimated more easily. 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 up to, or longer than, 24 hours. During its 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 and strike to adults may be different than for other life stages (e.g., eggs, larvae, juveniles) because these life stages do not necessarily occur together in the same location (Botsford et al., 2009; Sabates et al., 2007), and because they have different response capabilities. The numbers of eggs and larvae exposed to vessel movements would be low relative to total ichthyoplankton biomass (Able & Fahay, 1998); therefore, measurable effects on fish recruitment would not be expected. Also, the early life stages of most marine fishes (excluding sharks and other livebearers) already have extremely high natural mortality rates (10–85 percent per day) from predation on these life stages (Helfman et al., 2009), and therefore, most eggs and larvae are not expected to survive to the next life stage.

3.6.3.4.1 Impacts from Vessels and In-Water Devices

Representative Navy vessel types, lengths, and speeds of vessels used in the Study Area is presented in Table 3.0-16. The number and location of activities including vessels for each alternative is presented in Table 3.0-17, while Table B-1 (Appendix B) lists the activities in each alternative that use the devices.

Vessels

Vessels do not normally collide with adult fishes, most of which can detect and avoid them. One study on Barents sea capelin (*Mallotus villosus*) 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, such as Polar cod (*Boreogadus saida*), haddock (*Melanogrammus aeglefinus*), jack mackerel (*Trachurus symmetricus*), sardine (*Sardina pilchardus*), herring, anchovy (*Engraulis ringens*), and capelin, that were ahead of a ship showed avoidance reactions and did so at ranges of 50–350 m. When the vessel passed over them, some fishes had sudden avoidance 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. Fishes involved in that study included herring (*Clupea harengus*), sprat (*Sprattus sprattus*), and whitefish (*Merlangius merlangus*) (Rostad et al., 2006). 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 & Greer, 1984). 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 & Hawkins, 1973), but avoidance ended within 10 seconds after the vessel departed.

There are a few notable exceptions to this assessment of potential vessel strike impacts on fish groups. Large slow-moving fishes such as whale sharks (Ramirez-Macias et al., 2012; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007), basking sharks (Pacific Shark Research Center, 2017; The Shark Trust, 2017), manta rays (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016), and sturgeon (Balazik et al., 2012; Brown & Murphy, 2010; Foderaro, 2015) may occur near the surface in open-ocean and coastal areas, thus making them more susceptible to ship strikes which may result in blunt trauma, lacerations, fin damage, or mortality. Stevens (2007) noted that increases in the numbers and sizes of shipping vessels in the modern cargo fleets make it difficult to gather strike-related mortality data for whale sharks because personnel on large ships are often unaware of collisions; therefore, the occurrence of vessel strikes is likely much higher than has been documented by the few studies that have been conducted. This holds true not just for whale sharks, but also for any of the aforementioned fish species.

In addition to whale sharks, Atlantic sturgeon have also been documented to be susceptible to vessel strikes. Brown and Murphy (2010) found that 28 deaths of Atlantic sturgeon in the Delaware Bay and the Delaware River were reported over the four-year period of 2005 to 2008. Of those, 50 percent were caused by vessel collisions, although the size and type of the vessels was unknown. An unknown number of additional sturgeon were likely struck by vessels and were not included in this total. Based on an egg-per-recruit analysis of the Delaware River population, the authors concluded that an annual mortality rate of 2.5 percent of the females could have adverse impacts on the population (Brown & Murphy, 2010). In Virginia, Balazik et al. (2012) investigated Atlantic sturgeon mortalities due to vessel strikes that occurred in upstream areas of the James River. Based on observations of fish implanted with acoustic transmitters, the authors concluded that when moving the tracked individuals occurred in water depths overlapping with the draft of ocean cargo vessels (about 23 ft.), but were rarely in depths overlapping the draft of tugboats and small recreational craft (about 3 to 7 ft.). However, as a result of the very small sample size (three fish), this conclusion bears little support. The fish were detected in the navigation channel of the river 69 percent of the time. More recently in New York, it was noted that over the latest three-year period (2012 through 2014), there were 76 known Atlantic sturgeon fatalities attributed to boat strikes around the Tappan Zee Bridge on the Hudson River, in addition to over two dozen more reported during the first six months of 2015 (Foderaro, 2015). This reflects a significant increase when compared to the previous three-year period (2009 through 2011) during which only six sturgeon fatalities were documented. Many have attributed this increase in sturgeon mortality to the increased boat traffic associated with the expansion of the Tappan Zee Bridge, which began in 2012. However, they may also, in part, be the result of an increased effort into monitoring for fish strandings. Regardless, it illustrates the level of susceptibility of Atlantic sturgeon to vessel strikes.

Based on the typical physiological responses described in Section 3.6.3.4 (Physical Disturbance and Strike Stressors), vessel movements are not expected to compromise the general health or condition of individual fishes, except for large slow-moving fishes such as whale sharks, basking sharks, manta rays, sturgeon, and ocean sunfish (Balazik et al., 2012; Brown & Murphy, 2012; Foderaro, 2015; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007).

In-Water Devices

In-water devices do not normally collide with adult fishes, as most can detect and avoid them. Fish responses to in-water devices would be similar to those discussed above for vessels. Fishes would likely show varying behavioral avoidance responses to in-water devices. Early life stages of most fishes could be displaced by in-water devices and not struck in the same manner as adults of larger species. Because in-water devices are continuously moving, most fishes are expected to move away from it or to follow behind it.

3.6.3.4.1.1 Impacts from Vessels and In-Water Devices Under Alternative 1

Impacts from Vessels and In-Water Devices Under Alternative 1 for Training Activities

Section 3.0.3.3.4.1 (Vessels and In-Water Devices) provide estimates of relative vessel and in-water devices use and location for each of the alternatives. These estimates are based on the number of activities predicted for each alternative. While these estimates predict use, actual Navy vessel usage depends on military training and testing requirements, deployment schedules, annual budgets, and other unpredictable factors. Training concentrations mostly depend on locations of Navy shore installations and established training areas. The Navy's use of these areas has not appreciably changed in the last decade and are not expected to change in the foreseeable future. Under Alternative 1, the concentration of vessel movement and in-water device use and the manner in which the Navy trains would remain consistent with the range of variability observed over the last decade. As underwater technologies advance, it is likely that the frequency of in-water device use may increase. However, the Navy does not foresee any appreciable changes in the locations where in-water devices have been used over the last decade, and therefore the level at which strikes are expected to occur is likely to remain consistent with the previous decade.

Navy training vessel traffic could occur anywhere in the Study Area, but would especially be concentrated in Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes, as presented in Table 3.0-17. In addition, there are numerous areas within inland waters where vessels during training activities would be concentrated, including the lower Chesapeake Bay; James River and tributaries; Norfolk, VA; Mayport, FL; Groton, CT; and Newport, RI (see Table 3.0-18). Of particular importance would be inland areas where activities involving large amounts of high-speed vessel movements occur, such as the Lower Chesapeake Bay; James River and tributaries; York River; Cooper River, SC; and Narragansett, RI (see Table 3.0-19). Navy training in-water device use could also take place anywhere in the Study Area, but primarily occurs in the Virginia Capes, Jacksonville, and Navy Cherry Point Range Complexes. A large number of activities involving in-water devices also occur in inland waters, predominately in the Lower Chesapeake Bay; James River and tributaries; St. Andrew's Bay; Mayport, FL; and Kings Bay, GA (see Table 3.0-22).

The risk of a strike from vessels and in-water devices such as a remotely operated vehicles, unmanned surface vehicles, unmanned underwater vehicles, motorized autonomous targets, or towed mine warfare devices used in training activities would be extremely low because (1) most fishes 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 most frequently used. Potential impacts from 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.

As described above, the potential exception would be large, slow-moving fish species, such as Atlantic sturgeon, which are documented to be highly susceptible to vessel strikes and are concentrated in inshore areas where intense high speed vessel movement activities as part of the Proposed Action are common (see Table 3.0-19). Atlantic sturgeon may be susceptible to vessel strikes in these areas, including Lower Chesapeake Bay, James River and tributaries, York River, and Cooper River, resulting in potential injury or mortality. This species is most susceptible to vessel and in-water device strikes in these areas because all five distinct population segments congregate in large numbers in the lower Chesapeake Bay, all sturgeon belonging to two separate and genetically distinct spawning populations from the James River and the York River populations must pass through the lower Chesapeake Bay on their way to and from their spawning grounds, and the York River spawning population is estimated to be very small (several hundred fish) and likely consists of higher numbers of males and relatively few females. As a result, even a loss of a couple of females to this spawning population could have long-term consequences. Gulf sturgeon, a congener of Atlantic sturgeon, are also likely susceptible to vessel and in-water device strikes.

Due to their preference for riverine habitats, absence from the lower Chesapeake Bay and its tributaries, and close association to the seafloor, shortnose sturgeon are not considered to be highly susceptible to vessel and in-water device strikes, with only a few ship strike have been documented for this species (Shortnose Sturgeon Status Review Team, 2010). Likewise, smalltooth sawfish are typically found in shallow, coastal waters where training activities do not occur. When in deeper waters, smalltooth sawfish tend to remain along the seafloor. Nassau grouper are strongly associated with reef and live hard bottom seafloor habitats and, as such, would not be susceptible to vessel and in-water device use.

Giant manta rays in offshore areas may be susceptible to vessel strikes in those areas, as are the closely related reef manta ray (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016). However, unlike the reef manta ray, the giant manta ray is typically found in low numbers and rarely aggregates.

As Atlantic salmon, scalloped hammerhead sharks, and oceanic whitetip sharks also typically occur within the upper water column or at the surface, there is the potential for an interaction to occur, though it is highly unlikely given their ability to detect and avoid vessel and in-water device movements.

Vessel and in-water device use during training activities potentially overlaps with designated critical habitat for Atlantic salmon, Gulf sturgeon, and smalltooth sawfish and proposed critical habitat for Atlantic sturgeon. Unimpeded migratory passageways are included as part of the physical and biological features associated with Atlantic salmon, Atlantic sturgeon, and Gulf sturgeon critical habitat. While unlikely, vessel and in-water device use in inland waters has the potential to delay passage through certain migratory pathways. Vessel and in-water device use in smalltooth sawfish critical habitat is extremely unlikely and would not affect the physical and biological identified for these habitats.

Pursuant to the ESA, the use of vessels and in-water devices during training activities, as described under Alternative 1, will have no effect on Nassau grouper, smalltooth sawfish, and designated critical habitat for smalltooth sawfish. Vessel and in-water device use during training activities under Alternative 1 may affect Atlantic salmon, Atlantic sturgeon, Gulf sturgeon, shortnose sturgeon, oceanic whitetip sharks, Central and Southwestern Atlantic Distinct Population Segment of scalloped hammerhead sharks, designated critical habitat for Atlantic salmon and Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Vessels and In-Water Devices Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), most of the testing activities involve vessel movements. However, the number of activities that include the vessel movement for testing is comparatively lower than the number of training activities. In addition, testing often occurs jointly with a training event, so it is likely that the testing activity would be conducted from a training vessel. Vessel movement in conjunction with testing activities could be widely dispersed throughout the Study Area, but would be concentrated near naval ports, piers, range complexes, and testing ranges. Specifically, testing activities that include vessels would be conducted within the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, Key West, and Gulf of Mexico Range Complexes; the Naval Undersea Warfare Division, Newport Testing Range; South Florida Ocean Measurement Facility Testing Range; Naval Surface Warfare Center, Panama City Division Testing Range; as well as inland waters within the AFTT Study Area. Testing activities involving the use of in-water devices would also occur in the AFTT Study Area at any time of year. Under Alternative 1, testing activities involving the use of in-water devices would be conducted throughout the AFTT Study Area, including the same areas where vessel movement is occurring.

As previously discussed, with the exception of some large, slow-moving species that may occur at the surface, the risk of a strike from a vessel or in-water device used in testing activities would be extremely low because most fishes can detect and avoid in-water device movements, and 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.

As described above in the Alternative 1 training analysis, Atlantic sturgeon, Gulf sturgeon, and giant manta rays have been shown to be susceptible to vessel strikes. As Atlantic salmon, scalloped hammerhead sharks, and oceanic whitetip sharks also typically occur within the upper water column or at the surface, there is the potential for an interaction to occur, though it is highly unlikely given their ability to detect and avoid vessel and in-water device movements.

