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

TABLE OF CONTENTS

List of Figures

List of Tables

3.4 Invertebrates

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. Invertebrate populations are typically lower offshore, where most training and testing occurs, than inshore due to the scarcity of habitat structure and comparatively lower nutrient levels. Exceptions occur at nearshore and inshore 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 with explosives do not typically occur. Invertebrate populations are generally lower offshore than inshore due to the scarcity of habitat structure and comparatively lower nutrient levels. Exceptions occur where explosives are used on the bottom within nearshore or inshore waters on or near sensitive live 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 activities would produce electromagnetic energy that briefly affects 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 only been documented at much higher field strength than what the proposed activities generate. High-energy lasers can damage invertebrates. However, 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 when the target is missed. Due to the relatively small number of individuals that may be affected, population-level impacts are unlikely.
- 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 (where invertebrates are less abundant) and near the surface where relatively few invertebrates occur during the day when actions are typically occurring. The majority of expended materials are used in areas far from nearshore and inshore bottom areas where invertebrates are the most abundant. Exceptions occur for actions taking place within inshore and nearshore waters over primarily soft bottom communities, such as related to vessel transits, inshore and nearshore vessel training, nearshore explosive ordnance disposal training,

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INVERTEBRATES SYNOPSIS

- Physical Disturbance and Strike (continued): 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. The risk of entangling invertebrates is minimized by the typically linear nature of the expended structures (e.g., wires, cables), although decelerators/parachutes have mesh that could pose a risk to those invertebrates that are large and slow enough to be entangled (e.g., jellyfish). Deep-water coral could also be entangled by drifting decelerators/parachutes, but co-occurrence 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, which could be ingested by filter- or deposit-feeding invertebrates. Ingestion of such materials would likely occur infrequently, and only invertebrates located very close to the fragmented materials would potentially be affected. Furthermore, the vast majority of human-deposited 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 are mostly limited to nearshore soft bottom habitats that recover quickly from disturbance. Following detonation, concentrations of explosive byproducts are rapidly diluted to levels that are not considered toxic to marine invertebrates. Furthermore, most explosive byproducts are common seawater constituents. Contamination leaching 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 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 marine 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 dilution and dispersion of some stressors (e.g., chemical contaminants), potential drifting of small invertebrates out of an impact area, and the relatively greater mobility of open water invertebrates large enough to actively leave 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 United States (U.S.) Continental Shelf 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) (Chuenpagdee et al., 2003; Food and Agriculture Organization of the United Nations, 2005; 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 all depths of the water column in all the 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 (Brusca & Brusca, 2003). Many species that occur in the water column are either microscopic or not easily observed with the unaided eye (e.g., protozoans, copepods, and the larvae of larger invertebrate species). Many invertebrates migrate to deeper waters during the day, presumably to decrease predation risk. However, some invertebrates, such as some jellyfish and squid species, may occur in various portions of the water column, including near the surface, at any time of day. In addition, under certain oceanographic conditions, other types of invertebrates (e.g., pelagic crabs and by-the-wind sailors [*Velella velella*]) may occur near the surface during the day. 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. 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. 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. 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).

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 are typically greater in coastal water habitats compared to the open ocean due to the increased availability of food and protection that coastal habitats provide (Levinton, 2009).

The diversity and abundance of Arthropoda (e.g., crabs, lobsters, and barnacles) and Mollusca (e.g., snails, clams, scallops, and squid) are 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 & National Oceanic and Atmospheric Administration, 1996b; 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 & National Oceanic and Atmospheric Administration, 1996a). 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, such as 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 inshore 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 (National Ocean Service, 2016a; Nybakken, 1993). Shallow-water corals occur in the euphotic zone, which is the upper layer of the ocean where light levels are sufficient to support photosynthesis in the symbiotic algae. Shallow-water coral species typically occur in water depths less than 30 meters (m). Shallow-water coral reefs occur on hard substrate in southern and southeastern portions of the Study Area, including 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 historical 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 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 typically 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 Ocean and Atmospheric Administration, 2016; National Oceanic and Atmospheric Administration & National Marine Fisheries Service, 2008). To build their supporting structures, stony corals require calcium carbonate in the form of aragonite or calcite, 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 stony 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. The primary taxa of deep-water corals include hexacorals (stony corals, black corals, and gold corals), octocorals (e.g., true soft corals, gorgonians, and sea pens), and hydrocorals (e.g., lace corals) (Hourigan et al., 2017a). Of the approximately 600 coral species that occur at depths below 50 m, about 20 are considered structure-forming (Hourigan et al., 2017a). Stony corals such as ivory tree coral (*Oculina varicosa*), *Lophelia pertusa*, and *Enallopsammia profunda* provide three-dimensional structure that may be utilized by other marine species. However, taxa such as black corals, gorgonians, and sea pens may also provide habitat for other marine species, particularly when they occur in dense aggregations. With the exception of sea pens, which occur in soft substrate, 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). Spatial information on the hard and intermediate substrate habitats typically occupied by deep-water structure-forming corals is provided in Section 3.5 (Habitats).

A transition zone of reduced light levels, called the mesophotic zone, occurs between the water depths typically associated with shallow-water and deep-water corals. Mesophotic coral communities are composed of stony corals, soft corals, and other structure-forming organisms such as algae and sponges. Some corals with symbiotic, photosynthetic algae occur in the mesophotic zone, although the algae often undergo photosynthesis at reduced rates and the corals, therefore, rely more heavily on planktonic food capture compared to individuals that occur in the euphotic zone. Black corals and octocorals, which do not contain photosynthetic algae, are also characteristic of mesophotic communities. The depth range of the mesophotic zone depends on water clarity, but it is generally considered to extend from 30 m to about 100 to 150 m. Mesophotic communities may occur as deeper extensions of shallow-water reefs or other hard bottom communities (typically in the coastal zone), or they may occur in offshore locations with no connection to shallow-water communities. Mesophotic reefs are usually not detectable on satellite images, which increases the difficulty of identifying and mapping these features. The highest concentrations of stony corals typically occur on persistent, high-relief bottom features that represent a small subset of the hard and, to a lesser extent, intermediate substrates of the Study Area. Spatial information on the hard and intermediate habitats typically occupied by mesophotic structure-forming corals is provided in Section 3.5 (Habitats). Pulley Ridge, which is located within the Key West Range Complex about 100 miles west of the Dry Tortugas, is an example of a mesophotic coral ecosystem occurring in the Study Area. The ridge is about 5 kilometers (km) wide and rises less than 10 m above the surrounding seafloor, with a depth range of about 60 to 90 m (Baker et al., 2016; Halley et al., 2005). Corals containing photosynthetic algae occur in water depths to 70 m. Surveys conducted at Pulley Ridge using remotely operated vehicles found that stony corals covered only about 1.3 percent of observed substrate overall (Reed et al., 2015).

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 of solution 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. Of these features, only seamounts and the Mid-Atlantic Ridge occur in the abyssal zone portion of the Study Area, outside of the Coastal Large Marine Ecosystems.

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 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 vertebrates). 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). Planktonic 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 and Explosive Concepts, 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 statocysts. 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., 2016a). Aquatic invertebrates that are able to sense local water movements with ciliated cells include cnidarians, flatworms, segmented worms, 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 (e.g., toothed whales) 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 (dB) referenced to 1 micropascal (dB re 1 µPa) (Wilson et al., 2007) (refer to Appendix D, Acoustic and Explosive Concepts, 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 vibrating the 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 & 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) (which may be introduced as a result of growth on vessel hulls or bilge water discharge), oil spills (Yender et al., 2010), 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, 2016a). 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, 2016b, 2016c). 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, turbidity and increased particle deposition that may occur as a result of sediment disturbance, 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. Sediment disturbance 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 (USEPA) and the U.S. Department of Defense 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/extraction 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 (White et al., 2012; Yender et al., 2010). 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 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. In one experiment, three coral species that experienced bleaching had reduced ability to remove sediments from their tissue surface (Bessell-Browne et al., 2017). 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). The results of one study suggest that some corals may acclimate to increased water temperature over time, exhibiting less temperature sensitivity and resulting bleaching activity (McClanahan, 2017). Skeletal formation of post-settlement individuals of the plate coral *Acropora spicifera* was not affected by increased water temperature (Foster et al., 2016). However, exposure to lowered pH was found to increase the potential for negative effects associated with subsequent water temperature increase in one stony coral species (Towle et al., 2016). In addition to potential physiological effects, the distribution of some invertebrates may be affected by changing water temperature. Northern and southern shifts in the geographic center of abundance of some benthic invertebrates along the U.S. Atlantic coast have occurred over the last 20 years, presumably in response to increased water temperature (Hale 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). For example, newly settled individuals of the plate coral *A. spicifera* that were exposed to elevated carbon dioxide and lowered pH levels showed decreased mineral deposition and evidence of skeletal malformation (Foster et al., 2016), and water acidification decreased the survival, size, and weight of bay barnacles (*Balanus improvises*) (Pansch et al., 2018). The results of one study suggest that community-level effects to corals can be more evident than effects to individual corals (Carpenter et al., 2018). 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 (Fox et al., 2016; 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 invertebrate species may be more tolerant of changing acidity levels than others (Bahr et al., 2016). One study found that lowered pH caused a significant decrease in black band disease progression in mountainous star coral (Muller et al., 2017). Another study of three Arctic marine bivalves concluded that at least two of the species are generally resilient to decreased pH (Goethel et al., 2017). A study of the deep-water stony coral *Desmophyllum dianthus* found that the species was not affected by increased acidity under conditions of ambient water temperature but that stress and decreased calcification occurred when acidity and water temperature were both increased (Murray et al., 2016). Gelatinous invertebrates such as jellyfish generally seem to be tolerant of increased water acidity (Treible et al., 2018).

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.

Researchers conducted an extensive marine debris survey at selected beach locations from Maine to the southern Florida Atlantic coast (Ribic et al., 2010). The survey found relatively low debris levels in the northern and southern portions of the investigated area but higher amounts of debris and a trend of increasing debris occurrence over time in the mid-Atlantic region. All debris items were identified as either land-based, general-source (e.g., plastic bags and bottles), or ocean-based (e.g., items originating from recreational and commercial fishing, shipping, and tourism activities). No items of military origin were differentiated. An assessment of marine debris collected between 2008 and 2015 in the mid-Atlantic region (Delaware to Virginia) found that the most abundant debris items were plastic, foam, and tobacco-related products (Mid-Atlantic Regional Council On The Ocean, 2015). Overall, plastic was the type of debris most often observed. A study of marine debris in the Gulf of Mexico and U.S. Caribbean Sea (Puerto Rico and U.S. Virgin Islands) conducted from 1996 to 2003 found a decrease in the amount of land-based, ocean-based, and general debris in the eastern Gulf of Mexico and Caribbean (Ribic et al., 2011). A decrease in land-based debris only was noted in the western Gulf of Mexico. Similar to survey results of the U.S. Atlantic coast, the majority of debris items were plastic bottles. U.S. Navy vessels have a zero-plastic discharge policy and return all plastic waste to appropriate disposal or recycling sites onshore.