Due to their preference for riverine habitats, absence from the lower Chesapeake Bay and its tributaries, and close association to the seafloor, shortnose sturgeon are susceptible to vessel and in-water device strikes, but the risk is low. As stated above, only a few ship strike have been documented for this species (Shortnose Sturgeon Status Review Team, 2010). Likewise, smalltooth sawfish are typically found in shallow, coastal waters where testing activities do not occur. When in deeper waters, smalltooth sawfish tend to remain along the seafloor. Nassau grouper are strongly associated with reef and live hardbottom seafloor habitats and, as such, would not be susceptible to vessel and in-water device use.

Vessel and in-water device use potentially overlaps with designated critical habitat for Atlantic salmon, Gulf sturgeon, and smalltooth sawfish and proposed critical habitat for Atlantic sturgeon. Unimpeded migratory passageways are included as part of the physical and biological features associated with

Atlantic salmon, Atlantic sturgeon, and Gulf sturgeon critical habitat. While unlikely, vessel and in-water device use in inland waters has the potential to delay passage through certain migratory pathways. Vessel and in-water device use in smalltooth sawfish critical habitat is extremely unlikely and would not affect the physical and biological identified for these habitats.

Vessel and in-water device use during testing activities potentially overlaps with designated critical habitat for Atlantic salmon, Gulf sturgeon, and smalltooth sawfish and proposed critical habitat for Atlantic sturgeon. Unimpeded migratory passageways are included as part of the physical and biological features associated with Atlantic salmon, Atlantic sturgeon, and Gulf sturgeon critical habitat. While unlikely, vessel and in-water device use in inland waters has the potential to delay passage through certain migratory pathways within Atlantic salmon and Atlantic sturgeon critical habitat, but testing activities should not affect Gulf sturgeon critical habitat as inland testing activities do not overlap with critical habitat for this species. Vessel and in-water device use in smalltooth sawfish critical habitat is extremely unlikely and would not affect the physical and biological identified for these habitats.

Pursuant to the ESA, the use of vessels and in-water devices during testing activities, as described under Alternative 1, will have no effect on Nassau grouper, smalltooth sawfish, and designated critical habitat for Gulf sturgeon and smalltooth sawfish. Vessel and in-water device use during testing activities under Alternative 1 may affect Atlantic salmon, Atlantic sturgeon, Gulf sturgeon, shortnose sturgeon, oceanic whitetip sharks, Central and Southwestern Atlantic Distinct Population Segment of scalloped hammerhead *s*harks, designated critical habitat for Atlantic salmon, and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.4.1.2 Impacts from Vessels and In-Water Devices Under Alternative 2

Impacts from Vessels and In-Water Devices Under Alternative 2 for Training Activities

Activities under Alternative 2 would occur at a slightly higher rate and frequency relative to Alternative 1 for certain activities. Therefore physical disturbance and strike stress experienced by fishes from vessel use and in-water devices under Alternative 2 are expected to be slightly increased in comparison to those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are slightly greater than they are for Alternative 1.

Pursuant to the ESA, the use of vessels and in-water devices during training activities, as described under Alternative 2, will have no effect on Nassau grouper, smalltooth sawfish, and designated critical habitat for smalltooth sawfish. Vessel and in-water device use during training activities under Alternative 2 may affect Atlantic salmon, Atlantic sturgeon, Gulf sturgeon, shortnose sturgeon, proposed oceanic whitetip sharks and giant manta rays, Central and Southwestern Atlantic Distinct Population Segment of scalloped hammerhead *s*harks, designated critical habitat for Atlantic salmon and Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon.

Impacts from Vessels and In-Water Devices Under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 would occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from vessel use and in-water device under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of vessels and in-water devices during testing activities, as described under Alternative 2, will have no effect on Nassau grouper, smalltooth sawfish, and designated critical habitat for Gulf sturgeon and smalltooth sawfish. Vessel and in-water device use during testing activities under Alternative 2 may affect Atlantic salmon, Atlantic sturgeon, Gulf sturgeon, shortnose sturgeon, proposed oceanic whitetip sharks and giant manta rays, Central and Southwestern Atlantic Distinct Population Segment of scalloped hammerhead *s*harks, designated critical habitat for Atlantic salmon, and proposed critical habitat for Atlantic sturgeon.

3.6.3.4.1.3 Impacts from Vessels and In-Water Devices Under the No Action Alternative

Impacts from Vessels and In-Water Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various physical strike stressors to fishes from vessels or in-water devices would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4.2 Impacts from Aircraft and Aerial Targets

Aircraft and aerial targets stressors are not applicable to fishes because they are conducted in the air and not underwater and will not be analyzed further in this section.

3.6.3.4.3 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; small-, medium-, and large-caliber projectiles; or sinking exercises with ship hulks. 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 disturbance or strike potential to fishes of the following categories of military expended materials: (1) non-explosive practice munitions, (2) fragments from high-explosive munitions, and (3) expended materials other than munitions, such as sonobuoys, ship hulks, and expendable targets. Section 3.0.3.3.4.2 (Military Expended Materials) provides information on the quantity and location where activities would occur under each alternative. Appendix F (Military Expended Materials and Direct Strike Impact Analyses) provides additional information on each military expended material proposed to be used, where it would be used, how many would be used, and the amount of area impacted by each device. Analysis of all potential impacts (disturbance, strike) of military expended materials on critical habitat is included in this section.

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. 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 high-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.

Ship Hulk. During a sinking exercise, aircraft, ship, and submarine crews fire or drop munitions on a seaborne target, usually a clean deactivated ship (Section 3.2, Sediments and Water Quality), which is deliberately sunk using multiple weapon systems. A description of Sinking Exercises is presented in Appendix A (Navy Activity Descriptions). Sinking exercises occur in specific open ocean areas, outside of the coastal range complexes, in waters exceeding 3,000 m (9,842.5 ft.) in depth. Direct munitions 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 in the respective sections. 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 and testing events, include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including 5-in. naval gun shells, and small-, medium-, and large-caliber projectiles. The larger-caliber projectiles are primarily used in the open ocean beyond 20 NM. Direct munitions 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 practice munitions delivery. Expended rounds may strike the water surface with sufficient force to cause injury or mortality. However, limited fish species swim right at, or near, the surface of the water (e.g., with the exception of pelagic sharks, herring, salmonids, flying fishes, jacks, tuna, mackerels, billfishes, ocean sunfish, and other similar species).

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. Most munitions would sink through the water column and come to rest on the seafloor, stirring up sediment and possibly inducing an alarm 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 munitions, the water depth, the number of rounds delivered, the frequency of training and testing, and the sensitivity of the fish (U.S. Department of the Navy, 2013).

Bombs, Missiles, and Rockets. Direct munitions 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 munitions 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.

Even though statistical modeling conducted for the Study Area (discussed in Appendix F –Military Expended Materials and Direct Strike Impact Analyses) indicates that the probability of military expended materials striking marine mammals or sea turtles is extremely low, modeling could not be conducted to estimate the probability of military expended material strikes on an individual fish. This is primarily due to the lack of fish density data available at the scale of a range complex 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 Appendix F.

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, herring, salmonids, flying fishes, jacks, tuna, mackerels, billfishes, and ocean sunfish (Table 3.6-2) 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 3.6-2). 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 fishes 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).

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 show that fragments are large and decelerate rapidly (O'Keeffe & Young, 1984; Swisdak & Montaro, 1992), posing little 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 range complexes, or the remainder of the Study Area. The expected reaction of fishes exposed to military expended materials 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).

3.6.3.4.3.1 Impacts from Military Expended Materials Under Alternative 1

Impacts from Military Expended Materials Under Alternative 1 for Training Activities

As stated above, Section 3.0.3.3.4.2 (Military Expended Materials) provides information on the number and location where activities would occur under each alternative, while Appendix F (Military Expended Materials and Direct Strike Impact Analyses) has more information on where the military expended material would be used, how many would be used, and the amount of area impacted by each device.

Major fish groups identified in Table 3.6-2 that are particularly susceptible to military expended material strikes are those occurring at the surface, within the offshore and continental shelf portions of the range complexes (where the strike would occur). Those groups include pelagic sharks, herring, salmonids, flying fishes, jacks, tuna, mackerels, billfish, ocean sunfish, and other similar species (Table 3.6-2). 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 hagfish, dragonfish, lanternfishes, Aulopiformes, anglerfishes, and oarfishes.

Projectiles, bombs, missiles, rockets, 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. Fishes at and just below the surface would be most susceptible to injury or death from strikes, because velocity of these materials would rapidly decrease upon contact with the water and as they travel through the water column. Consequently, most water column fishes would have ample time to detect and avoid approaching munitions or fragments that fall through the water column. 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 range complexes. While serious injury or mortality to individual fish would be expected if they were present within range of high-explosive activities (analyzed in Section 3.6.3.1, Acoustic Stressors), sinking exercises under Alternative 1 would not result in impacts on pelagic fish populations at the surface based on the placement of these activities in deep ocean areas where fish abundance is low or widely dispersed. Also, these activities are very few in number. Disturbances to benthic fishes from sinking exercises would be highly localized to the sinking exercise box. Any deep-sea fishes 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 and the wide dispersal of fish in deep ocean areas.

All of the ESA-listed fish species occurring in training areas would be potentially exposed to military expended materials. The Atlantic salmon occurs only in the Northeast Range Complexes and in the three northernmost Large Marine Ecosystems, where the density of military expended materials is very low. Therefore, while military expended materials could overlap with Atlantic salmon, the likelihood of a strike would be extremely low, with discountable effects. Within the Study Area, scalloped hammerhead sharks belonging to the Central and Southwestern Atlantic Distinct Population Segment occur only in the North Atlantic Gyre Open Ocean Area, the Caribbean Sea Large Marine Ecosystem and around Puerto Rico, and the southeastern portion of the Gulf of Mexico Large Marine Ecosystem adjacent to the Key West OPAREA. Therefore, while military expended materials could overlap with scalloped hammerhead sharks, the likelihood of a strike would be extremely low, with discountable effects. Nassau groupers are found in reefs areas of the Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea Large Marine Ecosystems. Even though there's likely some overlap with military expended materials and Nassau grouper, the likelihood of a strike would be extremely low, with discountable effects. All sturgeon are restricted to the continental shelf, particularly the shallow, coastal, or nearshore waters of the Study Area (Dadswell, 2006; Ross et al., 2009) and, therefore, could be exposed to military expended materials in these locations. Sawfishes typically occur in shallow coastal waters of South Florida and the Gulf of Mexico, usually near the ocean bottom, but may occur out to depths of 120 m.

There is no overlap of military expended materials use with designated critical habitat for Atlantic salmon or smalltooth sawfish. All of the physical and biological features required by Atlantic salmon within the Study Area are applicable to freshwater only and are outside of areas where military materials may be expended. Therefore, none of the military expended materials would affect Atlantic salmon critical habitat. The physical and biological features for smalltooth sawfish critical habitat are red mangrove habitats and shallow marine waters of less than 1 m deep. No activities involving military expended materials would occur at these depths and thus would not overlap with smalltooth sawfish critical habitat. Military expended materials could be expended within Gulf sturgeon critical habitat within coastal waters where the Panama City Operating Area overlaps with the critical habitat. Likewise, the use of military expended materials during training activities overlaps with the proposed critical habitat for Atlantic sturgeon in the James and York rivers in Virginia, the Cooper River in South Carolina, and the Savannah River in Georgia. In each case for both Gulf and Atlantic sturgeon critical habitat, while overlap occurs, military expended materials from training exercises are not anticipated to impact any of the physical and biological features identified for these habitats.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). The mitigation will consequently help avoid potential impacts on fishes that inhabit shallow-water coral reefs.

The impact of military expended material strikes on fishes 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, (3) the ability of most fishes to detect and avoid an object falling through the water below the surface, and (4) the implementation of mitigation. 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.

Pursuant to the ESA, military expended material from training activities, as described under Alternative 1, will have no effect on Atlantic salmon and smalltooth sawfish critical habitat, but may affect all ESA-listed fishes and critical habitat designated for Gulf sturgeon and proposed for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Military Expended Materials Under Alternative 1 for Testing Activities

Appendix F (Military Expended Materials and Direct Strike Impact Analyses) has more information on the type and quantities of military expended materials proposed to be used. The type, quantity, and location of testing activities would be substantially less than training activities described above.

Potential impacts from military expended material strikes on marine fish groups and ESA-listed species during testing activities would be similar to those described for comparable training activities. Some fish species potentially impacted by testing activities would be different than those fishes impacted during training activities based on the specific activity and the location of the activity. For example, torpedoes are tested at nine locations (Table 3.0-25) compared to three training locations (Table 3.0-23). Military expended materials hitting the water could result in an extremely unlikely strike of an individual fish, or more likely in a 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.

Similarly, military expended materials are not anticipated to overlap with designated critical habitat for Atlantic salmon or smalltooth sawfish or proposed for Atlantic sturgeon. Military expended materials could be expended within Gulf sturgeon critical habitat within coastal waters where the Panama City Operating Area overlaps with the critical habitat. While overlap with Gulf sturgeon critical habitat may occur, military expended materials from testing exercises are not anticipated to impact any of the physical and biological features identified for these habitats.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). The mitigation will consequently help avoid potential impacts on fishes that inhabit shallow-water coral reefs.

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, (3) the ability of most fishes to detect and avoid an object falling through the water below the surface, and (4) the implementation of mitigation. The potential impacts of military expended material strikes would range from short-term (seconds) and localized disturbances of the water surface and long-term impacts for individuals if struck. However these impacts are not expected to yield any behavioral changes or lasting effects on the survival, growth, recruitment, or reproduction at the population level.

Pursuant to the ESA, military expended material from testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon or smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes and designated critical habitat for Gulf sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.4.3.2 Impacts from Military Expended Materials Under Alternative 2

Impacts from Military Expended Materials Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from military expended materials under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended material from training activities, as described under Alternative 2, will have no effect on Atlantic salmon and smalltooth sawfish critical habitat, but may affect all ESA-listed fishes and critical habitat designated for Gulf sturgeon and proposed for Atlantic sturgeon.

Impacts from Military Expended Materials Under Alternative 2 for Testing Activities

Testing activities under Alternative 2 would occur at a similar rate and frequency relative to Alternative 1. In addition, physical disturbance and strike stress experienced by fishes from military expended materials under Alternative 2 would be the same as those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended material from testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon or smalltooth sawfish, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes and designated critical habitat for Gulf sturgeon.

3.6.3.4.3.3 Impacts from Military Expended Materials Under the No Action Alternative

Impacts from Military Expended Materials Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Various military expended materials stressors for fishes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4.4 Impacts from Seafloor Devices

The number and location of activities including seafloor devices is presented in Section 3.0.3.3.4.3 (Seafloor Devices). Additional information on stressors by testing and training activity is provided in Appendix B. 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 underwater vehicles, and bottom-placed targets that are not expended. As discussed in the military expended materials strike section, objects falling through the water column would slow in velocity as they sink toward the bottom and could be avoided by most, if not all 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 (e.g., bottom crawl vehicles) are also included here. Some fishes are attracted to virtually any tethered object in the water column for food or refuge (Dempster & Taquet, 2004) and could be attracted to a non-explosive mine assembly. However, while a fish might be attracted to the object, its sensory abilities allow it to avoid colliding with fixed tethered objects in the water column (Bleckmann & 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.

3.6.3.4.4.1 Impacts from Seafloor Devices Under Alternative 1

Impacts from Seafloor Devices Under Alternative 1 for Training Activities

Table 3.0-34 shows the number and location of activities that use seafloor devices. As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, training activities that deploy seafloor devices occur in the Northeast and Southeast U.S. Continental Shelf, Caribbean, and Gulf of Mexico Large Marine Ecosystems and the Gulf Stream Open Ocean Area—specifically within eight locations, including Virginia Capes Range Complex, Navy Cherry Point Range Complex, Jacksonville Range Complex, Key West Range Complex, Gulf of Mexico Range Complex, Inland Waters, Chesapeake Bay Area, and Naval Surface Warfare Center Panama City Testing Range.

Aircraft deployed mine shapes, anchor blocks, anchors, and bottom-placed instruments, and targets all have the potential to strike fish upon deployment as they are sinking through the water column and settling on the seafloor. While seafloor device use during training activities could overlap with ESA-listed species, with the exception of Atlantic sturgeon and the Central and Southwestern Distinct Population Segment of scalloped hammerheads, the likelihood of a strike would be extremely low given the low abundance of ESA-listed species recorded in the Study Area, the ability for the species to detect and avoid falling objects through the water below the surface, and the dispersed nature of the activities. However, there would be the potential for effect.

Activities that employ seafloor devices would overlap the critical habitat of the Atlantic sturgeon and Gulf sturgeon. For example, the use of seafloor devices during training activities would overlap proposed critical habitat for Atlantic sturgeon in inland waters such as the Delaware River in Delaware, James and York rivers in Virginia, Cooper River in South Carolina, and Savannah and St. Marys rivers in Georgia and with Gulf sturgeon critical habitat within coastal waters where the Panama City Operating Area overlaps with the critical habitat. Seafloor device use would not overlap with designated Atlantic salmon and smalltooth sawfish critical habitat.

The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that inhabit these areas.

Pursuant to the ESA, the use of seafloor devices during training activities, as described under Alternative 1, will have no effect on Atlantic salmon, the Central and Southwestern Atlantic Distinct

Population Segment of scalloped hammerhead sharks, and designated critical habitat for Atlantic salmon and smalltooth sawfish, but may affect Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, Nassau grouper, proposed oceanic whitetip sharks and giant manta rays, designated critical habitat for Gulf sturgeon and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Seafloor Devices Under Alternative 1 for Testing Activities

Table 3.0-34 shows the number and location of activities that use seafloor devices. As indicated in Section 3.0.3.3.4.3 (Seafloor Devices), under Alternative 1, testing activities that deploy seafloor devices occur in the Northeast Range Complexes, Virginia Capes Range Complex, Navy Cherry Point Range Complex, Jacksonville Range Complex, Key West Range Complex, Gulf of Mexico Range Complex, Naval Undersea Warfare Center Newport Testing Range, South Florida Ocean Measurement Facility, Naval Surface Warfare Center Panama City Testing Range, and Inland Waters such as Little Creek and Norfolk, VA.

As discussed in Section 3.6.3.4.3 (Impacts from Military Expended Material), objects falling through the water column will slow in velocity as they sink toward the bottom and could be avoided by most fishes. While seafloor device use during training activities could overlap with ESA-listed species, the likelihood of a strike would be extremely low given the low abundance of ESA-listed species recorded in the Study Area, the ability for the species to detect and avoid falling objects through the water below the surface, and the dispersed nature of the activities. However, there would be the potential for effect.

Activities that employ seafloor devices would overlap the critical habitat of the Atlantic sturgeon and Gulf sturgeon. For example, the use of seafloor devices during testing activities would overlap proposed critical habitat for Atlantic sturgeon in the, James River in Virginia and with Gulf sturgeon critical habitat within coastal waters where the Panama City Operating Area overlaps with the critical habitat. Seafloor device use would not overlap with designated Atlantic salmon and smalltooth sawfish critical habitat.

The Navy will implement mitigation to avoid potential impacts from seafloor devices on seafloor resources in mitigation areas within the South Florida Ocean Measurement Facility, as discussed in Section 5.4.1 (Mitigation Areas for Seafloor Resources). For example, the Navy will use real-time geographic information system and global positioning system (along with remote sensing verification) during deployment, installation, and recovery of anchors and mine-like objects to avoid impacts on shallow-water coral reefs and live hard bottom. This mitigation will consequently help avoid potential impacts on fishes that occur in these areas.

Pursuant to the ESA, the use of seafloor devices during testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish, but may affect ESA-listed fishes and designated critical habitat for Gulf sturgeon and proposed critical habitat for Atlantic sturgeon. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.4.4.2 Impacts from Seafloor Devices Under Alternative 2

Impacts from Seafloor Devices Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from seafloor device use under Alternative 2 are not expected to be meaningfully different than those described under

Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of seafloor devices during training activities, as described under Alternative 2, will have no effect on Atlantic salmon, the Central and Southwestern Atlantic Distinct Population Segment of scalloped hammerhead sharks, and designated critical habitat for Atlantic salmon and smalltooth sawfish, but may affect Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, smalltooth sawfish, Nassau grouper, proposed oceanic whitetip sharks and giant manta rays, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon.

Impacts from Seafloor Devices Under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, physical disturbance and strike stress experienced by fishes from seafloor device use under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of seafloor devices during testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon and smalltooth sawfish, but may affect ESA-listed fishes, designated critical habitat for Gulf sturgeon, and proposed critical habitat for Atlantic sturgeon.

3.6.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

Impacts from Seafloor Devices Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Stressors for fishes such as seafloor devices would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.4.5 Impacts from Pile Driving

Physical disturbance and strike stressors from pile driving activities are not applicable to fishes because they are mobile and would be able to avoid the stressors and will not be analyzed further in this section.

3.6.3.5 Entanglement Stressors

This section evaluates potential entanglement impacts of various types of expended materials used by the Navy during training and testing activities within the Study Area. The likelihood of fishes being affected by an entanglement stressor is a function of the physical properties, location, and buoyancy of the object and the behavior and physical features of the fish, as described in Section 3.0.3.6.4 (Conceptual Framework for Assessing Effects from Entanglement). Three types of military expended materials are considered here: (1) wires and cables (2) decelerators/parachutes, and (3) biodegradable polymer.

Most entanglement observations involve abandoned or discarded nets, lines, and other materials that form loops or incorporate rings (Derraik, 2002; Keller et al., 2010; Laist, 1987; Macfadyen et al., 2009). A 25-year dataset assembled by the Ocean Conservancy reported that fishing line, rope, and fishing nets accounted for 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 fishes 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.

Some fishes are more susceptible to entanglement in derelict fishing gear and other marine debris, compared to other fish groups. Physical features, such as rigid or protruding snouts of sawfishes and sturgeon and some elasmobranchs (e.g., the wide heads of hammerhead sharks and cephalic fins on manta rays), increase the risk of entanglement compared to fishes with smoother, more streamlined bodies (e.g., lampreys and eels). High rates of shark mortality have been associated with entanglement in fish aggregating devices (Filmalter et al., 2013). Sawfishes occur only in nearshore, and continental shelf waters of the Gulf of Mexico Large Marine Ecosystem and portions of the Southeast U.S. Continental Shelf Large Marine Ecosystem (74 *Federal Register* 45353 and 74 *Federal Register* 37671), where they are concentrated in south Florida and the Florida Keys. Scalloped hammerhead sharks, giant mantas, oceanic whitetip sharks, and ESA-listed sturgeon species occur in nearshore and offshore waters within one or more of the Large Marine Ecosystems that overlap Navy training and testing areas in the Study Area. Most fishes, except for jawless fishes and eels that are too smooth and slippery to become entangled, are susceptible to entanglement in gear specifically designed for that purpose (e.g., gillnets). The Navy uses a biodegradable polymer to function as entanglement objects. Biodegradable polymer systems designed to entangle the propellers of small in-water vessels would only be used during testing activities, not during training and the number and location of proposed testing activities is presented in Table 3.0-40.

The overall impacts of entanglement are highly variable, ranging from temporary disorientation to mortality due to predation or physical injury. The evaluation of a species' entanglement potential should consider the size, location, and buoyancy of an object as well as the size, physical characteristics, and behavior of the fish species.

The following sections seek to identify entanglement potential due to military expended material. Where appropriate, specific geographic areas (Large Marine Ecosystems, open ocean areas, range complexes, testing ranges, and bays and inland waters) of potential impact are identified.

3.6.3.5.1 Impacts from Wires and Cables

Fiber optic cables, guidance wires, and sonobuoys (which contain a wire) are used during training and testing activities. The number and location of items expended under each alternative is presented in Sections 3.0.3.3.5.1 (Wires and Cables), with additional details provided in Appendix B.

Major fish groups identified in Table 3.6-2, that could be susceptible to entanglement in expended cables and wires are those like sawfishes, 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 manta rays) and billfishes occurring within the offshore and continental shelf portions of the range complexes and testing ranges (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 and testing ranges would not be exposed to fiber optic cables or guidance wires and sonobuoy 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 a guidance wire or sonobuoy wire because of its size and rigidity (Environmental Sciences Group, 2005).

Because of their physical characteristics, guidance wires and fiber optic cables pose a potential, though unlikely, entanglement risk to susceptible fishes. Analysis of potential entanglement for fishes is based on 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 fishes than the wires expended by the Navy. 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 3.0.3.3.5.1 (Wires and Cables). 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.