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 NMFS 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 Stylasteridae (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; introduced 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***	***Bays, Harbors, and Inshore Waterways***
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
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

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*	*Bays, Harbors, and Inshore Waterways*
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, although it has been reported as deep as 30 m (Aronson et al., 2008b; Boulon et al., 2005). The optimal water temperature range for elkhorn coral is 77 to 84 degrees Fahrenheit, and it requires a salinity range of 34 to 37 parts per thousand (Aronson et al., 2008b; 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., 2008b). 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 corals (Bruckner, 2003; Rothenberger et al., 2008).

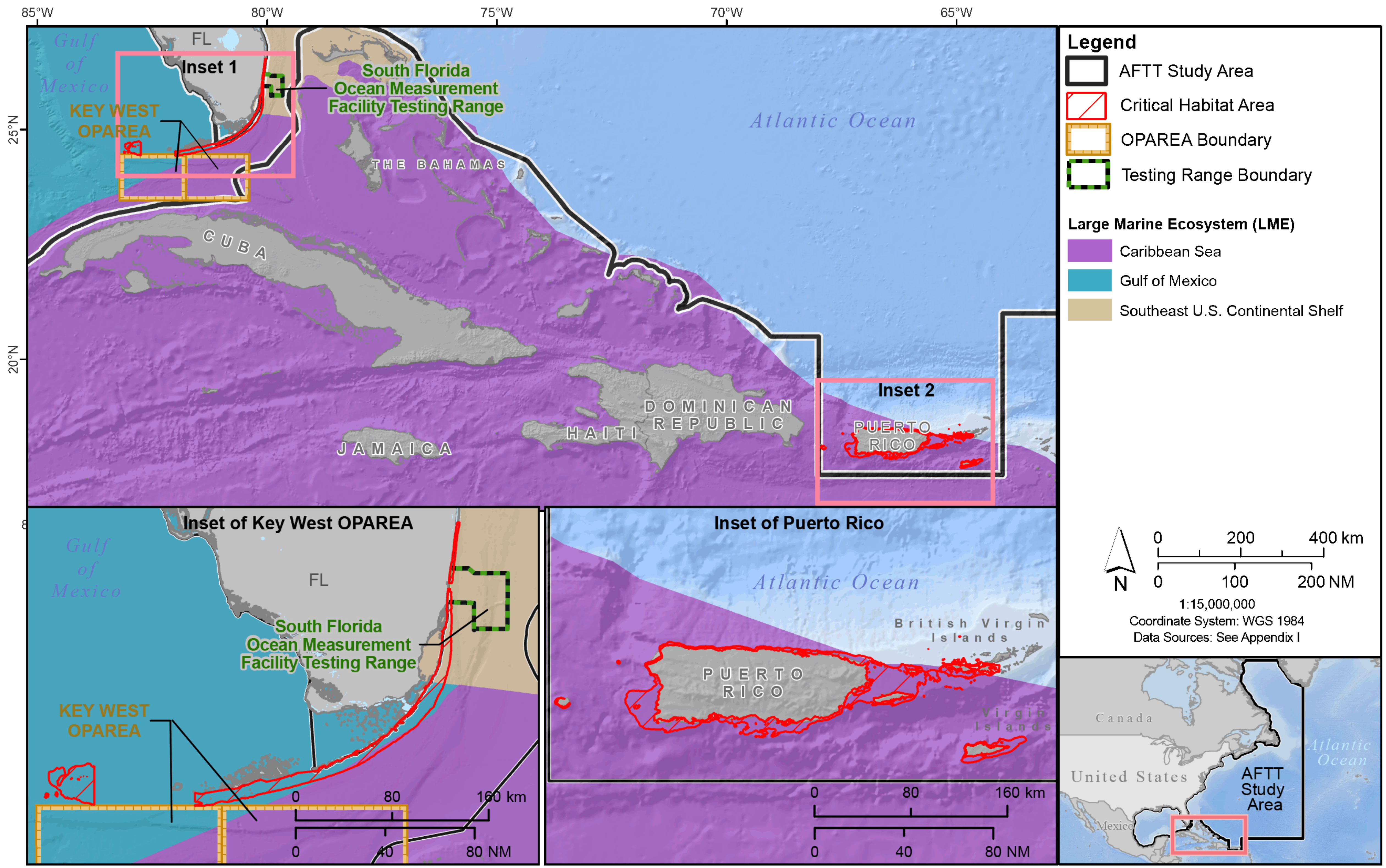
Research on the population status of elkhorn coral in particular indicates a drastic decline. Surveys of Carysfort Reef (1974 to 1982) and Molasses Reef (1981 and 1986) revealed slight declines or stable colonies (Jaap et al., 1988). It was not until the observation of a 93 percent decrease of coral 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 (Wallace, 1999). The average generation time is 10 years, and longevity is likely longer than 10 years based on average growth rates and size (Aeby et al., 2008). 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; OPAREA: Operating Area

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, and requires a salinity range of 34 to 37 parts per thousand (Aronson et al., 2008d; 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 palmata* 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)
- 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, 2012). 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 palmata* 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 Marine Fisheries Service, 2012a; 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 (Brainard et al., 2011; National Marine Fisheries Service, 2012a). *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 Marine Fisheries Service, 2012a). *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 6 to 8 nights following the new moon in late summer (late August to early October) (Brainard et al., 2011). Buoyant gametes are fertilized at the surface. Fertilization success is low and recruitment rates are apparently extremely low. For example, one study found only a single *O. annularis* recruit over 16 years of observation of 12 square meters of reef in Discovery Bay, Jamaica (Hughes & Tanner, 2000). 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 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, 2012). 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 (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, 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 (different species of the same genus) 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*. Mountainous 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 within depths from 0.5 m to at least 40 m (Brainard et al., 2011), and like *O. annularis* it is more commonly found in the shallower portions of this depth range. The *O. annularis* complex has been reported to at least 70 to 90 m, 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 but has been documented at depths of 1 to 25 m (Brainard et al., 2011; National Oceanic and Atmospheric Administration, 2012). 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 Marine Fisheries Service, 2012a).

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 Marine Fisheries Service, 2012a).

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 Marine Fisheries Service, 2012a). Though reported to commonly occur at depths of 5 to 30 m (Aronson et al., 2008a), this could be an artifact of scuba diver-based survey intensity, which decreases dramatically below 30 m. Rough cactus coral occurs in patch and fore reef (the part of the reef exposed to the open ocean) habitat types, generally in lower energy parts of the reef (Brainard et al., 2011; National Marine Fisheries Service, 2012a). It is known to occur 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., 2008a). 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. 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

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***	***Inshore 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
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

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***	***Inshore Waters***
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, 2000b). 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, 2010b). 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, 2010c). This filtering process is an important coupler of processes that occur in the water column and on the bottom (Perea-Blázquez et al., 2012). Many sponges form calcium carbonate or silica spicules or bodies embedded in cells to provide structural support (Castro & Huber, 2000a; 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, 1995b). 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 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 stony 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, 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 U.S. Department of Defense 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 consist primarily of hexacorals (stony corals, black corals, and gold corals), octocorals (e.g., true soft corals, gorgonians, sea pens), and hydrocorals (e.g., lace corals) (Hourigan et al., 2017a). A total of 77 deep-water coral species have been identified off the northeastern United States from Maine to North Carolina, including the continental shelf and slope of the Gulf of Maine, Georges Bank, southern New England, Mid-Atlantic Bight (to Cape Hatteras), and various seamounts located off New England near Georges Bank (Packer et al., 2017). The majority of these coral species consist of gorgonians. Soft corals are more common at shallower sites. Large bioherm formations resulting from stony coral species such as *L. pertusa* have not been observed in the northeast region. Numerous submarine canyons, which often contain hard substrate necessary for most deep-water corals, occur on the continental slope and shelf from Georges Bank to Cape Hatteras. Available information indicates that deep-water corals are more densely distributed in canyons than on the adjacent slope, although there is considerable variation between individual canyons (Packer et al., 2017). Colonial and solitary stony corals, black corals, and gorgonians have often been observed on hard substrate within the canyons, while solitary stony corals, sea pens, and bamboo corals are common on soft sediments. Overall, gorgonians appear to be the dominant structure-forming corals. Deep-sea coral occurrence in canyons along Georges Bank and the Mid-Atlantic Bight generally extends from depths of about 200 m to below 2,000 m. Corals were generally found to be uncommon in most open slope and inter-canyon sites, with the exception of some soft-sediment areas that supported sea pens and bamboo corals (Quattrini et al., 2015). Corals and deep-sea sponges were also observed on boulders and outcrops in some open slope and inter-canyon areas. Multiple seamount areas off the northeastern United States have been explored in recent years (Packer et al., 2017; Quattrini et al., 2015). Species composition was different among the various seamounts but generally included sea pens and stony cups corals in soft-sediment areas, and taxa such as black corals and gorgonians on hard bottom, walls, ledges, and rocky outcrops. Exploratory surveys in the Gulf of Maine have documented extensive coral aggregations in surveyed areas at depths of about 200 to 250 m. Structure-forming corals at these sites consisted mostly of gorgonians. Dense sea pen patches were observed in some mud and gravel habitats adjacent to hard bottom habitats. Two of the surveyed sites that support dense coral growth (Outer Schoodic Ridge and Mount Desert Rock) occur in the inshore portion of the Gulf of Maine, approximately 20 to 25 nautical miles (NM) from the coast. In 2016, the Northeast Canyons and Seamounts Marine National Monument was designated. The monument consists of two units, with one unit encompassing three canyons on the edge of Georges Bank and the other encompassing four seamounts. Designation of the monument is intended to protect deep-sea corals, among other resources.