Tube-launched optically tracked wire-guided missiles would expend wires in the nearshore or offshore waters of the Navy Cherry Point Range Complex during training only, and are discussed together with torpedo guidance wires because their potential impacts would be similar to those described here for torpedo guidance wires.

Sonobuoys consist of a surface antenna and float unit and a subsurface hydrophone assembly unit. The two units are attached through a thin gauge, dual-conductor, and hard-draw copper strand wire, which is then wrapped by a hollow rubber tubing or bungee in a spiral configuration. The tensile breaking strength of the wire and rubber tubing is no more than 40 lb. The length of the cable is housed in a plastic canister dispenser, which remains attached upon deployment. The length of wire that extends out is no more than 1,500 ft. and is dependent on the water depth and type of sonobuoy. Attached to the wire is a kite-drogue and damper disk stabilizing system made of non-woven nylon fabric. The nylon fabric is very thin and can be broken by hand. The wire runs through the stabilizing system, and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy, but pose no entanglement risk. Each sonobuoy has a saltwater-activated polyurethane float that inflates when the sonobuoy is submerged and keeps the sonobuoy components floating vertically in the water column below it. Sonobuoys remain suspended in the water column for no more than 30 hours, after which they sink to the seafloor.

The sonobuoy itself is not considered an entanglement hazard upon deployment (Environmental Sciences Group, 2005), but their components may pose an entanglement hazard once released into the ocean. Aerial-launched sonobuoys are deployed with a decelerator/parachute. Sonobuoys contain cords, electronic components, and plastic mesh that may entangle fish (Environmental Sciences Group, 2005). Open-ocean filter feeding species, such as basking sharks, whale sharks, and manta rays could become entangled in these items, whereas smaller species such as Atlantic herring could become entangled in the plastic mesh in the same manner as a small gillnet. Smalltooth sawfish, scalloped hammerheads, Nassau grouper, giant manta rays, oceanic whitetip sharks, and sturgeon may co-occur with newly expended sonobuoy, as these fishes are found in areas where sonobuoys are expended. Additionally, since most sonobuoys are expended in offshore areas, many other coastal fishes would not encounter or have any opportunity to become entangled in materials associated with sonobuoys, apart from the risk of entanglement in decelerators/parachutes mentioned above.

3.6.3.5.1.1 Impacts from Wires and Cables Under Alternative 1

Impacts from Wires and Cables Under Alternative 1 for Training Activities

The entanglement potential of discarded sections of fiber optic cable is low due to the brittle nature of the cable, which is easily broken when kinked, twisted, or bent sharply. The physical properties of the fiber optic cable prevent it from forming loops, greatly reducing or even eliminating the risk to fishes (U.S. Department of the Navy, 2001a). Additionally, encounter rates with fiber optic cables is limited by the small number that are expended.

Fiber optic cables may be expended within the Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico range complexes. Atlantic and shortnose sturgeon could encounter fiber optic cables in the Virginia Capes, Navy Cherry Point, or Jacksonville Range Complexes; smalltooth sawfish could occur in the Jacksonville Range Complex as well. Nassau grouper occur in the Jacksonville and Gulf of Mexico range complexes. For sawfishes, early life stages have the same body-type as adults. However, the likelihood of entanglement of early life stages would be slightly less than that of adults, because nursery habitats are found in very shallow water (less than 1 m deep) (National Marine Fisheries Service, 2009b), where no cables or wires would be expended. Early life stages of sturgeon and Atlantic salmon are typically (or exclusively, for salmon) found in freshwater rivers and not in marine environments, so only sub-adults and adults would be potentially exposed to entanglement stressors. Gulf sturgeon and scalloped hammerhead sharks belonging to the Central and Southwest Distinct Population Segment could encounter fiber-optic cables because they are expended during training activities where these species are found, including the Gulf of Mexico. Nassau grouper are found over high-relief reefs along the southeast coast of Florida in the Southeast U.S. Continental Shelf Large Marine Ecosystem, Dry Tortugas National Park, and Key West, Florida in the Gulf of Mexico, and areas in Florida and near Puerto Rico in the Caribbean Sea. Some of these areas overlap the geographic range of this species, so it is possible that they would be exposed to entanglement stressors. In the rare instance where a fish did encounter a fiber optic cable, entanglement is unlikely because the cable is not strong enough to bind most fishes (U.S. Department of the Navy, 2001a). Giant manta rays and oceanic whitetip sharks occur in offshore areas in the large marine ecosystems where training activities would occur. While entanglement is possible, these species would be able to break the wires and cables.

Guidance wires may be expended in the Northeast, Virginia Capes, and Jacksonville range complexes, as well as in the designated Sinking Exercise areas. Benthic-associated ESA-listed species, including Atlantic and shortnose sturgeon, smalltooth sawfish, and Nassau grouper, could encounter guidance wire because they can occur in nearshore waters out to the shelf break, where they feed on the bottom and could become entangled in a guidance wire while feeding. Pelagic species such as Atlantic salmon, oceanic whitetip sharks, and scalloped hammerhead sharks belonging to the Central and Southwestern Distinct Population Segment may encounter guidance wires in the water column. Guidance wires sink too quickly to be transported very far before reaching the seafloor (Environmental Sciences Group, 2005), thus limiting the amount of exposure time for pelagic species. Gulf sturgeon would not be exposed to guidance wires as they would not be expended within the waters of the northern Gulf of Mexico where this species occurs. Fish would rarely encounter guidance wires expended during training activities. If a guidance wire were encountered, the most likely result would be that the fish ignores it, which is an inconsequential and immeasurable effect. In the rare instance where an individual fish became entangled in guidance wire and could not break free, the individual could be impacted as a result of impaired feeding, bodily injury, or increased susceptibility to predators. However, this is an extremely unlikely scenario because the density of guidance wires would be very low, as discussed in Section 3.0.3.3.5.1 (Wires and Cables).

Sonobuoy wires may be expended within any of the range complexes throughout the Study Area. As described above, a sonobuoy wire runs through the stabilizing system and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy, but pose no entanglement risk. This is mainly due to the sonobuoy being made of a single wire that hangs vertically in the water column. Therefore, it would be highly unlikely that a fish, including ESA-listed species would be entangled by a sonobuoy wire.

While individual fish susceptible to entanglement could encounter guidance wires, fiber optic cables, and sonobuoy wires, the long-term consequences of entanglement are unlikely for either individuals or populations because (1) the encounter rate for cables and wires is low, (2) the types of fishes that are susceptible to these items is limited, (3) the restricted overlap with susceptible fishes, and (4) the physical characteristics of the cables and wires reduce entanglement risk to fishes compared to monofilament used for fishing gear. Potential impacts of exposure to guidance wires and fiber optic cables 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.

Pursuant to the ESA, the use of wires and cables during training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Wires and Cables Under Alternative 1 for Testing Activities

As discussed in Section 3.0.3.3.5.1 (Wires and Cables), under Alternative 1 testing activities, fiber optic cables, guidance wires, and sonobuoy components that would pose an entanglement risk to marine fishes, including ESA-listed species, would be similar to those described training activities, even though testing activities occur at a higher frequency and in more locations compared to training activities. Testing activities involving wires and cables occur at Virginia Capes Range Complex, Jacksonville Range Complex, Key West Range Complex, Northeast Range Complexes, Navy Cherry Point Range Complex, Gulf of Mexico Range Complex, Naval Undersea Warfare Center Newport Testing Range, Naval Surface Warfare Center Panama City Testing Range, and South Florida Ocean Measurement Facility.

Atlantic salmon would not be as prone to entanglement because they do not possess the morphological features (rigid or protruding snouts) associated with high entanglement rates. ESA-listed species more susceptible to entanglement (sawfish and sturgeon species, and giant manta rays) and those not as susceptible to entanglement (Atlantic salmon, Nassau grouper, and oceanic whitetip sharks) occur in testing locations, but are unlikely to encounter the guidance wires because of their low densities in the areas where they are expended. Early life stages of sturgeon and Atlantic salmon are typically (or exclusively, for salmon) found in freshwater rivers and not in marine environments, so only sub-adults and adults would be potentially exposed to entanglement stressors. For sawfishes, the early life stages have the same body-type as adults; however, the likelihood of entanglement of early life stages would be slightly less than that of adults, because nursery habitats are found in very shallow water (less than 1 m deep), where no cables or wires would be expended. The Central and Southwest Atlantic Distinct Population Segment of scalloped hammerhead sharks may encounter expended cables and wires in the Key West Range Complex.

While individual fish susceptible to entanglement could encounter guidance wires, fiber optic cables, and sonobuoy wires, the long-term consequences of entanglement are unlikely for either individuals or populations because (1) the encounter rate for cables and wires is low, (2) the types of fishes that are susceptible to these items is limited, (3) the restricted overlap with susceptible fishes, and (4) the physical characteristics of the cables and wires reduce entanglement risk to fishes compared to monofilament used for fishing gear. Potential impacts from exposure to guidance wires and fiber optic cables 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.

Pursuant to the ESA, the use of wires and cables during testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.5.1.2 Impacts from Wires and Cables Under Alternative 2

Impacts from Wires and Cables Under Alternative 2 for Training Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, entanglement stress experienced by fishes from guidance wires, fiber optic cables, and sonobuoy wires under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of wires and cables during training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

Impacts from Wires and Cables Under Alternative 2 for Testing Activities

Even though testing activities under Alternative 2 occur at a slightly higher rate and frequency relative to Alternative 1, entanglement stress experienced by fishes from guidance wires, fiber optic cables, and sonobuoy wires under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, the use of wires and cables during testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

3.6.3.5.1.3 Impacts from Wires and Cables Under the No Action Alternative

Impacts from Wires and Cables Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Entanglement stressors for fishes from wires and cables would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.5.2 Impacts from Decelerators/Parachutes

Decelerators/Parachutes of varying sizes are used during training and testing activities. Section 3.0.3.3.5.2 (Decelerators/Parachutes) describes the use and platforms where decelerators/parachutes would be released into the marine environment and therefore present an entanglement risk to fishes. 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 decelerator/parachute activities proposed under each alternative are presented in Appendix B. Fishes 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 fishes because it is abundant, essentially invisible, strong, and easily tangled. In contrast, decelerators/parachutes are rare, highly visible, and not designed to capture fishes. The weak entangling features reduce the risk to ESA-protected fishes.

Once a decelerator/parachute has been released to the water, it poses a potential entanglement risk to fishes. 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, 2001a). Unlike other materials in which fish become entangled (such as gill nets and nylon fishing line), the decelerator/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 (Ocean Conservancy, 2010; U.S. Department of the Navy, 2001a). Entanglement in a newly expended decelerator/parachute and its attachment lines 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 3.6.3.4.3, 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 decelerator/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 attachment 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 fishes with elongated spines could become caught on the decelerator/parachute or lines. Most sharks and other smooth-bodied fishes 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, manta rays, billfishes, sturgeon, or sawfishes) 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 fishes, it is not considered a likely event.

3.6.3.5.2.1 Impacts from Decelerators/Parachutes Under Alternative 1

Impacts from Decelerators/Parachutes Under Alternative 1 for Training Activities

Fish species that could be susceptible to entanglement in decelerators/parachutes are the same as discussed for cables and wires. As discussed in Section 3.0.3.3.5.2 (Decelerators/Parachutes), training activities involving decelerators/parachutes use that would pose an entanglement risk to fishes under Alternative 1 would be expended primarily in the Northeast, Virginia Capes, Navy Cherry Point, Jacksonville, and Gulf of Mexico Range Complexes. Based on the numbers and geographic locations of their use, decelerators/parachutes pose a risk of entanglement for all fish species that occurs in the Study Area. Table 3.0 33 show the number and location of decelerator/parachutes expended during proposed training and testing activities under Alternative 1.

Some elasmobranchs (sawfishes, hammerhead sharks, and manta rays), sturgeon, swordfishes, and billfishes occurring within the offshore and continental shelf portions of the range complexes (where the potential for entanglement would occur) may be more susceptible to entanglement in decelerators/parachutes than most fish species due to their unusual body shape or projections. As described above, the highly maneuverable swimming capabilities of these fishes make it unlikely that any entanglement would occur while the decelerators/parachutes are at the surface or sinking through the water column. It is conceivable that ESA-listed species near the seafloor such as a sawfish or sturgeon could encounter an expended decelerator/parachute that has settled to the bottom. These species could encounter decelerators/parachutes because they can occur at the surface or on the bottom in nearshore waters out to the shelf break.

The Atlantic salmon occurs in offshore areas where decelerators/parachutes would be expended in the Northeast Range Complexes and may encounter decelerators/parachutes in the water column. However, the Atlantic salmon, like all salmonids, is a strong swimmer with a streamlined body that is unlikely to become entangled in decelerators/parachutes or lines. The impacts of entanglement with decelerators/parachutes are discountable because of the low density of decelerators/parachutes expended in this location and the body shape of Atlantic salmon, which makes it unlikely to become entangled.

Sawfishes are highly mobile, visual predators that could easily avoid a floating or suspended decelerator/parachute. If a rare decelerator/parachute encounter by a sawfish led to entanglement, the fish would likely thrash its rostral saw in an effort to break free. If such an effort were unsuccessful, the individual could remain entangled, possibly resulting in injury or death. However, this scenario is considered so unlikely that it would be discountable.

For sawfishes, the early life stages have the same body-type as adults; however, the likelihood of entanglement of early life stages would be slightly less than that of adults because nursery habitats are found in very shallow water (less than 1 m deep) (National Marine Fisheries Service, 2009c), where no decelerators/parachutes would be expended. Early life stages of sturgeon and Atlantic salmon are typically (or exclusively, for salmon) found in freshwater rivers and not in marine environments, so only sub-adults and adults would be potentially exposed to entanglement stressors.

Scalloped hammerhead sharks belonging to the Central and Southwest Atlantic Distinct Population Segment may potentially encounter decelerators/parachutes in the Key West Range Complex. Likewise, due to their widespread distribution, giant manta rays may encounter parachutes/decelerators throughout most of the Study Area where these items are used. Both scalloped hammerhead sharks and giant manta rays are highly mobile species that could likely avoid floating or suspended decelerators/parachutes. If a rare decelerator/parachute encounter by one of these species led to entanglement, it would likely thrash in an effort to break free. If such an effort were unsuccessful, the individual could remain entangled, possibly resulting in injury or death. However, this scenario is considered so unlikely that it would be discountable. Similarly, oceanic whitetip sharks occurring offshore could come into contact with a parachute/decelerator during training activities. This species is also a highly mobile, visual predators that could easily avoid floating or suspended decelerators/ parachutes or break free if it got entangled.

Nassau groupers are found in reefs areas of the Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea. However, this species is known to have large spawning aggregations in areas such as the ends of islands or reef pinnacles seaward from the general reef contour. This species is highly mobile and could easily avoid floating or suspended decelerators/parachutes, so the likelihood of this species being entangled would be extremely low. If a rare decelerator/parachute encounter by a Nassau grouper led to entanglement, the fish would likely thrash in an effort to break free. If such an effort were unsuccessful, the individual could remain entangled, possibly resulting in injury or death. However, this scenario is considered so unlikely that it would be discountable.

Fishes are unlikely to encounter or become entangled in decelerators/parachutes because of the large size of the range complexes and the resulting widely scattered expended decelerators/parachutes. Individual fish are not prone to be repeatedly exposed to decelerators/parachutes; thus the long-term consequences of entanglement risks from decelerators/parachutes are unlikely for either individuals or populations.

Pursuant to the ESA, the use of decelerators/parachutes during training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Decelerators/Parachutes Under Alternative 1 for Testing Activities

As discussed in Section 3.0.3.3.5.2 (Decelerators/Parachutes), under Alternative 1 testing activities, decelerators/parachutes that would pose an entanglement risk to fishes would be expended primarily in Jacksonville Range Complex, Virginia Capes Range Complex, Northeast Range complexes Gulf of Mexico Range Complex, and Naval Undersea Warfare Center Newport Testing Range. Appendix F (Military Expended Materials and Direct Strike Impact Analyses) provides a list of expended materials that would include decelerators/parachutes. Table F-2 provides the number of each type of military expended material used for testing activities under Alternative 1.

Based on the numbers and geographic locations of their use, decelerators/parachutes pose a risk of entanglement for all fish species that occurs in the Study Area, including ESA-listed species and would be the same as discussed for cables and wires. It is conceivable that a sawfish or sturgeon could encounter an expended decelerator/parachute that has settled to the bottom. Any of the sturgeon species could encounter decelerators/parachutes because sturgeon can occur at the surface or on the bottom in nearshore waters out to the shelf break. For sawfishes, the early life stages have the same body-type as adults; however, the likelihood of entanglement of early life stages would be slightly less than that of adults because nursery habitats are found in very shallow water (less than 1 m deep), where no decelerators/parachutes would be expended. Early life stages of sturgeon and Atlantic salmon are typically (or exclusively, for salmon) found in freshwater rivers and not in marine environments, so only sub-adults and adults would be potentially exposed to entanglement stressors.

Scalloped hammerhead sharks, oceanic whitetip sharks, and manta rays are highly mobile pelagic species and would likely avoid floating or suspended decelerators/parachutes. If one of these species were to become entangled in a decelerator/parachute, they would likely thrash in an effort to break free. If such an effort were unsuccessful, the individual could remain entangled, possibly resulting in injury or death. This scenario is considered so unlikely that it would be discountable.

Fish are unlikely to encounter or become entangled in decelerators/parachutes because of the large size of the range complexes and testing ranges and the resulting widely scattered expended decelerators/parachutes. Individual fish are not prone to be repeatedly exposed to these entanglement stressors, thus the long-term consequences of entanglement risks from decelerators/parachutes are unlikely for either individuals or populations.

Pursuant to the ESA, the use of decelerators/parachutes during testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.5.2.2 Impacts from Decelerators/Parachutes Under Alternative 2

Impacts from Decelerators/Parachutes Under Alternative 2 for Training Activities

Under Alternative 2, the number of decelerators/parachutes that would be expended during training activities is the same as for Alternative 1 and entanglement stress experienced by fishes from decelerators/parachutes under Alternative 2 are not expected to be different than those described under Alternative 1. Therefore, the impact conclusion for decelerators/parachutes under Alternative 2 training activities is the same as for Alternative 1.

Pursuant to the ESA, the use of decelerators/parachutes during training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

Impacts from Decelerators/Parachutes Under Alternative 2 for Testing Activities

Under Alternative 2, the number of decelerators/parachutes that would be expended during testing activities is the same as for Alternative 1 and entanglement stress experienced by fishes from decelerators/parachutes under Alternative 2 are not expected to be different than those described under Alternative 1. Therefore, the impact conclusion for decelerators/parachutes under Alternative 2 testing activities is the same as for Alternative 1.

Pursuant to the ESA, the use of decelerators/parachutes during testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

3.6.3.5.2.3 Impacts from Decelerators/Parachutes Under the No Action Alternative

Impacts from Decelerators/Parachutes Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Entanglement stressors for fishes from decelerators/parachutes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.5.3 Impacts from Biodegradable Polymer

For a discussion of the types of activities that use biodegradable polymers see Appendix B (Activity Stressor Matrices) and for a discussion on where they are used and how many activities would occur under each alternative, see Section 3.0.3.3.5.3 (Biodegradable Polymer). Navy activities that involve vessel entanglement systems include the development of the biodegradable polymer and would be associated with testing activities in the AFTT Study Area. As indicated by its name, vessel entanglement systems that make use of biodegradable polymers are designed to entangle the propellers of in-water vessels, which would significantly slow and potentially stop the advance of the vessel. A biodegradable polymer is a high molecular weight polymer that degrades to smaller compounds as a result of microorganisms and enzymes The rate of biodegradation could vary from hours to years and the type of small molecules formed during degradation can range from complex to simple products, depending on whether the polymers are natural or synthetic (Karlsson & Albertsson, 1998). Based on the constituents of the biodegradable polymer the Navy proposes to use, it is anticipated that the material will breakdown into small pieces within a few days to weeks. This will breakdown further and dissolve into the water column within weeks to a few months. The final products, which are all environmentally benign, will be dispersed quickly to undetectable concentrations. Unlike other entanglement stressors, biodegradable polymers only retain their strength for a relatively short period of time; therefore, the potential for entanglement by a fish would be limited. Furthermore the longer the biodegradable polymer remains in the water, the weaker it becomes making it more brittle and likely to break. A fish would have to encounter the biodegradable polymer after it was expended for it to be a potential entanglement risk. If an animal were to approach the polymer a more than a few weeks after it was expended, it is very likely that it would break easily and would not be able to entangle a fish. Since biodegradable polymers are only proposed for testing activities within the AFTT Study Area, the concentration of these items being expended throughout the AFTT Study Area is considered very low and the rate of encounter and risk of entanglement for fishes would be considered extremely low.

3.6.3.5.3.1 Impacts from Biodegradable Polymer Under Alternative 1

Impacts from Biodegradable Polymer Under Alternative 1 for Training Activities

Biodegradable polymers would not be used during Navy training activities associated with the Proposed Action.

Impacts from Biodegradable Polymer Under Alternative 1 for Testing Activities

Testing activities under Alternative 1 that use of biodegradable polymers would be conducted within the Virginia Capes, Jacksonville, Key West and Gulf of Mexico Range Complexes, as well as the Naval Undersea Warfare Center Newport Testing Range. Biodegradable polymers would be expended equally throughout these areas.

ESA-listed species such as smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, oceanic whitetip sharks, and giant manta rays may occur in these range complexes and may be exposed to the biodegradable polymer during testing activities. However, the likelihood of a fish encountering the biodegradable polymers when they are first expended is low because: (1) very few polymers are used annually within each range complex; and (2) polymers only remain intact for relatively short periods of time (generally a few days to weeks) and they are brittle and would break apart over time.

Pursuant to the ESA, the use of biodegradable polymers during testing activities, as described under Alternative 1, will have no effect on Atlantic salmon, Nassau grouper, the Central and Southwestern Distinct Population Segment of scalloped hammerhead sharks, designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon, or proposed critical habitat for Atlantic sturgeon. The use of biodegradable polymers during testing activities under Alternative 1 may affect smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, and proposed oceanic whitetip sharks and giant manta rays. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.5.3.2 Impacts from Biodegradable Polymer Under Alternative 2

Impacts from Biodegradable Polymer Under Alternative 2 for Training Activities

Biodegradable polymers would not be used during Navy training activities associated with the Proposed Action.

Impacts from Biodegradable Polymer Under Alternative 2 for Testing Activities

Testing activities that expend biodegradable polymers under Alternative 2 would be identical to what is proposed under Alternative 1. The analysis presented above in Section 3.6.3.5.3.1 (Impacts from Biodegradable Polymer under Alternative 1) for testing activities would also apply to Alternative 2.

Pursuant to the ESA, the use of biodegradable polymers during testing activities, as described under Alternative 1, will have no effect on Atlantic salmon, Nassau grouper, the Central and Southwestern Distinct Population Segment of scalloped hammerhead sharks, designated critical habitat for Atlantic salmon, smalltooth sawfish, and Gulf sturgeon, or proposed critical habitat for Atlantic sturgeon. The use of biodegradable polymers during testing activities under Alternative 1 may affect smalltooth sawfish, Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, oceanic whitetip sharks, and giant manta rays.

3.6.3.5.3.3 Impacts from Biodegradable Polymer Under the No Action Alternative

Impacts from Biodegradable Polymer Under the No Action Alternative for Training and Testing Activities

Biodegradable polymer is not a part of ongoing Navy activities in the Study Area and this entanglement stressor would not be introduced into the marine environment under the No Action Alternative. Therefore, no change in baseline conditions of the existing environment would occur.

3.6.3.6 Ingestion Stressors

This section analyzes the potential ingestion impacts of the various types of munitions and military expended materials other than munitions used by the Navy during training and testing activities within the Study Area. Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Section 3.0.3.6.5 (Conceptual Framework for Assessing Effects from Ingestion). Ingestion of expended materials by fishes 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 fishes that feed at or near the water surface (e.g., ocean sunfish, basking sharks, whale sharks, manta rays, herring, or flying fishes), while materials that sink to the seafloor present a higher risk to bottom-feeding fishes (e.g., sturgeon, hammerhead sharks, skates, and flatfishes).

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 potential for fish, including the ESA-listed fish species, to encounter and ingest expended materials is evaluated with respect to their feeding group, size, and geographic range, which influence the probability that they would eat military expended materials.