In the southeastern U.S. region (Cape Hatteras, North Carolina to the Straits of Florida, including deep water areas such as Blake Plateau), deep-water stony corals reach their greatest abundance and structure formation in U.S. waters (Hourigan et al., 2017b). Research has been more extensive in this area than in the northeast United States, although many of the deeper portions remain poorly explored. A total of 197 deep-water coral species have been identified off the southeastern United States. Most of these species consist of stony and gorgonian corals. Broadly, the major concentrations of hard bottom habitat that are known to support or likely support deep-water corals off the southeastern United States include the continental shelf break, *Oculina* coral mounds, the continental slope and Blake Plateau, and the Miami and Pourtales Terraces and Escarpments. High relief ridges and rock outcrops at the shelf break and on the upper slope are often heavily encrusted with gorgonians. Other coral taxa observed in these areas include colonial stony corals (e.g., *O. varicosa*, *Madracis myriaster*, and *Madrepora oculata*), black corals, and soft corals. *Oculina* bioherms (also referred to as reefs or mounds) occur extensively along the shelf break off central Florida. These bioherms function as habitat for other coral taxa including gorgonians, soft corals, black corals, and stony cup corals. *O. varicosa* coverage may reach up to 30 to 40 percent of available hard substrate in some areas, although in other areas the density may be much less and specimens may occur as thickets, isolated colonies, and coral rubble. *L. pertusa* bioherms have been recently found in relatively shallow water (about 200 m) off northeastern Florida. Relative to other parts of the Study Area, *L. 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 *L. 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, 2010). The dominant structure-forming scleractinian corals on the southeastern continental slope (waters generally deeper than 200 m) are *L. pertusa* and *Enallopsammia profunda*, which may form bioherms or other types of mounds. Such structures are dominant features of the Blake Plateau from North Carolina to south Florida and the Bahamas. *Lophelia* mounds off North Carolina are apparently the northernmost bioherms in the United States. Coral occurrence in the central Blake Plateau region appears to consist mostly of smaller aggregations on coral mounds and rocky substrate. Non-structure forming octocorals, black corals, bamboo corals, soft corals, and cup corals may be relatively abundant throughout the southeast region in areas of suitable habitat. The Miami Terrace occurs off southeast Florida beginning at about 275 m depth, with a series of terraces and ridges at increasing depth (beyond 870 m). The Pourtales Terrace occurs at depths of 200 to 450 m along the southern edge of the Florida Keys reef tract and provides extensive, high relief, hard bottom habitat (Hourigan et al., 2017b). Various deep-water corals occur on these features, including *L. pertusa*, *E. profunda*, octocorals, gorgonians, black corals, and stylasterids (hydrocorals). Bioherms are rare in these areas, although a *Lophelia* mound at Pourtales Terrace represents the southernmost occurrence known in U.S. waters.

The geological complexity of the deep northern Gulf of Mexico (U.S.-Mexico border to the Florida Straits) supports a high diversity of deep-water corals (Boland et al., 2016). A total of 258 deep-water coral species have been identified in the Gulf (Etnoyer & Cairns, 2017). Substrate in the western and central portion of the Gulf generally consists of fine sand, silt, and clay, while hard bottom consists of old coral reefs, salt domes, and carbonate structures. In the eastern Gulf, the Florida platform and escarpment were primarily formed by sediment deposition and carbonate-producing organisms. Research to date indicates that mesophotic reefs (approximately 30 to 150 m depth) and deep coral habitats are widespread throughout the Gulf of Mexico, but are generally restricted to relatively rare hard substrates. Although data specific to the west Florida shelf are limited, available information suggests the extent of hard bottom habitat and the associated abundance and diversity of deep-sea corals is high. Structure-forming corals are generally found on hard substrates with moderate to high relief, including banks, mounds, carbonate structures, and artificial substrates (e.g., shipwrecks and offshore energy platforms). Various species of stony corals (e.g., *Enallopsammia*, *Lophelia*, *Oculina*, and *Madrepora* species), black corals, soft corals, gorgonians, and sea pens have been documented in suitable habitat throughout the Gulf of Mexico along the continental shelf and slope, and on the outer portion of the west Florida shelf. Hydrozoans (e.g., lace corals) have only been identified in the eastern Gulf, primarily along the shelf break and slope of the southern portion of the west Florida shelf.

Deep-water corals are likely absent from the open ocean biogeographic zone because water depth is typically greater than the depth of the aragonite saturation zone (in the case of stony corals), and because of 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 (Boland et al., 2016; Hourigan et al., 2017b; Packer et al., 2017; Rooper et al., 2017; Rooper et al., 2016; Yoklavich et al., 2017). 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 is also a potential threat. For example, during one study, a fishing trap, fishing line, balloon remnants, and ribbon was observed either lying on or wrapped around deep-sea corals located off the northeastern United States (Quattrini et al., 2015). Other potential human-caused threats to deep-water corals include hydrocarbon exploration and extraction, cable and pipeline installation, and other bottom-disturbing activities (Boland et al., 2016; Hourigan et al., 2017b; Packer et al., 2017). 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, 2000a). The largest single group of flatworms are parasites commonly found in fishes, seabirds, and marine mammals (Castro & Huber, 2000a; University of California Berkeley, 2010e). 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, 2000a). 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, 2000b). 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, 2008; 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, abundant in sediment habitats such as soft to intermediate shores and soft to intermediate bottoms, and also found in host organisms as parasites (Castro & Huber, 2000a). 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, 2000a). Round worms are found throughout the Study Area.

3.4.2.3.7 Segmented Worms (Phylum Annelida)

Segmented worms include approximately 14,000 marine species worldwide in the phylum Annelida, although the number of potentially identified marine species is nearly 25,000 (World Register of Marine Species Editorial Board, 2015). Most marine annelids are in the class Polychaeta. Polychaetes are the most complex group of marine worms, with a well-developed respiratory and gastrointestinal system (Castro & Huber, 2000a). Different species of segmented worms may be highly mobile or burrow in the bottom (soft to intermediate shore or bottom habitats) (Castro & Huber, 2000b). 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., 2015). 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 inshore waters and 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, 2000a), 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, 2000a; Colin & Arneson, 1995a; Hoover, 1998c). Clams, mussels, and other bivalves are filter feeders, ingesting suspended food particles (e.g., phytoplankton, detritus) (Castro & Huber, 2000a). 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, 2000b; Colin & Arneson, 1995a). 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, 2000a; 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 (including inshore waters) 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, 2000a), 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, 2009c; 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). Eggs of the horseshoe crab (*Limulus polyphemus*) are a particularly important food source for some migratory birds at spring stopover sites along the northeastern U.S. coast (U.S. Fish and Wildlife Service, 2011). The American lobster is a commercially and recreationally important crustacean that has increased dramatically in population due, in part, to successful fishery management (National Marine Fisheries Service, 2012b).

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** (explosions in water)
- **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.

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 farther 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 (Myrberg, 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, and one study investigated zooplankton mortality in response to air gun firing.

Researchers have investigated the effects of noise on 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 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 dB 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 statocysts, 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 per second (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, resulting in reduced sound levels.

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(s) of the injuries and strandings cannot be determined conclusively.

Zooplankton abundance and mortality was investigated in the context of exposure to air gun firings in an open ocean environment (McCauley et al., 2017). Net tows and sonar surveys were conducted after transects involving air gun firings were completed. The results indicated decreased zooplankton abundance and increased mortality as a result of exposure. The most abundant organisms (copepods and cladocerans [water fleas]) showed a 50 percent decrease in abundance at distances of about 500 to 700 m from the source. Received noise level at this distance was about 156 dB re 1 μPa^2 per 1 second (dB re 1 μPa^2 s^{-1}) SEL and 183 dB re 1 µPa peak-to-peak. There was no effect on the abundance of these specific taxa at distances of about 1 km from the source (153 dB re 1 μPa^2 s^{-1} SEL and 178 dB re 1 µPa peak-to-peak). However, an overall decrease in zooplankton abundance was reported at distances to about 1.2 km from the source. The authors speculate that the effects could have been caused by damage to external sensory hairs on the organisms.

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). 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 statocysts 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-second 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 individuals exposed to acoustic stressors would be in the far field where particle motion would not occur and, therefore, the types of damage described above would not be expected. In addition, 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 conclusion regarding 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 consists of 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 compared to abundances in offshore portions of the Study Area. 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

A 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 in the subject organisms.

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 a 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*) (30-minute exposure to sound levels of 100 to 140 dB re 1 µPa rms) and European spiny lobsters (30-minute 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). Mediterranean mussels (*Mytilus galloprovincialis*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 60 kHz, maximum SPL of 150 dB rms re 1 µPa), although exhibiting no behavioral changes at any tested frequency, showed statistically significant increases in some biochemical stress indicators (e.g., glucose and heat shock protein) in the low-frequency exposure category (0.1 to 5 kHz) (Vazzana et al., 2016). Changes in glucose levels were found in blue crabs (*Callinectes sapidus*) exposed to low-frequency sound (broadband noise with a significant component of 60 Hz at approximately 170 dB re 1 µPa SPL) and mid-frequency pulsed tones and chirps (1.7 to 4 kHz at approximately 180 dB re 1 µPa SPL) (Dossot et al., 2017).

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 feet [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. In general, exposure to continuous noise such as vessel operation during Navy training or testing events would occur over a shorter duration and sound sources would be more distant than those associated with most of the studies. 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 abundances are 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 from physiological stress associated with Navy training and testing events.

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.

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 velocity 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, and potential impacts on invertebrates would be associated with all anthropogenic sources.

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 (crustaceans and cephalopods) have typically been conducted with equipment used for seismic exploration, and the limited results suggest responses may vary among taxa. 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 both 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. Pacific oysters (*Magallana gigas*) exposed to 3-minute pure tones responded behaviorally (shell closure) to low-frequency sounds, primarily in the range of 10 to 200 Hz (Charifi et al., 2017). The oysters were most sensitive to sounds of 10 to 80 Hz at 122 dB rms re 1 µPa, with particle acceleration of 0.02 meter per squared second. 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., 2016a). 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. Follow-up experiments showed that particle acceleration detection sensitivity in mussels and hermit crabs ranged from 0.06 to 0.55 meters per squared second (Roberts et al., 2016b). Subsequent semi-field experiments consisted of operating a small pile driver for 2-hour periods in an enclosed dock (90 m long by 18 m wide, water depth of 2 to 3 m, and sediment depth of 3 to 4 m). Vibration in the sediment propagated farther (up to 30 m) in shallower water than in deeper water (up to 15 m). The signal in the sediment was mostly below 100 Hz and primarily from 25 to 35 Hz. Experimental animals in the enclosed area exhibited behavioral (e.g., width of shell opening) and physiological (e.g., oxygen demand) responses as a result of exposure, although information such as distance from the pile driver and particle acceleration at specific locations was not provided.

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). Decreased activity levels were found in blue crabs exposed to low-frequency broadband sound with a significant component of 60 Hz (approximately 170 dB re 1 µPa SPL) and mid-frequency pulsed tones and chirps (1.7 to 4 kHz at approximately 180 dB re 1 µPa SPL) (Dossot et al., 2017). Exposure to low-frequency sounds resulted in more pronounced effects than exposure to mid-frequency sounds. American lobsters appeared to be less affected than crabs.

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. Razor clams (*Sinonovacula constricta*) exposed to white noise and sine waves of 500 and 1,000 Hz responded by digging at a sound level of about 100 dB re 1 µPa (presumably as a defense reaction), but did not respond to sound levels of 80 dB re 1 µPa (Peng et al., 2016). Mediterranean mussels exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 60 kHz, maximum SPL of 150 dB rms re 1 µPa) showed no statistically significant behavioral changes compared to control organisms (Vazzana et al., 2016).

The results of these studies indicate that at least some invertebrate 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. 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 are 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 with distance 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 portions 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 been studied specifically. 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

<u>Impacts from Sonar and Other Transducers Under Alternative 1 for Training Activities</u>

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. Only individuals within a short distance (potentially a few feet) of the most intense sound levels would 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 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.

Current research does not support a biologically relevant impact of sound from sonar and other transducers at the levels predicted to occur within the Key West Range Complex or Gulf of Mexico. Sound produced by sonar and other transducers is, therefore, not likely to impact ESA-listed coral species in these areas. 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. Only individuals within a short distance (potentially a few feet) of the most intense sound levels would experience impacts on 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 ESA-listed corals because the northernmost distribution of these species occurs south of Port Canaveral. 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 NM from shore), and coral exposure would therefore not be expected because the distribution of shallow-water corals in the South Florida Ocean Measurement Facility Testing Range is limited to a relatively narrow band very close to shore. ESA-listed coral species may occur in deeper mesophotic waters seaward of the coastal zone, but an exposure close enough to cause particle motion and potential response from coral species also represents a hazard to safe navigation and would, therefore, be avoided. Coral larvae may be exposed to sonar and other transducers close enough to experience brief particle motion, but the available research does not support a biologically relevant response to that level of exposure. 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 ESA-listed shallow-water or mesophotic 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 shallow-water corals would most likely occur) would result in a temporary exposure only very close to the near surface sources affecting primarily pelagic invertebrates. ESA-listed coral species may occur in deeper mesophotic waters seaward of the coastal zone, but an exposure close enough to cause particle motion and potential response from coral species also represents a hazard to safe navigation and would, therefore, be avoided.

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 to be detected by corals. However, in the South Florida Ocean Measurement Facility Testing Range, low-frequency sonar would not be used within 3 NM of shore, and shallow-water 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 between Alternatives 1 and 2 in sonar and other transducer use 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. In the context of overall invertebrate population sizes and vertical distribution (benthic versus pelagic) within training areas, few individuals of any species would 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 exposures 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.

Current research does not support a biologically relevant impact of sound from sonar and other transducers at the levels predicted to occur within the Key West Range Complex or Gulf of Mexico. Sound produced by sonar and other transducers is, therefore, not likely to impact ESA-listed coral species in these areas. 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 between Alternatives 1 and 2 in sonar and other transducer use 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. Therefore, the increase in sonar and other transducer use would likely result in only a negligible increase in the number of individual invertebrates potentially affected. In the context of overall invertebrate population sizes and vertical distribution (benthic versus pelagic) within testing areas, few individuals of any species would 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. ESA-listed coral species may occur in deeper mesophotic waters seaward of the coastal zone, but an exposure close enough to cause particle motion and potential response from coral species also represents a hazard to safe navigation and would, therefore, be avoided. Coral larvae may be exposed to sonar and other transducers close enough to experience brief particle motion, but the available research does not support a biologically relevant response to that level of exposure. 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 ESA-listed shallow-water or mesophotic 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. ESA-listed coral species may occur in deeper mesophotic waters seaward of the coastal zone, but an exposure close enough to cause particle motion and potential response from coral species also represents a hazard to safe navigation and would, therefore, be avoided. 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 to be detected by corals. However, in the South Florida Ocean Measurement Facility Testing Range, low-frequency sonar would not be used within 3 NM of shore, and shallow-water 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 3.4.3.2.2, 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 training and testing 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 relatively large 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, but one study reported injury and mortality for zooplankton at exposures below Navy source levels. 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 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; Tables A.3.2.7.7, Semi-Stationary Equipment Testing, and A.3.3.1.1, Acoustic and Oceanographic Research, in Appendix A, Navy Activity Descriptions). Sounds produced by air guns are described in Section 3.0.3.3.1.2 (Air Guns).

Compared to offshore areas where air gun use would primarily affect invertebrates in the water column, 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 (e.g., pilings) that may be colonized by invertebrates. 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 the potential to affect pelagic invertebrates such as jellyfish and squid. Zooplankton could be affected by air gun use at any location. Available information indicates that zooplankton could be injured or killed, but injury to relatively large crustaceans (e.g., lobsters and crabs) would not be expected. Potential injury to squid 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). Activities conducted at pierside locations could potentially result in multiple exposures of sessile species or species with limited mobility to impulsive sound. Air gun use in offshore areas would be unlikely to affect individuals multiple times due to the relative mobility of invertebrates in the water column (passive and active movement) and the mobile nature of the sound source. 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., 2016a; Solan et al., 2016; Spiga, 2016). Responses include changes in chorusing (snapping shrimp), shell 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 fish and crabs to Navy pile driving in the Mid-Atlantic region (Chappell, 2018).

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 90 minutes per 24-hour period during installation, and could be exposed to noise and substrate vibration for a total of 72 minutes per 24-hour period 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. Reactions such as shell 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 90 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 Navy 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 vessel transit during training could occur in all of the range complexes and inshore 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 inshore 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 inshore waters are generally smaller than those in offshore waters (small craft less than 50 ft.). Vessel movements in the inshore 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 inshore waters, is provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices).

Marine invertebrates capable of sensing sound may alter their 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 inshore 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, vessel noise would not be expected to adversely affect the viability of common or widely distributed invertebrate species in navigation channels or near naval port facilities.

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, submerged aquatic vegetation, and shipwrecks would be avoided during precision anchoring and 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 inshore 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 inshore 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 inshore 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, vessel noise would not be expected to adversely affect the viability of common or widely distributed invertebrate species in navigation channels or near naval port facilities.

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, submerged aquatic vegetation, and shipwrecks would be avoided during 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, rocket, and bombing activities and mine-laying 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 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), mapped areas of shallow-water coral reefs, live hard bottom, artificial reefs, submerged aquatic vegetation, and shipwrecks would be avoided during precision anchoring and 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 of designated critical habitat for elkhorn coral and staghorn coral. 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), mapped areas of shallow-water coral reefs, live hard bottom, artificial reefs, submerged aquatic vegetation, and shipwrecks would be avoided during 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, rocket, and bombing activities and mine-laying 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 of designated critical habitat for elkhorn coral and staghorn coral. 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 behind the projectile in the direction of fire 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-in. 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-in. gun. Behavioral reactions have not been found in crustaceans, but have been observed for squid. 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 weapons firing and launch occur infrequently. Weapons firing and launch typically occurs greater than 12 NM from shore, which because of the greater water depths 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 weapon firing occurs infrequently. 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 limited to a relatively small volume of water near the surface. 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 number of 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 weapon firing occurs infrequently. 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. 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 because the number of munitions potentially used during testing activities under Alternative 2 would be greater. 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.

3.4.3.1.8 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 distance from the source in which individual invertebrates would potentially be exposed to acoustic impacts. 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 occur infrequently 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.

3.4.3.2 Explosive Stressors

3.4.3.2.1 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 and Explosive Concepts). 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. Given the small range of effects due to fragments, the potential for impacts on invertebrates at the population or subpopulation level would be negligible. 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 invertebrate species. Surface explosions typically occur during the day at offshore locations more than 12 NM from shore. There is a general pattern of lower invertebrate abundance in offshore portions of the Study Area compared to relatively productive estuarine and nearshore waters. Therefore, the typical offshore location of detonations would result in fewer invertebrates potentially exposed to detonation effects. In addition, invertebrate abundances in offshore surface waters tend to be lower during the day, when surface explosions typically occur, than at night.

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. A report summarizing the results of all known historical experiments (from 1907 to the 1980s) involving invertebrates and detonations concluded that marine invertebrates are generally insensitive to pressure-related damage from underwater explosions (Keevin & Hempen, 1997). 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. from the source, and shrimp, lobster, and oysters are less sensitive (i.e., greater survivability) to underwater explosions than crabs. Similar information on the effects of explosions to planktonic invertebrates and invertebrate larvae is not available.

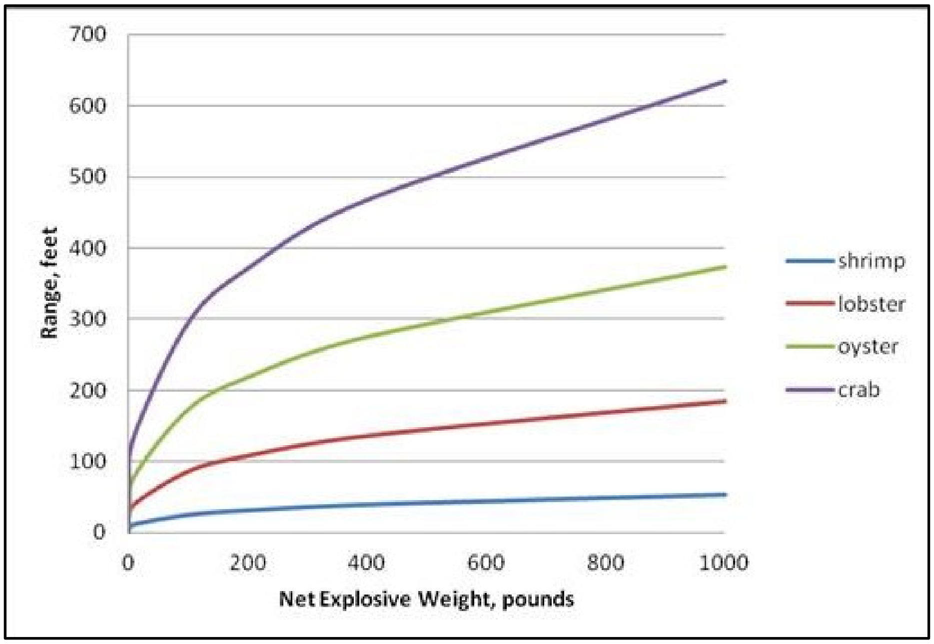

Figure 3.4-2: Prediction of Distance to 90 Percent Survivability of Marine Invertebrates Exposed to an Underwater Explosion (Young, 1991)

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 activities involving detonations on or near the bottom 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, moderate to substantial recovery from a single small blast directly on a reef was observed within 5 years, but reef areas damaged by multiple blasts showed no evidence of recovery during the 6-year observation period (Fox & Caldwell, 2006). In another study, modeling results indicated that deep-water corals off Alaska damaged by trawling activities could require over 30 years to recover 80 percent of the original biomass (Rooper et al., 2011). The extent of trawling damage is potentially greater than that associated with detonations due to the small footprints of detonations compared to the larger surface area typically affected by trawling, as well as the avoidance of known shallow-water coral reefs and live hard bottom habitat during activities involving detonations. While the effects of trawling activities and underwater detonations are not directly comparable, the trawling model results illustrate the extended recovery time that may be required for deep-water coral regrowth following physical disturbance.