The Navy 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 high-explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), small decelerators/parachutes, and biodegradable polymer. The location and number of activities that expend these items are detailed in Section 3.0.3.3.6 (Ingestion Stressors) and in Appendix B. Metal items eaten by 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 (Dantas et al., 2012; Davison & Asch, 2011; Possatto et al., 2011). Ingestion of plastics has been shown to increase hazardous chemicals in fish leading to liver toxicity of fishes (Rochman et al., 2013). 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. For many small fish species (e.g., herring, anchovy, etc.), even these items (with the exception of chaff) are often too large to be ingested, even though small pieces could sometimes be nibbled off by small fishes. Therefore, the discussion in this section focuses on those fish species large enough to potentially ingest these materials.

The analysis of ingestion impacts on fishes 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 fishes, such as salmon, tuna, dolphin fish, sharks, and billfishes, feed on fast-swimming prey in the water column of the Study Area. These fishes range widely in search of unevenly distributed food patches. Atlantic salmon generally travel alone (Fay et al., 2006) but gather in common feeding areas near Greenland and Labrador, where they prey on schooling fish associated with the surface and water column of shallow open-water areas (Hansen & Windsor, 2006). Smaller military expended materials could be mistaken for prey items and ingested purposefully or incidentally as the fish is swimming. A few of these predatory fishes (e.g., bull sharks, tiger sharks) are known to ingest any type of marine debris that they can swallow, even automobile tires. Some marine fishes, such as the dolphinfish (*Coryphaena hippurus*) (South Atlantic Fishery Management Council, 2011) and tunas, eat plastic fragments, strings, nylon lines, ropes, or even small light bulbs (Choy & Drazen, 2013; Rochman et al., 2015).
- **Open-Ocean Planktivores.** Plankton-eating fishes in the open-ocean portion of the Study Area include herring, flying fishes, ocean sunfish, whale sharks, manta rays, and basking sharks. These fishes 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, pistons) at or just below the surface or in the water column (Table 3.6-17). Giant manta rays are the only ESA-listed species in the Study Area that is an open ocean planktivore, while some species in this group of fishes (e.g., herring) constitute a major prey base for many important predators, including salmon, tuna, sharks, marine mammals, and seabirds. While not a consumer of plankton, the ocean sunfish eats jellyfish and may consume a parachute/decelerator by accident at or just below the surface in the open ocean. Larger filter feeders such as whale sharks, basking sharks, and manta rays could also inadvertently ingest a parachute or decelerator.

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).

Table 3.6-17: Ingestion Stressors Potential for Impact on Fishes Based on Location

Feeding Guild	*Representative Species*	*Endangered Species Act-Protected Species*	*Overall Potential for Impact*
Open-ocean predators	Dolphinfishes, most shark species, tuna, mackerel, wahoo, jacks, billfishes, swordfishes	Atlantic salmon, Scalloped hammerhead sharks, Oceanic whitetip sharks	These fishes 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)	Atlantic herrings, Menhaden, basking shark, whale shark	Giant manta rays	These fishes 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	Atlantic cod, skates, cusks, and rays	Atlantic salmon, Scalloped hammerhead sharks, Nassau grouper	These fishes 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 foragers and scavengers	Skates and rays, flounders	Sturgeon species, Sawfish species	These fishes could incidentally eat some expended materials while foraging, especially in muddy waters with limited visibility. May result in individual injury or death but is not anticipated to have population-level effects.

Note: The scientific names of the listed species are as follows: Atlantic cod (Hippoglossus hippoglossus), Atlantic salmon (Salmo salar), basking shark (Cetorhinus maximus), cusk (Brosme brosme), dolphinfish (Coryphaena hippurus), whale shark (Rhincodon typus), rays (Manta species), and scalloped hammerhead shark (Sphyrna lewini), sawfish species (Pristis species), sturgeon species (Acipenser species), rays (Manta species), skates (Amblyraja species), and flounders (Bothidae).

Fishes Feeding at the Seafloor

- **Bottom Dwelling Predators.** Large predatory fishes near the seafloor are represented by species such as Atlantic cod and cusk, which are typical predators in the northern portion of the Study Area Table 3.6-14. The cod and cusk feed opportunistically on or near the bottom, taking fishes and invertebrates from the water column (e.g., shrimp) and from the sediment (e.g., crabs) (Collette & Klein-MacPhee, 2002). The cod also ingests marine debris while feeding on or near the bottom. In the United Kingdom, plastic cups thrown from ferries have been discovered in cod stomachs (Hoss & Settle, 1990). The varied diet of the cod and the low visibility in its deep shelf habitat may promote the ingestion of foreign objects. The Atlantic salmon also feeds on fish on or near the seafloor such as sand lances and capelin. Cusks and sturgeon normally eats hard-shelled and spiny organisms, increasing the likelihood that it would swallow a sharp plastic or metal item rather than reject it.
- **Bottom Dwelling Foragers and Scavengers.** Bottom dwelling fishes in the nearshore coasts and estuaries may feed by seeking prey and by scavenging on dead fishes and invertebrates. All sturgeon in the Study Area suction-feed along the bottom in coastal waters on small fish and invertebrate prey, which increases the likelihood of incidental ingestion of marine debris (Ross et al., 2009).

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

Potential impacts of ingestion on some adult fishes are different than for other life stages (eggs, larvae, and juveniles) because early life stages for some species are too small to ingest any military expended materials except for chaff, which has been shown to have limited effects on fishes in the concentration levels that it is released at (Arfsten et al., 2002; Spargo et al., 1999; U.S. Department of the Air Force, 1997). 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).

3.6.3.6.1 Impacts from Military Expended Materials – Munitions

Different types of explosive and non-explosive practice munitions are expended at sea during training and testing activities. This section analyzes the potential for fishes to ingest non-explosive practice munitions and fragments from high explosive munitions.

Types of non-explosive practice munitions generally include projectiles, missiles, and bombs. Of these, only small- or medium-caliber projectiles would be small enough for a large fishes to ingest. Small- and medium-caliber projectiles include all sizes up to and including 2.25 in. in diameter. These solid metal materials would quickly move through the water column and settle to the seafloor. Ingestion of non-explosive practice munitions in the water column is possible when shiny fragments of the munitions sink quickly and could be ingested by fast, mobile predators that chase moving prey (e.g., tunas, jacks, billfishes, swordfishes, dolphinfishes, mackerel, wahoo, and barracudas). In addition, these fragments may also be accidentally ingested by fishes that forage on the bottom such as sturgeon, flounders, skates, and rays.

Types of high explosive munitions that can result in fragments include demolition charges, projectiles, missiles, and bombs. Fragments would result from fractures in the munitions casing and would vary in size depending on the size of the net explosive weight and munitions type; however, typical sizes of fragments are unknown. These solid metal materials would quickly move through the water column and settle to the seafloor. Similar to non-explosive practice munitions described above, ingestion of high explosive munition fragments by fast-moving mobile predators such tunas, jacks, billfishes, swordfishes, dolphinfishes, mackerel, wahoo, and barracudas in the water column is possible. 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, 2001b). High-melting-point explosive or royal demolition explosive would not accumulate in the tissues of fish (Lotufo et al., 2010; Price et al., 1998). Fragments are primarily encountered by species that forage on the bottom.

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.

The potential impacts of ingesting foreign objects on a given fish depend on the species and size of the fish. Fishes that normally eat spiny, hard-bodied invertebrates may 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 fishes that feed on invertebrates with sharp appendages. These items could include fragments from high-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 (Danner et al., 2009; Hoss & Settle, 1990). Ingestion of large foreign objects could lead to disruption of a fish's normal feeding behavior, which could be sublethal or lethal.

3.6.3.6.1.1 Impacts from Military Expended Materials – Munitions Under Alternative 1

Impacts from Military Expended Materials – Munitions Under Alternative 1 for Training Activities

Use of military expended materials from munitions may occur throughout the AFTT Study Area. Fishes in the vicinity of these activities would have the potential to ingest military expended materials from munitions.

When these items explode, they may break apart or remain largely intact in irregularly shaped pieces—some of which may be small enough for some fishes to ingest. Some fishes such as sturgeon are able to feed on crustaceans that have hard, sharp, or irregular parts, without any impacts. Most fragments from high-explosives would be too large for a fish to ingest. Also, it is assumed that fragments from larger munitions are similar in size to fragments from smaller munitions. Although fragment size cannot be quantified, more individual fragments would result from larger munitions than from smaller munitions. The number of fragments that would result from the proposed explosions cannot be quantified. However, it is believed to be smaller than the number of small-caliber projectiles to be expended in the Study Area. Small-caliber projectiles would likely be more prevalent throughout the Study Area and more likely to be encountered and potentially ingested by bottom-dwelling fishes and some reef fishes, such as Nassau grouper, than fragments from any type of high-explosive munitions.

The Atlantic and Gulf sturgeon and smalltooth sawfish may occur in portions of the Study Area out to the continental shelf break where projectiles and munitions are used. Shortnose sturgeon can migrate long distances in coastal waters to their natal river or estuary (Wippelhauser et al., 2015), only occasionally moving to nearshore marine environments. The current Chesapeake Bay system population of shortnose sturgeon appears to be centered in the upper Chesapeake Bay (Welsh et al., 2002), outside of the Study Area. Training activities expending projectiles or munitions could expose sturgeon and sawfish to ingestion risk. These species could be injured if it ingested a small-caliber projectile or fragment and couldn't pass it.

Scalloped hammerhead sharks could encounter some munitions-related material; although the likelihood is remote because only medium-caliber projectiles (no small-caliber projectiles) would be expended in the Key West Range Complex portion of the Study Area where this species would most likely occur. Although less likely, smalltooth sawfish could encounter some munitions-related material in the Jacksonville and Gulf of Mexico Range Complexes. Giant manta rays and oceanic whitetip sharks are generally surface-oriented feeders, with rays feeding on plankton in the upper water column, while oceanic whitetips are high-level predators feeding on fishes and cephalopods such as squid. It is unlikely that these species would mistake larger military expended materials in the water column for prey. If these species accidentally ingested military expended materials, it is likely that they would "taste" the item and then expel it, in the same manner that a fish would take a lure into its mouth then spit it out. It is also possible that giant mantas could ingest smaller fragments as they fall through the water column, although this species would be able to distinguish between a food item and non-food item such as fragments of military expended materials.

The likelihood of ingestion of munitions (or fragments) by early life stages of smalltooth sawfish would be slightly less than that of adults because nursery habitats are found in very shallow water (less than 1 m deep), where no munitions would be expended. Juvenile sturgeon are also found in the same freshwater rivers and tributaries as adults, including the James River, and would also be potentially exposed to ingestion stressors.

Overall, the potential impacts of ingesting munitions (whole or fragments) would be limited to individual fish that might suffer a negative response from a given ingestion event. While ingestion of munitions or fragments identified here could result in sublethal or lethal effects to a small number of individuals, the likelihood of a fish encountering an expended item is dependent on where that species feeds and the amount of material expended. Furthermore, an encounter may not lead to ingestion, As a fish might "taste" an item, then expel it (Felix et al., 1995), in the same manner that a fish would take a lure into its mouth then spit it out. The number of fishes potentially impacted by ingestion of munitions or fragments from munitions would be assumed to be low, and population-level effects would not be expected. The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that feed on shallow-water coral reefs.

Pursuant to the ESA, military expended materials such as munitions from training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Military Expended Materials – Munitions Under Alternative 1 for Testing Activities

Use of military expended materials from munitions may occur throughout the AFTT Study Area. Fish in the vicinity of these activities would have the potential to ingest military expended materials from munitions.

When these items explode, they may break apart or remain largely intact in irregularly shaped pieces—some of which may be small enough for a fish to ingest. Some fish species feed on crustaceans that have hard, sharp, or irregular parts, without any impacts. Most fragments from high-explosives would be too large for a fish to ingest. Also, it is assumed that fragments from larger munitions are similar in size to fragments from smaller munitions. Although fragment size cannot be quantified, more individual fragments would result from larger munitions than from smaller munitions. The number of fragments that would result from the proposed explosions cannot be quantified. However, it is believed to be smaller than the number of small-caliber projectiles to be expended in the Study Area. Small-caliber projectiles would likely be more prevalent throughout the Study Area and more likely to be encountered and potentially ingested by bottom-dwelling fishes than fragments from any type of high-explosive munitions. 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 fishes potentially impacted by ingestion of munitions would be low and population-level impacts are not likely to occur.