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).

Underwater surveys of a Navy bombing range in the Pacific Ocean (Farallon De Medinilla) were conducted from 1999 to 2012 (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. However, 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 detected. 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 in an area of cavitation that forms near the surface above a large underwater detonation could be killed or injured. Cavitation is where the reflected shock wave creates a region of negative pressure followed by a collapse, or water hammer (see Appendix D, Acoustic and Explosive Concepts). 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 at night (e.g., squid and zooplankton) typically move down in the water column during the day, making them less vulnerable to explosions 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.

3.4.3.2.2 Impacts from Explosives

3.4.3.2.2.1 Impacts from Explosives Under Alternative 1

Impacts from Explosives Under Alternative 1 for Training Activities

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 projectiles), 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 to 9 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 because the impact of the underwater impulsive sounds would be dampened. Pelagic invertebrates, such as squid and zooplankton, are typically less abundant near the surface during the day, when explosions typically 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 within weeks) by recruitment from 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 requiring more time to fill (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. The total bottom area potentially disturbed by explosions over a 5-year period would be approximately 44 acres (see Table F-25, Potential Impact from Explosives On or Near the Bottom for Training Activities Under Alternatives 1 and 2 Over Five Years, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis). Of this total, less than 0.03 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted, including less than 0.01 percent of hard bottom habitat. 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 less abundant during the day when training activities typically occur. Exceptions occur where explosives are used on the bottom within nearshore or inshore 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 live 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 likely be undetectable. Although individuals of widespread marine invertebrate species would likely be injured or killed during an explosion, the number of such invertebrates affected would be small relative to overall population sizes, and activities would be unlikely to impact survival, growth, recruitment, or reproduction of populations or subpopulations. Species with limited distribution, such as stony corals, would be of greater concern.

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, submerged aquatic vegetation, 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. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during sinking exercises (Section 5.3.3.6, Sinking Exercises) and ship shock trials (Section 5.3.3.11, Ship Shock Trials).

Due to the mitigation described above, the probability of shallow-water corals being exposed to detonation effects is low. Explosions on or over soft bottom up-current from shallow-water coral reefs could kill or injure some coral larvae that could have otherwise settled on suitable habitat down-current. However, this situation is unlikely considering most water-based training areas in the Key West OPAREA do not intersect shallow-water coral reefs. Exposure in the context of shock wave impacts would occur only if explosions inadvertently occurred near unmapped shallow-water coral reefs or other substrate potentially supporting shallow-water corals (e.g., hard substrate in the mesophotic zone). 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 and critical habitat. The Navy has consulted 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 projectiles), 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 areas with water depths greater than 200 ft. (but detonations still would occur at the surface) and greater than 3 NM from shore. Ship shock charges would occur off the continental shelf in water depths 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. The invertebrates that occur at or near the surface consist primarily of squid, jellyfish, and zooplankton, which are typically active near the surface at night, when explosions occur infrequently. 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 be recolonized rapidly (potentially within weeks) by recruitment from 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 requiring more time to fill (U.S. Army Corps of Engineers, 2001). The total bottom area potentially disturbed by explosions over a 5-year period would be approximately 43 acres (see Table F-26, Potential Impact from Explosives On or Near the Bottom for Testing Activities Under Alternatives 1 and 2 Over Five Years, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis). Of this total, less than 0.04 percent of the total area of each habitat type (hard, intermediate, and soft) would be impacted.

In summary, explosives produce pressure waves that can harm invertebrates in the immediate vicinity of where the explosions occur. The majority of explosions would occur in offshore surface waters where the predominant invertebrate species are prevalent mostly at night when testing activities typically occur infrequently. Exceptions occur where explosives are used on the bottom within nearshore or inshore 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 live 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 likely be undetectable because of the small spatial and temporal scale of potential changes. Although individual marine invertebrates would likely be injured or killed during an explosion, the 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, submerged aquatic vegetation, 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. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during the use of explosive torpedoes (Section 5.3.3.2, Explosive Torpedoes).

The only in-water explosions in the Key West Range Complex, where ESA-listed corals are known to occur, would result from explosive buoys, sonobuoys, torpedoes, and medium- and large-caliber projectiles detonating at or near the surface. Due to the mitigation described above, in addition to the fact that most of these activities would occur more than 12 NM from shore, the probability of shallow-water corals being exposed to detonation effects is low. Exposure would result only if explosions inadvertently occurred near unmapped shallow-water coral reefs, other substrate potentially supporting shallow-water corals, or deeper (i.e., greater than 30 m) hard substrate supporting mesophotic coral species. 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 has consulted with the NMFS, as required by section 7(a)(2) of the ESA in that regard.

3.4.3.2.2.2 Impacts from Explosives Under Alternative 2

<u>Impacts from Explosives Under Alternative 2 for Training Activities</u>

The locations of training activities using explosives on or near the bottom would be the same under Alternatives 1 and 2. The total area affected for all training activities combined over a 5-year period would decrease by less than 1 acre under Alternative 2 (see Table F-25, Potential Impact from Explosives On or Near the Bottom for Training Activities Under Alternatives 1 and 2 Over Five Years, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis) and, therefore, the potential impacts would be similar between the two alternatives. Refer to Section 3.4.3.2.2.1 (Impacts from Explosives Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.2.2.1 (Impacts from Explosives Under Alternative 1), 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, submerged aquatic vegetation, 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. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during sinking exercises (Section 5.3.3.6, Sinking Exercises) and ship shock trials (Section 5.3.3.11, Ship Shock Trials).

Due to the mitigation described above, the probability of shallow-water corals being exposed to detonation effects is low. Explosions on or over soft bottom up-current from shallow-water coral reefs could kill or injure some coral larvae that could have otherwise settled on suitable habitat down-current. However, this situation is unlikely considering most water-based training areas in the Key West OPAREA do not intersect shallow-water coral reefs. Exposure in the context of shock wave impacts would occur only if explosions inadvertently occurred near unmapped shallow-water coral reefs or other substrate potentially supporting shallow-water corals, including hard substrate areas up to 90 m deep. 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 2 may affect ESA-listed coral species and critical habitat.

Impacts from Explosives Under Alternative 2 for Testing Activities

The locations of testing activities using explosives on or near the bottom would be the same under Alternatives 1 and 2. The total area affected for all testing activities combined over a 5-year period would increase by approximately 17 acres, including about 12 acres in the Virginia Capes Range Complex and 5 acres in the Naval Surface Warfare Center, Panama City Testing Range (see Table F-26, Potential Impact from Explosives On or Near the Bottom for Testing Activities Under Alternatives 1 and 2 Over Five Years, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis). The area of hard substrate potentially impacted would increase by less than 0.01 percent in each of these areas. The increased area of bottom habitat affected would not result in substantive changes to the potential for or the types of impacts on invertebrates. Refer to Section 3.4.3.2.2.1 (Impacts from Explosives Under Alternative 1) for a discussion of impacts on invertebrates.

As discussed in Section 3.4.3.2.2.1 (Impacts from Explosives under Alternative 1), 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, submerged aquatic vegetation, 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. In addition, procedural mitigations include the requirement to avoid jellyfish aggregations during the use of explosive torpedoes (Section 5.3.3.2, Explosive Torpedoes).

The only in-water explosions in the Key West Range Complex, where ESA-listed corals are known to occur, would result from explosive buoys, sonobuoys, torpedoes, and medium- and large-caliber projectiles detonating at or near the surface. Due to the mitigation described above, in addition to the fact that most of these activities occur more than 12 NM from shore, the probability of shallow-water corals being exposed to detonation effects is low. Exposure would occur only if explosions inadvertently occurred near unmapped shallow-water coral reefs or other substrate potentially supporting shallow-water corals, including hard substrate areas to 90 m deep. Although unlikely, there is a small potential for exposure. 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.

3.4.3.2.2.3 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 (Bureau of Ocean Energy Management, 2011; Lohmann et al., 1995; Lohmann & Lohmann, 2006). 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 (Ernst & Lohmann, 2018; 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 (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 (Bureau of Ocean Energy Management, 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 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 theorized 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 inshore water locations (Table 3.0-15, Number and Location of Activities in Inshore 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 (Bureau of Ocean Energy Management, 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 and the fact that electromagnetic devices are operated in the water column away from the bottom, 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 Surface Warfare Center, Panama City Testing Range, South Florida Ocean Measurement Facility Testing Range, and one inshore water location (Little Creek Virginia).

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 (Bureau of Ocean Energy Management, 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 and the fact that electromagnetic devices are operated in the water column away from the bottom, 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 in the South Florida Ocean Measurement Facility Testing Range would have the potential to be exposed to electromagnetic fields. However, this exposure from predominantly mobile sources is considered unlikely because the coral is distributed as a narrow band that is avoided as a navigation hazard during testing activities. 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 number of individuals potentially impacted would be low based on the relatively low number of events, very localized potential impact area of the laser beam, and the temporary duration (seconds) of potential impact. 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 number of individuals potentially impacted would be low based on the relatively low number of events, very localized potential impact area of the laser beam, and the temporary duration (seconds) of potential impact. 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 (seconds) of potential exposure. 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. Invertebrate habitats generally cover enormous areas (Section 3.5, Habitats) and, in this context, a physical strike or disturbance would impact individual organisms directly or indirectly, but not to the extent that viability of populations of common species would be impacted. While the potential for overlap between Navy activities and invertebrates is reduced for those species living in rare habitats, if overlap does occur, any potential impacts would be amplified for those invertebrate species or taxa with limited spatial extent. Examples of such organisms include shallow-water, mesophotic, and deep-water corals and sponges, which are mostly restricted to hard bottom habitat. Shallow-water coral reefs and some other areas of hard substrate are protected to the extent they are included in current mitigation measures. 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). However, bottom-disturbing activities are not conducted on mapped coral reefs or live hard bottom. 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 is a proxy for impacts due to amphibious landings) have reported initial declines 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 3.0-17 (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) 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 potentially 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, reducing potential exposures during daytime vessel operations. 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, 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 large 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.

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. Invertebrates on or near the bottom in such relatively shallow areas could be affected by sediment disturbance or direct strike during amphibious landings. 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. The results of a small number of studies suggest that the wave energy resulting from boat wakes produced in relatively narrow water bodies may affect oyster occurrence, and studies of shallow freshwater areas found that waves generated from small boats caused about 10 percent of benthic invertebrates (e.g., amphipods) to become suspended in the water column where they presumably would be more vulnerable to predation (Bilkovic et al., 2017).

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 and, therefore, would be unlikely to affect benthic invertebrates, 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 inshore waters, where propeller movement may disturb sediments and associated benthic invertebrate communities in sheltered areas.

Activities that occur in inshore waters can last from a few hours up to 12 hours of daily movement per vessel per activity, and can involve speeds greater than 10 knots. Vessel movements in the inshore 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 inshore 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 number of invertebrates impacted during amphibious landings would be small compared to the number affected during activities such as beach nourishment. 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 both 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 3.0-21 (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, when Navy training and testing typically are conducted, decreasing the potential for impacts in the upper portions of the water column. 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 numbers and locations of activities that include vessels are shown in Table 3.0-18 (Number and Location of Activities Including Vessels) and Table 3.0-19 (Number and Location of Activities in Inshore Waters Including Vessels), and the numbers and locations of activities that include in-water devices are shown in Table 3.0-22 (Number and Location of Activities Including In-Water Devices) and Table 3.0-23 (Number and Location of Activities in Inshore 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. Most 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 inshore 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 and Jacksonville 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 and comparatively higher abundances of invertebrates in areas closer to shore. 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 by vessels and in-water devices 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. The potential for erosion-related impacts could be greater during high speed vessel operation, which occurs in numerous inshore waters but would be more concentrated in the Lower Chesapeake Bay, James River, Cooper River, and Narragansett Bay. 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. Although some training activities would be conducted in the Key West Range Complex, vessels would operate within waters deep enough to avoid bottom scouring or prop dredging, with at least a 1-ft. clearance between the deepest draft of the vessel (with the motor down) and the seafloor at mean low water. 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 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 with the bottom. 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 numbers and locations of activities that include vessels are shown in Table 3.0-18 (Number and Location of Activities Including Vessels) and Table 3.0-19 (Number and Location of Activities in Inshore Waters Including Vessels), and the numbers and locations of activities that include in-water devices are shown in Table 3.0-22 (Number and Location of Activities 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 Northeast, 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 and the comparatively lower invertebrate abundances 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. Overall, the area potentially 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, vessels would operate within waters deep enough to avoid bottom scouring or prop dredging, with at least a 1-ft. clearance between the deepest draft of the vessel (with the motor down) and the seafloor at mean low water. 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

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

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 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 marine 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 Analysis) 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 on 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 physical properties of the surrounding water (e.g., slight heating or increased dissolved gas concentrations due to turbulent mixing with the atmosphere), potentially affecting the suitability of the affected water mass as habitat for some invertebrate species. However, physical changes to the water column would be localized and temporary, persisting for only 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 invertebrate taxa, including sponges, cnidarians, worms, bryozoans, molluscs, arthropods, and echinoderms, may occur in areas affected by military expended materials. 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 coral reefs 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 (e.g., hydroids, sponges, soft corals) have fragile structures and sensitive body parts that could be damaged or covered by military expended materials. 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, 2010).

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, 2010, 2011). However, it is important to note that the survey was not designed to document military expended materials 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 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 those associated with 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 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 such as torpedo accessories, concrete slugs, marine markers, bathythermographs, endcaps, and pistons. Expended materials associated with testing activities are similar but include some additional items such as explosive sonobuoys and explosive mines. Some expended materials used during training and testing activities, including some types of torpedoes and targets, non-explosive mine shapes, and bottom-placed instruments, are recovered.

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). 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 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 Analysis), under Alternative 1, areas with the greatest amount of expended materials are expected to be the Northeast and Southeast U.S. Continental Shelf and the Gulf Stream Open Ocean Area—specifically within the Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes. In addition, military expended materials would be deposited at six inshore 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 inshore waters would include items such as flares (including flare o-rings and compression pad or pistons), marine markers, mine shapes, and non-explosive small-caliber munitions. Most items expended in inshore 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 training activities typically occur.

Proportional impact analysis determined that the total bottom area affected by all military expended materials in all training areas would be about 108 acres annually (see Table F-31, Proportional Impact to Bottom Habitat from Training Activities Under Alternatives 1 and 2 in a Single Year, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis). This represents only thousandths of 1 percent of available bottom habitat in any range complex. The areas impacted by bottom type would be approximately 12 acres (hard substrate), 11 acres (intermediate substrate), 85 acres (soft substrate), and less than 2 acres (unknown substrate). The substrate types and associated invertebrate assemblages within the potentially disturbed areas are difficult to predict, as discussed in Appendix F (Military Expended Materials and Direct Strike Impact Analysis). 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 the results of limited investigation indicate a low percentage of this available hard substrate may be inhabited by deep-water corals or other invertebrate species in some areas (Harter et al., 2009; U.S. Department of the Navy, 2010). In other areas, such as parts of the Gulf of Maine, the shelf break offshore of central Florida (Atlantic side), and the west Florida shelf, deep-water corals may cover a greater portion of available hard habitat (refer to Section 3.4.2.3.3, Corals, Hydroids, Jellyfish [Phylum Cnidaria]). However, it is expected that most of the bottom type affected would be soft substrate (Appendix F, Military Expended Materials and Direct Strike Impact Analysis). 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. While the potential for overlap between Navy activities and invertebrates is reduced for those species living in rare habitats, if overlap does occur, any potential impacts would be amplified for those invertebrate species or taxa with limited spatial extent. With the exception of some shallow-water corals, detailed distribution and habitat utilization information sufficient to support species-specific analysis is generally unavailable.

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-water, deep-water, and mesophotic reefs and live 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 affect corals. With the exception of mine neutralization and explosive ordnance disposal 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. Prevailing water currents flowing parallel to the shoreline (e.g., the Loop Current, Florida Current, and Gulf Stream) would tend to prevent decelerators/parachutes from drifting onto shallow-water corals located close to shore. There would be a slightly greater potential to impact ESA-listed corals located in mesophotic habitats (water depths to 90 m) that occur seaward of the coastal zone (e.g., small sonobuoy parachutes drifting onto Pulley Ridge). However, it is unlikely that large parachutes (e.g., illumination flare parachutes) would settle on mesophotic habitats supporting ESA-listed corals because the associated activity would take place more than 40 NM from shore. These areas are not included in designated critical habitat, and relatively few ESA-listed coral species may occur in mesophotic habitats due to their typical depth distribution. 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 and will not place mine shapes, anchors, or mooring devices on the seafloor within a specified distance of shallow-water coral reefs. These mitigations 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, particularly ESA-listed coral species occurring in deeper mesophotic areas beyond the coastal zone. 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 has consulted 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 Analysis), 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. Proportional impact analysis determined that the total bottom area affected by all military expended materials in all testing areas would be about 52 acres annually (see Table F-32, Proportional Impact to Bottom Habitat from Testing Activities Under Alternatives 1 and 2 in a Single Year, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis). This represents only thousandths of 1 percent of available bottom habitat in any range complex. The area impacted by bottom type would be approximately 5 acres (hard substrate), 5 acres (intermediate substrate), 42 acres (soft substrate), and less than 1 acre (unknown substrate). The substrate types and associated invertebrate assemblages within the disturbed area is difficult to predict, as discussed in Appendix F (Military Expended Materials and Direct Strike Impact Analysis). 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 the items are moved 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 in some areas (U.S. Department of the Navy, 2010). In other areas, such as parts of the Gulf of Maine, the shelf break offshore of central Florida, and the west Florida shelf, deep-water corals may cover a greater portion of available hard habitat (refer to Section 3.4.2.3.3, Corals, Hydroids, Jellyfish [Phylum Cnidaria]. It is expected that most of the bottom type affected would be soft substrate (Appendix F, Military Expended Materials and Direct Strike Impact Analysis). 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), explosive torpedoes and torpedo accessories, chaff cartridges, targets (air, surface, and subsurface), bathythermographs, sabots, explosive sonobuoys, sonobuoy wires, and decelerators/parachutes. Recovered items consist of non-explosive 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, various targets, anchors, bathythermographs, torpedo accessories, sonobuoys, sonobuoy wires, decelerators/parachutes, and sabots. Recovered materials include non-explosive torpedoes, various targets, anchors, and mine shapes. Materials are primarily expended far from shore, although there are exceptions, including mine countermeasure testing and unmanned underwater vehicle testing. These activities may occur in the coastal zone of the Key West Range Complex or South Florida Ocean Measurement Facility Testing Range. Non-explosive sonobuoys expended during anti-submarine tracking testing include small decelerators/parachutes that could impact ESA-listed coral species and critical habitat. Most weapons firing takes place in offshore waters away from the source of coral eggs and larvae. Decelerator/parachute interactions are unlikely because, with the exception of anti-submarine tracking, they are generally expended in water deeper than 600 ft. and would most likely not travel far enough to impact shallow-water species. Prevailing water currents flowing parallel to the shoreline (e.g., the Loop Current, Florida Current, and Gulf Stream) would tend to prevent decelerators/parachutes from drifting onto shallow-water corals located close to shore. There would be a slightly greater potential to impact ESA-listed corals located in mesophotic habitats (water depths up to 90 m) that occur seaward of the coastal zone. However, these areas are not included in designated critical habitat, and relatively few ESA-listed coral species may occur in mesophotic habitats due to their typical depth distribution.

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 and will not place mine shapes, anchors, or mooring devices on the seafloor within a specified distance of mapped shallow-water coral reefs. These mitigations 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, particularly ESA-listed coral species occurring in deeper mesophotic areas beyond the coastal zone. 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 has consulted 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

<u>Impacts from Military Expended Materials Under Alternative 2 for Training Activities</u>

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 annually under Alternative 2 (see Table F-31, Proportional Impact to Bottom Habitat from Training Activities Under Alternatives 1 and 2 in a Single Year, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis), 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), 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 and will not place mine shapes, anchors, or mooring devices on the seafloor within a specified distance of shallow-water coral reefs. These mitigations will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including areas inhabited by shallow-water corals.

Potential impacts to shallow-water corals would be minimized by the offshore location of many activities involving expended materials and 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, particularly ESA-listed coral species occurring in deeper mesophotic areas beyond the coastal zone. 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.

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 annually under Alternative 2 (see Table F-32, Proportional Impact to Bottom Habitat from Testing Activities Under Alternatives 1 and 2 in a Single Year, in Appendix F, Military Expended Materials and Direct Strike Impact Analysis), 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), 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 and will not place mine shapes, anchors, or mooring devices on the seafloor within a specified distance of mapped shallow-water coral reefs. These mitigations will consequently also help avoid potential impacts on invertebrates that inhabit these areas, including areas inhabited by shallow-water corals.