The Atlantic and Gulf sturgeon and smalltooth sawfish may occur in portions of the Study Area out to the continental shelf break where projectiles and munitions are used. Shortnose sturgeon generally remain within their natal river or estuary, only occasionally moving to nearshore marine environments (Dadswell et al., 1984). The current Chesapeake Bay system population of shortnose sturgeon appears to be centered in the upper Chesapeake Bay (Welsh et al., 2002), outside of the Study Area. The likelihood of ingestion of munitions (or fragments) by early life stages of sawfishes would be slightly less than that of adults, because nursery habitats are found in very shallow water (less than 1 m deep), where no munitions would be expended. Early life stages of sturgeon are typically found in freshwater rivers and not in marine environments, so only sub-adults and adults would be potentially exposed to ingestion stressors.

As described above for training activities, giant manta rays and oceanic whitetip sharks are generally surface-oriented feeders. It is unlikely that these species would mistake larger military expended materials in the water column for prey, but if this occurred they accidentally ingested military expended materials, it is likely that they would “taste” the item and then expel it. Smaller fragments could be consumed and these species would be able to distinguish between food and non-food items.

Overall, the impacts on fishes ingesting munitions or fragments from munitions resulting from proposed testing activities would be low. The number of fishes potentially impacted by ingestion of munitions or fragments from munitions would be low, and population-level effects would not be expected. The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from military expended materials on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources).

This mitigation will consequently help avoid potential impacts on fishes that feed on shallow-water coral reefs.

Pursuant to the ESA, military expended materials such as munitions from testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish and Gulf sturgeon or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.6.1.2 Impacts from Military Expended Materials – Munitions Under Alternative 2

Impacts from Military Expended Materials – Munitions Under Alternative 2 for Training Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials and munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training and testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended materials such as munitions from training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

Impacts from Military Expended Materials – Munitions Under Alternative 2 for Testing Activities

Because activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials and munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended materials such as munitions from testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

3.6.3.6.1.3 Impacts from Military Expended Materials – Munitions Under the No Action Alternative

Impacts from Military Expended Materials – Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Ingestion stressors for fishes from military expended materials such as munitions would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.6.2 Impacts from Military Expended Materials – Other Than Munitions

Fishes feed throughout the water column and could mistake many types of marine debris for prey items. Ingesting nonfood items is common among a variety of marine fishes, particularly those that feed on the seafloor (Boerger et al., 2010; Hoss & Settle, 1990; Jackson et al., 2000). Many fishes are also known to accidentally ingest plastic materials and the extent to which an individual fish might discriminate between a plastic item perceived as prey and an indistinct or less appealing shape is not clear. Once eaten, any type of plastic could cause digestive problems for the fish (Danner et al., 2009). Fishes have been reported to ingest a variety of materials or debris, such as plastic pellets, bags, rope, and line (Hoss & Settle, 1990; Jackson et al., 2000). As discussed above in Section 3.6.3.6 (Ingestion Stressors), some fish species such as the ocean sunfish eat jellyfish and may consume a parachute/decelerator at or just below the surface in the open ocean by accident. Larger filter feeders such as whale sharks, basking sharks, and manta rays could also inadvertently ingest a small or medium parachute or decelerator.

Chaff is used throughout the Study Area and is composed of an aluminum alloy coating on glass fibers of silicon dioxide and is released or dispensed in cartridges or projectiles that contain millions of fibers. Based on the small size of chaff fibers, fishes would likely not confuse the fibers with prey items or purposefully feed on them. However, some fishes could occasionally ingest low concentrations of chaff incidentally while feeding on prey items on the surface, in the water column, or the seafloor. Chaff fiber ingestion is not expected to impact fishes based on the low concentration that could reasonably be ingested and the small size of the chaff fibers. Therefore, exposure to chaff would cause no injury, mortality, or tissue damage to fishes. Potential impacts of chaff ingestion by fishes are not discussed further. Impacts of ingestion of the end caps or pistons associated with chaff cartridges are analyzed together with impacts of flares below.

Chaff end caps and pistons sink in saltwater (Spargo et al., 1999). Fishes feeding on the seafloor where chaff canisters and flares are expended (e.g., range complexes, and testing ranges would be more likely to encounter and ingest these items than in other locations. Ingested end caps or pistons could disrupt a fish's feeding behavior or digestive processes. If the item is particularly large relative to the fish ingesting it, the item could become permanently encapsulated by the stomach lining, and potentially lead to starvation and death (Danner et al., 2009 ; Hoss & Settle, 1990).

As described above, surface-feeding fishes have little opportunity to ingest end caps or pistons before they sink. However, some of these items could become entangled in dense *Sargassum* mats near the surface. Predatory open-ocean fishes, such as tuna, dolphinfishes, and billfishes, are attracted to the many small prey species associated with *Sargassum* mats. While foraging near the floating mats, predatory fishes may incidentally ingest end caps and pistons. The density of these items in any given location would vary based on release points and dispersion by wind and water currents. The number of end-caps and pistons that would remain at or just below the surface in *Sargassum* mats and potentially available to fish is unknown. Unlike other plastic types of marine debris, end caps and pistons are heavier than water and not expected to float unless they are enmeshed in *Sargassum* or other floating debris.

Most materials associated with airborne mine neutralization system activities are recovered, but pieces of fiber optic cable may be expended (U.S. Department of the Navy, 2001a). For a discussion of the physical characteristics of these expended materials, where they are used, and the number of activities in each alternative, please see Section 3.0.3.3.5.1 (Wires and Cables). Only small amounts of fiber optic cable would be deposited onto the seafloor each year, and the small amount of fiber optic cable expended during training and testing would sink to the seafloor. Pelagic fishes would be unlikely to encounter the small, dispersed lengths of fiber optic cable unless they were in the immediate area when the cable was expended. The low number of fiber optic cables expended in the Study Area during this activity makes it unlikely that fishes would encounter any fiber optic cables. Potential impacts of fiber optic cable ingestion by fishes are not discussed further.

As stated in Section 3.0.3.3.5.3 (Biodegradable Polymer), based on the constituents of the biodegradable polymer, it is anticipated that the material will breakdown into small pieces within a few days to weeks. These small pieces will breakdown further and dissolve into the water column within weeks to a few months and could potentially be incidentally ingested by fishes. Because the final products of the breakdown are all environmentally benign, the Navy does not expect the use of biodegradable polymer to have any negative impacts for fishes.

3.6.3.6.2.1 Impacts from Military Expended Materials – Other Than Munitions Under Alternative 1

Impacts from Military Expended Materials – Other Than Munitions Under Alternative 1 for Training Activities

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials – Other Than Munitions) under Alternative 1, activities involving target materials use would occur throughout the Study Area. All of the ESA-listed species occur where target materials could potentially be expended.

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials – Other Than Munitions), under Alternative 1, activities that expend chaff and flare occur throughout the Study Area. No potential impacts would occur from the chaff itself, but there is some potential for fishes to ingest the end caps or pistons associated with the chaff cartridges.

Environmental concentrations would vary based on release points and dispersion by wind and water currents. The number of end caps and pistons that would remain at or just below the surface in *Sargassum* mats and potentially available to fish is unknown but is expected to be an extremely small percentage of the total.

ESA-listed species in the Key West Range Complex such as smalltooth sawfish and scalloped hammerhead sharks are bottom feeders and would not encounter end caps or flares at the surface, but could ingest an item after it settled to the bottom. However, these items would most likely pass through the digestive tract without causing harm. Based on the low density of expended endcaps and pistons, the encounter rate would be extremely low, and the ingestion rate even lower. No chaff or flares are planned for use in the Northeast Range Complexes where the Atlantic salmon occurs. The number of fishes potentially impacted by ingestion of end caps or pistons would be low based on the low environmental concentration. Population-level effects would not be expected.

As discussed above, it is unlikely that giant manta rays or oceanic whitetip sharks could mistake larger military expended materials other than munitions for prey, even though these species typically forage at or near the surface. If these species accidentally ingested military expended materials other than munitions, it is likely that they would “taste” the item and then spit it out. If these species accidentally ingested an item, it would most likely pass through the digestive tract without causing harm.

Overall, the potential impacts of ingesting decelerators/parachutes, target fragments, or end caps and pistons would be limited to individual fish that ingest an item too large to pass through its gut. Fishes encounter many items (natural and manmade) in their environment that are unsuitable for ingestion and most species have behavioral mechanisms for spitting out the item. If the item were swallowed, it could either pass through the digestive system without doing any harm, or become lodged inside the fish and cause injury or mortality.

For smalltooth sawfish, the likelihood of ingestion of military expended materials other than munitions by early life stages would be slightly less than that of adults, because nursery habitats are found in very shallow water (less than 1 m deep), where no military expended materials would occur. The potential impacts on smalltooth sawfish are discountable because they are historically rare in the locations where military expended materials are expended. Early life stages of sturgeon are typically found in freshwater rivers and not in marine environments, so only juveniles and adults would be potentially exposed to ingestion stressors.

Although ingestion of military expended materials identified here could result in sublethal or lethal effects, the likelihood of ingestion is low based on the dispersed nature of the materials, the limited encounter rate of fishes to the expended items, behavioral mechanisms for expelling the item, and the capacity of the fish's digestive system to simply pass the item through as waste. Based on these factors, the number of fishes potentially impacted by ingestion of military expended materials (such as chaff and flare end caps and pistons) would be low, and no population-level effects would be expected.

Pursuant to the ESA, military expended materials other than munitions from training activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

Impacts from Military Expended Materials – Other Than Munitions Under Alternative 1 for Testing Activities

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials – Other Than Munitions) under Alternative 1, testing activities involving target materials use would occur throughout the Study Area. All of the ESA-listed species occur where target materials could potentially be expended.

As indicated in Section 3.0.3.3.6.3 (Military Expended Materials – Other Than Munitions), under Alternative 1, activities involving chaff and flare use would occur in offshore locations throughout the Study Area. No potential impacts would occur from the chaff itself, but there is some potential for fishes, including ESA-listed species to ingest the end caps or pistons associated with the chaff cartridges.

The smalltooth sawfish or sturgeon could ingest one of these items after it settled to the bottom, but the item would most likely pass through the digestive tract of a larger fish without causing harm, as the items measure only 1.3 in. (3.3 cm) in diameter and 0.13 in. (0.3 cm) in thickness. Based on the low density of expended end caps and pistons, the encounter rate would be extremely low, and the ingestion rate even lower. The number of fishes potentially impacted by ingestion of end caps or pistons would be low based on the low environmental concentration. Population-level effects would not be expected.

The potential impacts on smalltooth sawfish are discountable because they are historically rare in the locations where decelerators/parachutes, chaff, targets, and end-caps are expended. Smalltooth sawfish are rare in the Gulf of Mexico Large Marine Ecosystem, but since 1999, the species has been documented in the vicinity of the Naval Surface Warfare Center, Panama City Division Testing Range, and a viable population exists off the coast of southwest Florida (Papastamatiou et al., 2015).

For sawfishes, the early life stages have the same body-type as adults; however, the likelihood of ingestion of military expended materials other than munitions by early life stages would be slightly less than that of adults, because nursery habitats are found in very shallow water (less than 1 m), where no military expended materials would be expended. Early life stages of sturgeon are typically found in freshwater rivers and not in marine environments, so only juveniles and adults would be potentially exposed to ingestion stressors.

As discussed above, it is unlikely that offshore species such as giant manta rays or oceanic whitetip sharks could mistake larger military expended materials other than munitions for prey during testing activities, even though these species typically forage at or near the surface. It is likely that these species would "taste" and then spit it out if an item were accidentally ingested; if ingested, the item would most likely pass through the digestive tract without causing harm.

Overall, the risk of potential impacts of fishes ingesting military expended materials resulting from proposed testing activities would be low.

Pursuant to the ESA, military expended materials other than munitions from testing activities, as described under Alternative 1, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.6.2.2 Impacts from Military Expended Materials – Other Than Munitions Under Alternative 2

Impacts from Military Expended Materials – Other Than Munitions Under Alternative 2 for Training Activities

Because training activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials other than munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with training activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended materials other than munitions from training activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

Impacts from Military Expended Materials – Other Than Munitions Under Alternative 2 for Testing Activities

Because testing activities under Alternative 2 occur at a similar rate and frequency relative to Alternative 1, ingestion stress experienced by fishes from military expended materials other than munitions under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. Therefore, impacts associated with testing activities under Alternative 2 are the same as Alternative 1.