Potential impacts to shallow-water corals would be minimized by the offshore location of many activities involving expended materials and 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, particularly ESA-listed coral species occurring in deeper mesophotic areas beyond the coastal zone. 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.

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 likely would be small compared to overall population numbers. These items could potentially break hard substrate and associated biogenic habitats (e.g., hard coral skeletons). 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 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. For example, an anchor may shift due to changing currents or vessel movement and the mooring chain may drag across the bottom, causing abrasion and impacts to benthic species (Davis et al., 2016). Anchor impacts 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

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

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, and within the Naval Surface Warfare Center, Panama City Division Testing Range. 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 inshore water locations, but primarily in the Lower Chesapeake Bay, James River and tributaries, and Truman Harbor and Demolition Key.

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 nearshore areas 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, 2010), although the percentage of coverage is apparently higher is some areas such as the shelf break off central Florida. The number of organisms affected is not expected to 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, submerged aquatic vegetation, 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. Seafloor devices would consist of a small number of bottom-placed instruments and metal plates. Bottom-disturbing activities have the potential to impact protected coral species and critical habitat. The metal plates are associated with activities that would be avoided in or near mapped areas of shallow-water coral reefs, per established mitigation measures. The activity using bottom-placed instruments in the Key West Range Complex does not have mitigation measures that explicitly avoid shallow-water coral reefs and may occur in the coastal zone. However, the probability of striking an ESA-listed coral species is considered negligible given the intended recovery of the instruments, ESA-listed coral species habitats represent a tiny fraction of the total area in the Key West Range Complex mostly very close to shore, and living coral represent an even smaller fraction of the total habitat area. Recovered instruments would most likely be placed on soft substrates, where ESA-listed coral species do not occur. Impacts to ESA-listed coral species 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 has consulted 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.

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 a device 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 soft bottom habitats predominate, impacts would consist primarily of disturbance; burrowing invertebrates are unlikely to be injured or killed as a result of 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 hard substrate is avoided, activities occurring at depths less than about 3,000 m may inadvertently impact deep-water corals, other invertebrates associated with live 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 live 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 bottom habitat in deep portions of 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, 2010), although the percentage of coverage is apparently higher is some areas such as the shelf break off central Florida. 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 overlap with mapped 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 ESA-listed coral species 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 has consulted 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.

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, submerged aquatic vegetation, 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. Seafloor devices would consist of a small number of bottom-placed instruments and metal plates. Bottom-disturbing activities have the potential to impact protected coral species and critical habitat. The metal plates are associated with activities that would be avoided in or near mapped areas of shallow-water coral reefs, per established mitigation measures. The activity using bottom-placed instruments in the Key West Range Complex does not have mitigation measures that explicitly avoid shallow-water coral reefs and may occur in the coastal zone. However, the probability of striking an ESA-listed coral species is considered negligible given the intended recovery of the instruments, the location of such activities in harbors and away from mapped areas of shallow-water coral reefs, and the fact that ESA-listed coral species habitats represent a tiny fraction of the total area in the Key West Range Complex mostly very close to shore and living coral represent an even smaller fraction of the total habitat area. Recovered instruments would most likely be placed on soft substrates, where ESA-listed coral species do not occur. Impacts to ESA-listed coral species 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 under Alternative 2 may affect ESA-listed coral species and designated elkhorn and staghorn coral critical habitat.

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.

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 and global positioning systems (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.

Impacts to ESA-listed coral species 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 2 may affect ESA-listed coral species and may affect designated elkhorn and staghorn coral critical habitat.

3.4.3.4.4.3 Impacts from Seafloor Devices Under the No Action Alternative

<u>Impacts from Seafloor Devices 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 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, shell 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 substrate vibration and other disturbance for a total of 90 minutes per 24-hour period during installation, and could be similarly exposed for a total of 72 minutes per 24-hour period 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. A summary of the effects of litter on various marine species identified potential impacts to some invertebrate taxa, particularly mobile benthic species such as crabs and sea stars, that may become entangled in debris (e.g., nets) after attempting to move through the items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014b). 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). Based on the constituents of the biodegradable polymer the Navy proposes to use, it is anticipated that the material would break down into small pieces within a few days to weeks and break down further and dissolve into the water column within weeks to a few months.

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 or could loop around objects due to water currents, but the items are not expected to form tight coils and the possibility of an invertebrate being ensnared is remote. Fiber-optic cables are relatively brittle and readily break if knotted, kinked, abraded against sharp objects, or looped beyond the items' bend radius of 3.4 mm. 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.

3.4.3.5.1.1 Impacts from Wires and Cables Under Alternative 1

<u>Impacts from Wires and Cables Under Alternative 1 for Training Activities</u>

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, within other AFTT areas, 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 live 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 live hard bottom habitat. The portion of suitable substrate occupied by living coral is generally low and coincidence with such low densities of linear materials is unlikely. However, in some areas such as the shelf break offshore of eastern central Florida, deep-water corals may cover a greater portion of available hard habitat (refer to Section 3.4.2.3.3, Corals, Hydroids, Jellyfish [Phylum Cnidaria]).

The impact of wires and cables on marine invertebrates is not likely to cause injury or mortality to individuals because of the linear and somewhat rigid nature of the material. Impacts to individuals and populations would be inconsequential because the area exposed to the stressor is extremely small relative to the distribution ranges of most marine invertebrates, 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, testing 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 Northeast, Virginia Capes, Navy Cherry Point, 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 expendable bathythermograph wires and sonobuoy wires. Expendable bathythermograph wires would be expended in all the range complexes but would be concentrated in the Northeast, Virginia Capes, and Gulf of Mexico Range Complexes. 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 live hard bottom areas in water depths less than 3,000 m. The spatial distribution of 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.

The impact of wires and cables on marine invertebrates is not likely to cause injury or mortality to individuals because of the linear and somewhat rigid nature of the material. Impacts to individuals and populations would be inconsequential because the area exposed to the stressor is extremely small relative to the distribution ranges of most marine invertebrates, 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 about 3,000 combined types of wires and cables would be expended annually in the Key West Range Complex, and a total of 42 would be expended in the South Florida Ocean Measurement Facility 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 slightly 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, aerial targets, and other devices deployed from aircraft or vessels use decelerators/parachutes that are made of nylon or a combination of cloth and nylon. Small and medium decelerators/parachutes have weights attached to the lines for rapid sinking, but large and extra-large decelerators/parachutes do not. At water impact, the decelerator/parachute assembly is expended, and it sinks away from the unit. Small and medium decelerator/parachute assemblies 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. Large and extra-large decelerators/parachutes may remain at the surface or suspended in the water column for a longer time due to the lack of weights, but eventually also sink to the bottom and become flattened. Because they are in the air and water column for a time span of minutes, it is unlikely that a small or medium 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. Larger decelerators/parachutes could move a greater distance due to their slower sinking time. 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 large enough spatial and temporal scales, 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 decelerators/parachutes very unlikely. Refer to Section 3.4.2.3.3 (Corals, Hydroids, Jellyfish [Phylum Cnidaria]) 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 some are weighted, decelerators/parachutes sink 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, predation, 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, Key West, and Gulf of Mexico Range Complexes, and in other AFTT areas. The vast majority of expended items would be small decelerators/parachutes; only a small number of medium, large, and extra-large decelerators/parachutes would be used. Most large decelerators/parachutes and all extra-large decelerators/parachutes would be expended in the Virginia Capes Range Complex. No large or extra-large decelerators/parachutes would 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 medium decelerators/parachutes per year) would be expended in the Key West Range Complex, where 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), where small decelerators/parachutes are expended. 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 shallow-water coral reefs or mesophotic coral habitat seaward of the coastal zone. Small and medium 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 for Alternative 1 would have no effect on ESA-listed coral species or critical habitat.

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 large decelerators/parachutes would be used, and no extra-large parachutes would be expended.

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 the distribution ranges of most marine invertebrates, 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 3,000 small decelerators/parachutes would be expended in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range, where 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 shallow-water coral reefs or mesophotic coral habitat seaward of the coastal zone. 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 would have no effect on ESA-listed coral species or critical habitat.

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 702 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 would have no effect on ESA-listed coral species or critical habitat.

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, 420 more small decelerators/parachutes would be expended throughout the Northeast, Virginia Capes, Navy Cherry Point, and Jacksonville Range Complexes compared to Alternative 1. 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 would have no effect on ESA-listed coral species or critical habitat.

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 that is designed to temporarily interact with the propeller(s) of target craft. 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). The material would degrade into small pieces within a few days to 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. Although it is unlikely that most invertebrates would become entangled in the biodegradable polymer material, entanglement is conceivable for relatively large invertebrates that occur in the water column (e.g., jellyfish and squid). 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 testing activities would involve the use of biodegradable polymer in the 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), small-caliber casings, fragments from high-explosives, fragments from targets, chaff and flares, chaff and flare accessories (including end caps, compression pads or pistons, and o-rings), and small decelerators/parachutes. Very few invertebrates are large enough to ingest intact small- and medium-caliber munitions and casings; 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). 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 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 polychlorinated biphenyls) 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 result from the breakdown of larger plastic items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014a; 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 (U.S. Department of the Navy, 1999). Many invertebrates ingest sponges, including the spicules, without suffering harm (U.S. Department of the Navy, 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; U.S. Department of the Navy, 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 (Systems Consultants, 1977). American oysters (various life stages), blue crabs, 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, 2014a; 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 for impacts on invertebrates from ingestion of military expended materials is also related to the locations of Navy training and testing activities relative to invertebrate population densities. 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, 2014a). 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. Metal particles in the water column may be taken up by suspension feeders (e.g., copepods, mussels) (Chiarelli & Roccheri, 2014; Griscom & Fisher, 2004), although metal concentrations in the water are typically much lower than concentrations in sediments (Bazzi, 2014; Brix et al., 2012).

3.4.3.6.1.1 Impacts from Military Expended Materials - Munitions Under Alternative 1

<u>Impacts from Military Expended Materials - Munitions Under Alternative 1 for Training Activities</u>

Under Alternative 1, military expended materials from munitions associated with training activities that could potentially be ingested include non-explosive practice munitions (small- and medium-caliber), small-caliber casings, 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 inshore waters, primarily in the James River and tributaries and Lower Chesapeake Bay. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each training location is provided in Chapter 3.0 (Affected Environment and Environmental Consequences). 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 particulate 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 associated with shallow-water coral reefs.

ESA-listed coral species occur in the Key West Range Complex. Military expended materials used in the Key West Range Complex consist of 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, minimizing the potential for shallow-water corals to ingest metal munitions particles. There would be a slightly greater potential to impact ESA-listed corals located in mesophotic habitats (water depths to 90 m) that occur seaward of the coastal zone. 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- and medium-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 types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each testing location is provided in Chapter 3.0 (Affected Environment and Environmental Consequences). 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 particulate 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 within shallow-water coral reefs.