Pursuant to the ESA, military expended materials other than munitions from testing activities, as described under Alternative 2, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes.

3.6.3.6.2.3 Impacts from Military Expended Materials – Other Than Munitions Under the No Action Alternative

Impacts from Military Expended Materials – Other Than Munitions Under the No Action Alternative for Training and Testing Activities

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. Ingestion stressors for fishes from military expended materials other than munitions would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities.

3.6.3.7 Secondary Stressors

This section analyzes potential impacts on fishes exposed to stressors indirectly through impacts on their prey availability and habitat (e.g., sediment or water quality, and physical disturbance). 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 Navy training and testing activities could pose secondary or indirect impacts on fishes via habitat (e.g., sediment, and water quality) and prey availability. These include (1) explosives and explosion byproducts; (2) metals; (3) chemicals; and (4) other materials such as targets, chaff, and plastics. Activities associated with these stressors are detailed in Tables 2.8-1 to 2.8-3, and their potential effects are analyzed in Section 3.2 (Sediments and Water Quality), Section 3.4 (Invertebrates), and Section 3.5 (Habitats). The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential impacts from explosives and physical disturbance and strike stressors on seafloor resources in mitigation areas throughout the Study Area (see Section 5.4.1, Mitigation Areas for Seafloor Resources). This mitigation will consequently help avoid potential impacts on fishes that shelter in and feed on shallow-water coral reefs, live hard bottom, artificial reefs, and shipwrecks.

3.6.3.7.1 Impacts on Habitat

The Proposed Action could result in localized and temporary changes to the benthic community during activities that impact fish habitat. Hard bottom is important habitat for many different species of fish, including those fishes managed by various fishery management plans. 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. The spatial area of habitat impacted by the Proposed Action would be relatively small compared to the available habitat in the Study Area. However, there would still be vast expanses of habitat adjacent to the areas of habitat impact that would remain undisturbed by the Proposed Action.

Explosions

Secondary impacts to fishes resulting from explosions at the surface, in the water column, or on the bottom would be associated with changes to habitat structure and effects to prey species. Most explosions on the bottom would occur in soft bottom habitat and would displace some amount of sediment, potentially resulting in cratering. However, water movement would redistribute the affected sediment over time. A small amount of sediment would be suspended in the water column temporarily (turbidity), but would resettle to the bottom. Activities that inadvertently result in explosions on or near hard bottom habitat or reefs could break hard structures and reduce the amount of colonizing surface available to encrusting organisms (e.g., corals, sponges). Given the large spatial area of the range complexes compared to the small percentage covered by hard bottom habitat, 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 biogenic habitat within the Study Area.

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, as covered in Section 3.6.3.1 (Acoustic Stressors). 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 & York, 2005; Macreadie et al., 2011).

The alternatives 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. Additionally, plankton and zooplankton that are eaten by fishes may also be negatively impacted by these same expended materials. The spatial area of habitat impacted by the Proposed Action would be relatively small compared to the available habitat in the Study Area. However, there would still be vast expanses of habitat adjacent to the areas of habitat impact that would remain undisturbed by the Proposed Action.

Impacts of vessel disturbance and strike during amphibious assaults could temporarily reduce the quality and quantity of benthic substrate (sand) over an extremely localized and limited area within Onslow Beach and Seminole Beach. Fishes in the taxonomic group that includes the snapper-grouper complex (as managed by the South Atlantic Fishery Management Council), use these designated amphibious assault areas with sandy benthic substrate as habitat and could be impacted by this activity. However, the secondary habitat impacts on these fishes would be extremely localized compared to the total available area of sandy substrate available in the Jacksonville and Virginia Capes Range Complexes and the overall Study Area.

Impacts of physical disturbance and strikes by small-, medium-, and large-caliber projectiles would be concentrated within designated gunnery box areas, resulting in localized disturbances of hard bottom areas, but could occur anywhere in the range complexes or the Study Area. Hard bottom is important habitat for many different species of fish, including those fishes managed by various fishery management plans. The likelihood these habitats would be impacted is greater in Jacksonville and Navy Cherry Point Range Complexes compared to the Virginia Capes and Key West Range Complexes, based solely on these percentages. However, the location with the smallest proportion of hard bottom habitat (the Virginia Capes Range Complex) has the greatest concentration of small-caliber projectiles expended in the Study Area, with nearly 58 percent of the total 6,550,400 small-caliber projectiles expended.

Explosion By-Products

Deposition of undetonated explosive materials into the marine environment can be reasonably well estimated by the known failure and low-order detonation rates of high-explosives. Undetonated explosives associated with munitions 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 result in unexploded munitions and unconsumed explosives 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.

High-order 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 remainder is rapidly diluted below threshold effect level. Explosion byproducts associated with high order detonations present no indirect stressors to fishes through sediment or water. However, low order detonations and unexploded munitions present elevated likelihood of impacts on fishes.

Indirect impacts of explosives and unexploded munitions to fishes via sediment is possible in the immediate vicinity of the munitions. Degradation of explosives proceeds via several pathways discussed in Section 3.2 (Sediments and Water Quality). Degradation products of royal demolition explosive are not toxic to marine organisms at realistic exposure levels (Rosen & Lotufo, 2010). Trinitrotoluene (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., 2008a; Rosen & Lotufo, 2010). Relatively low solubility of most explosives and their degradation products means that concentrations of these contaminants in the marine environment are relatively low and readily diluted. Furthermore, while explosives and their degradation products were detectable in marine sediment approximately 0.15–0.3 m away from degrading munitions, the concentrations of these compounds were not statistically distinguishable from background beyond 1–2 m from the degrading munitions (Section 3.2, Sediments and Water Quality). Taken together, it is likely that various life stages of fishes could be impacted by the indirect impacts of degrading explosives within a very small radius of the explosive (0.3–2 m).

If high-explosive munitions 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). High-melting-point explosive or royal demolition explosive would not accumulate in the tissues of fishes (Lotufo et al., 2010; Price et al., 1998). Fishes 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 trinitrotoluene (TNT) expected in the marine water column reduces the likelihood of a fish encountering high concentrations of trinitrotoluene (TNT) to near zero.

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Edwards et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the impacts of undetonated materials and unexploded munitions on marine life. A summary of this literature which investigated water and sediment quality impacts, on a localized scale, from munitions ocean disposal sites and ocean disposed dredge spoils sites is presented in the Sediment and Water Quality section and specifically in Section 3.2.3.1 (Explosives and Explosives Byproducts) and Section 3.2.3.3 (Metals). Findings from these studies indicate that there were no adverse impacts on the local ecology from the presence of degrading munitions and there was no bioaccumulation of munitions-related chemicals in local marine species. Therefore, water quality effects from the use of munitions, expended material, or devices would be negligible, would have no long-term effect on water quality, and therefore would not constitute a secondary indirect stressor for fishes.

Metals

Certain metals and metal-containing compounds at concentrations above background levels (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) can be toxic to fishes (Wang & Rainbow, 2008). Metals are introduced into seawater and sediments as a result of training and testing activities involving vessel hulks, targets, munitions, batteries, and other military expended materials (Section 3.2, Sediments and Water Quality). Some metals bioaccumulate, and physiological impacts begin to occur only after several trophic transfers concentrate the toxic metals (U.S. Department of the Navy, 2012). Indirect effects of metals on fish 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 seawater 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.

Chemicals

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, principally flares and propellants for rockets, missiles, and torpedoes. Polychlorinated biphenyls are discussed in Section 3.2 (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 polychlorinated biphenyls 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, missiles, 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 re-suspended contaminated sediments. Since perchlorate is highly soluble, it does not readily adsorb to sediments. Therefore, missile and rocket fuels pose no risk of indirect impact on fishes via sediment. In contrast, the principal toxic components of torpedo fuel, propylene glycol dinitrate, and nitrodiphenylamine, adsorb to sediments, have relatively low toxicity, and are readily degraded by biological processes (Section 3.2, Sediments and Water Quality). It is conceivable that various life stages 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.

Other Materials

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. These potential impacts may cease only (1) when the military expended materials are too massive to be mobilized by typical oceanographic processes, (2) if the military expended materials become encrusted by natural processes and incorporated into the seafloor, or (3) when the military expended materials become 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. In contrast to large decelerators/parachutes, other devices with decelerators such as sonobuoys are typically used in deep open ocean areas. These areas are much lower in fish numbers and diversity, so entanglement hazards are greatly reduced for commercially and recreationally targeted species (i.e., tuna, swordfishes, etc.), as well as mesopelagic prey of other species. The entanglement stressor would eventually cease to pose an entanglement risk as it becomes encrusted or buried.

Pursuant to the ESA, impacts on habitat from secondary stressors during training and testing activities, as described above, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.3.7.2 Impacts on Prey Availability

Impacts on fish prey availability resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would differ depending upon the type of prey species in the area, but would likely be negligible overall and have no population-level impacts on fishes. As discussed in Section 3.6.3.1 (Acoustic Stressors), fishes with swim bladders are more susceptible to blast injuries than fishes without swim bladders. 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. Additionally, plankton and zooplankton that are eaten by fishes may also be negatively impacted by these same expended materials some species of zooplankton that occur in the Pacific such as Pacific oyster (*Crassostrea gigas*) larvae have been found feeding on microplastics (Cole & Galloway, 2015).

In addition to physical effects of an underwater blast such as being stunned, 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 (Hanlon & Messenger, 1996; Mather, 2004). The sound from underwater explosions might induce startle reactions and temporary dispersal of schooling fish if they are within close proximity (Popper et al., 2014; Wright, 1982).

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. The sound from underwater explosions might induce startle reactions and temporary dispersal of schooling fishes, potentially increasing visibility to predators, if they are within close proximity (Kastelein et al., 2008). 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 food web would be expected. Indirect impacts of underwater detonations and high explosive munitions use under the Proposed Action would not result in a decrease in the quantity or quality of fish populations in the Study Area.

Pursuant to the ESA, impacts on prey availability from secondary stressors during training and testing activities, as described above, will have no effect on designated critical habitat for Atlantic salmon, smalltooth sawfish, and gulf sturgeon, or proposed critical habitat for Atlantic sturgeon, but may affect

ESA-listed fishes. The Navy will consult with the National Marine Fisheries Service, as required by section 7(a)(2) of the ESA in that regard.

3.6.4 Summary of Potential Impacts on Fishes

3.6.4.1 Combined Impacts of All Stressors Under Alternative 1

As described in Section 3.0.3.5 (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 and summarized in Section 3.6.5 (Endangered Species Act Determinations).

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, it 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).

A fish could also 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 (e.g., near naval ports, testing ranges, and routine activity locations and in areas that individual fish frequent because it is within the animal's home range, migratory corridor, spawning or feeding area. 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 Navy 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 (on the order of a few hours or less).

Multiple stressors may also have synergistic effects. For example, fishes 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. Fishes 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.

The combined impacts under Alternative 1 of all stressors would not be expected to impact fish populations because (1) activities involving more than one stressor are generally short in duration, and

(2) such activities are dispersed throughout the Study Area. Existing conditions would not change considerably, therefore, no impacts on fish populations would occur with the implementation of Alternative 1.

3.6.4.2 Combined Impacts of All Stressors Under Alternative 2

The combined impacts under Alternative 2 of all stressors would not be expected to impact fish populations because (1) activities involving more than one stressor are generally short in duration, and (2) such activities are dispersed throughout the Study Area. Existing conditions would not change considerably, therefore, no impacts on fish populations would occur after the implementation of Alternative 2.

3.6.4.3 Combined Impacts of All Stressors Under the No Action Alternative

Under the No Action Alternative, the Navy would not conduct the proposed training and testing activities in the AFTT Study Area. The combined impacts of all stressors for fishes would not be introduced into the marine environment. Therefore, baseline conditions of the existing environment would either remain unchanged or would improve slightly after cessation of ongoing training and testing activities and no impacts on fish population would occur.

3.6.5 Endangered Species Act Determinations

Pursuant to the ESA, Navy training and testing activities may affect ESA-listed fishes and will have no effect on designated critical habitat because the proposed action does not have any elements with the potential to modify such habitat. The Navy will consult with the National Marine Fisheries Service as required by section 7(a)(2) of the ESA in that regard. The outcome of those consultations pursuant to ESA will be described in the Final AFTT EIS/OEIS.

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