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 a very small increase in the number of fragments resulting from high explosives under Alternative 2 associated with five Airborne Mine Neutralization System neutralizers and mines expended in both the Virginia Capes Range Complex and the Naval Surface Warfare Center, Panama City Division Testing Range. 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 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 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 such as 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 from exposures to microplastic particles 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. The vast majority of marine debris by volume and ingestion potential consists of or is derived from non-military items (Kershaw et al., 2011).

Marine invertebrates may occasionally encounter chaff fibers 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; U.S. Department of the Navy, 1999).

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

<u>Impacts from Military Expended Materials Other Than Munitions Under Alternative 1 for Training Activities</u>

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 inshore waters. A comparatively low number of items would be expended in most inshore waters, although a relatively large quantity of flares and related accessories (o-rings, compression pads or pistons, and endcaps) would occur in the James River and tributaries. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each training location is provided in Chapter 3.0 (Affected Environment and Environmental Consequences). 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 particulate 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 (detritivores, planktivores, deposit-feeders, filter-feeders, and suspension-feeders) in the water column or on the bottom. 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.

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, chaff and flare accessories, targets, and marine markers. 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 do not occur, 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 would be a slightly greater potential to impact ESA-listed corals located in mesophotic habitats (water depths to 90 m) seaward of the coastal zone. 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 inshore waters during testing activities. The types of activities that would produce potentially ingestible military expended materials are listed in Appendix B (Activity Stressor Matrices). The quantity of military expended materials associated with each testing location is provided in Chapter 3.0 (Affected Environment and Environmental Consequences). 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 particulate 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.

ESA-listed coral species occur in the Key West Range Complex and South Florida Ocean Measurement Facility Testing Range. Chaff, targets, mine shapes, torpedo accessories, sabots, 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 do not occur, 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 would be a slightly greater potential to impact ESA-listed corals in mesophotic habitats (water depths to 90 m) seaward of the coastal zone. 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/ 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 subsurface targets, 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 (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 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. 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 and explosive byproducts, (2) chemicals other than explosives, and (3) metals.

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 and Explosives Byproducts

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, 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. 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 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.

Some 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.

High-order explosions consume most of the explosive material, leaving only small or residual amounts of explosives and combustion products. Most of the combustion products of trinitrotoluene (i.e., TNT), such as carbon dioxide and nitrogen, are common seawater constituents, although other products such as carbon monoxide are also produced (Becker, 1995). Other explosive compounds may produce different combustion products. All combustion products are rapidly diluted by ocean currents and circulation (see Section 3.2.3.1, Explosives and Explosives Byproducts). Therefore, explosives byproducts from high-order detonations would not degrade sediment or water quality or result in indirect stressors to marine invertebrates. 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 relatively high concentrations of various explosive materials in sediments and in the water may result in lethal and sub-lethal effects to invertebrates. 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*) exposed to trinitrotoluene (i.e., TNT), while mortality has not been found in other species (e.g., the polychaete worm *Neanthes arenaceodentata*), even when exposed to very high concentrations (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 to higher concentrations of explosive materials than the concentrations expected to occur in marine or estuarine waters of the Study Area due to training and testing activities.

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 1 in. of the materials, although no statistical increase in mortality was observed for any species. Concentrations causing toxicity were not found 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 be detectable only within a few feet of a degrading munition, and the spatial range of toxic sediment conditions could be less (inches). It has been suggested that the risk of toxicity 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. 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 occur in the water column. 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 would be exposed to chemical byproducts only in the immediate vicinity of degrading explosives (inches or less) due to the low solubility and dilution by water currents. 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.

Chemicals Other Than Explosives

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, primarily propellants and combustion products, other fuels, polychlorinated biphenyls in target vessels, 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 propellants (for example, over 99.9 percent of perchlorate is typically consumed), and therefore very little residual material would enter the water column. Additionally, perchlorate does not readily absorb into sediments, potentially reducing the risk to deposit- and detritus-feeding invertebrates. Torpedoes are expended in the water, and therefore torpedo propellant (e.g., Otto Fuel II) combustion products would enter the marine environment. 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 Otto Fuel II combustion occur naturally in seawater and most torpedoes are recovered after use, limiting the potential for unconsumed fuel to enter the water. 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.

Target vessels are only used during sinking exercises, which occur infrequently. Polychlorinated biphenyls may be present in certain solid materials (e.g., insulation, wires, felts, and rubber gaskets) on target vessels. The vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with USEPA guidelines. Sinking exercises must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep. USEPA estimates that as much as 100 lb. of polychlorinated biphenyls remain onboard sunken target vessels. USEPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 United States Code 1341, et seq.). Under a 2014 agreement with USEPA, the Navy will not likely use aircraft carriers or submarines as the targets for a sinking exercise. As discussed in Section 3.2.3.2 (Chemicals Other Than Explosives), based on these considerations, polychlorinated biphenyls are not evaluated further as a secondary stressor to invertebrate habitats.

Metals

Certain metals and metal-containing compounds (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) are harmful to marine invertebrates at various concentrations above background levels (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 (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). However, studies have found the concentrations of metals in the sediments within military ranges (e.g., Navy training areas such as Vieques, Puerto Rico) or munitions disposal sites, where deposition of metals is very high, to rarely be above biological effects levels (Section 3.2.3.3, Metals). For example, 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 at military ranges and disposal sites 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. Refer to Section 3.2.3.3 (Metals) for more detailed study results of metal contamination in sediments at military ranges.

Concentrations of metals in sea water affected by Navy training and testing activities are unlikely to be high enough to cause injury or mortality to marine invertebrates. Benthic invertebrates occurring very near (within a few inches) Navy-derived materials on the seafloor could be impacted by associated metal concentrations, but this is expected to affect relatively few individuals.

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 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 although, similar to the preceding discussion, any positive impacts would likely be undetectable at the population level. In addition, invertebrate communities on artificial substrate may be different than those found in adjacent natural substrate.

The potential for explosions occurring near the surface to damage seafloor resources such as ESA-listed coral habitat is considered negligible. The largest explosives are used more than 12 NM from shore where water depth is typically greater than 90 m, and explosive effects would not extend to the bottom at locations seaward of the coastal zone due to vertical compression of explosive impacts around the detonation point. Bottom explosions would not occur on known live 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. There is a relatively low abundance of suitable hard substrate in the zone between 3 and 12 NM from shore (U.S. Department of the Navy, 2018), and the results of underwater surveys at one mesopohotic reef indicate a very low abundance of hard coral species on suitable habitat in the mesopohtic zone (Reed et al., 2015). However, 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 has consulted 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). Invertebrates in the Study Area could potentially be impacted by introduction of invasive species due to direct predation, competition for prey, or displacement from suitable habitat. Invasive species could be introduced by growth on vessel hulls or discharges of bilge water. Refer to Section 3.2.1.2.2 (Federal Standards and Guidelines) for a discussion of naval vessel discharges.

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 invertebrates were within the potential impact range of those activities, they 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 may contribute 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 difficult to predict quantitatively. 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; Norstrom 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, these minor differences are 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 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.

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

Pursuant to the ESA, the Navy has concluded training and testing activities may affect the boulder star coral, elkhorn coral, lobed star coral, mountainous star coral, pillar coral, rough cactus coral, and staghorn coral. The Navy has also concluded that training and testing activities may affect designated critical habitat for elkhorn coral and staghorn coral. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA in that regard. The Navy's summary of effects determinations for each ESA-listed species is shown in Table 3.4-3. Where the effects determinations reached by NMFS in their Biological Opinion differed from the Navy's, those differences are noted in a footnote to Table 3.4-3. NMFS determinations are made on the overall Proposed Action and are not separated by training and testing activities.

Table 3.4-3: Invertebrate Effect Determinations for Training and Testing Activities Under Alternative 1 (Preferred Alternative)

Species	***Designation Unit***	***Effect Determinations by Stressor***																	
		Acoustic						***Explo-sives***	***Energy***		***Physical Disturbance and Strike***				***Entanglement***			***Ingestion***	
		Sonar and Other Transducers	***Air Guns***	***Pile Driving***	***Vessel Noise***	***Aircraft Noise***	***Weapons Noise***	***Explosives***	***In-water Electromagnetic Devices***	***High-energy Lasers***	***Vessels***	***In-water Devices***	***Military Expended Materials***	***Seafloor Devices***	***Wires and Cables***	***Decelerators/Parachutes***	***Biodegradable Polymer***	***Military Expended Materials - Munitions***	***Military Expended Materials - Other Than Munitions***
Training Activities																			
Boulder star coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
Elkhorn coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
	Critical habitat	NE	N/A	NE	NE	NE	NE	NLAA	NE	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE
Lobed star coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
Mountainous star coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
Pillar coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
Rough cactus coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
Staghorn coral	Throughout range	NE[1]	N/A	NE	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE[1]
	Critical habitat	NE	N/A	NE	NE	NE	NE	NLAA	NE	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	N/A	NE	NE

Table 3.4-3: Invertebrate Effect Determinations for Training and Testing Activities Under Alternative 1 (Preferred Alternative) (continued)

Species	Designation Unit	Effect Determinations by Stressor																	
		Acoustic						Explosives	Energy		Physical Disturbance and Strike				Entanglement			Ingestion	
		Sonar and Other Transducers	Air Guns	Pile Driving	Vessel Noise	Aircraft Noise	Weapons Noise	Explosives	In-water Electromagnetic Devices	High-energy Lasers	Vessels	In-water Devices	Military Expended Materials	Seafloor Devices	Wires and Cables	Decelerators/Parachutes	Biodegradable Polymer	Military Expended Materials - Munitions	Military Expended Materials - Other Than Munitions
Testing Activities																			
Boulder star coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
Elkhorn coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
	Critical habitat	NE	NE	N/A	NE	NE	NE	NLAA	NE	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE
Lobed star coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
Mountainous star coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
Pillar coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
Rough cactus coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
Staghorn coral	Throughout range	NE[1]	NE	N/A	NE[1]	NE	NE	NLAA	NE[1]	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE[1]
	Critical habitat	NE	NE	N/A	NE	NE	NE	NLAA	NE	NE	NE[1]	NE	NLAA[2]	NLAA	NE[2]	NE	NE[2]	NE	NE

Note: NE = no effect; NLAA = may effect, not likely to adversely affect; LAA = may effect, likely to adversely affect; N/A = not applicable, activity related to the stressor does not occur during specified training or testing events (e.g., there are no testing activities that involve the use of pile driving).

[1] Based on the analysis conducted in the Biological Opinion, NMFS reached the determination of NLAA.

[2] Based on the analysis conducted in the Biological Opinion, NMFS reached the determination of LAA.

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