3.8 Aquatic Macroinvertebrates

Invertebrates are animals without backbones and are the most diverse and numerous category of animals in the biosphere (New and Yen, 1995), comprising over 98 percent of the animal species on Earth classified to date by taxonomists (MarineBio, 2019). Aquatic macroinvertebrates are those aquatic invertebrates visible without the aid of a microscope. They evolved to live underwater in one or more stages of their life history, in both freshwater and salt water (marine) habitats. They are an extremely varied assortment of organisms that span a considerable number of taxonomic phyla.

3.8.1 Affected Environment

This section specifically covers aquatic macroinvertebrates that are found in the marine and freshwater environments included within the action area of this Draft PEIS.

3.8.1.1 Marine Macroinvertebrates

Marine macroinvertebrates have been classified by taxonomists into more than 30 different phyla, a very large number representing considerable biological diversity. A phylum (plural phyla) is a major taxonomic category that ranks just above class and just below kingdom (as in plant, animal, and fungus kingdoms); it classifies organisms by their fundamental body plan.

Among the more prominent and better known and studied phyla of marine macroinvertebrates are the following (MarineBio, 2019):

- Annelids – segmented worms, including polychaetes (bristle worms);
- Arthropods – animals with exoskeletons, especially the crustaceans in marine habitats, including lobsters, crabs, shrimp, amphipods, barnacles, and copepods;
- Brachiopods – marine animals with hard “valves” or shells on their upper and lower surfaces;
- Bryozoans – moss animals or sea mats;
- Cnidaria – includes jellyfish, sea anemones, and corals (**Figure 3.8-1**);
- Echinoderms – includes sea stars, sea urchins, sea cucumbers, sand dollars, and crinoids;
- Mollusks – includes gastropods (e.g., sea snails, whelks, limpets, abalone), bivalves (clams, mussels, oysters, scallops), cephalopods (e.g., squid, octopus), and chitins;
- Porifera – sponges; and
- Tunicates – sea squirts or sea pork.

Figure 3.8-1. NOS Diver on Gray's Reef with Variety of Marine Macroinvertebrates

Photo Credit: Greg McFall, Gray's Reef NMS, NOS, NOAA

Arthropods have the largest number of species of the phyla listed above, with over 1 million described and classified. Mollusks are the next most abundant in the ocean.

Marine macroinvertebrates are very important ecologically (New and Yen, 1995). They constitute a vital food source for vertebrates such as diving sea birds, fish, sea turtles, and marine mammals in the marine food web. Jellyfish (**Figure 3.8-2**), for example, are the main food source of leatherback turtles, which also prey upon other marine invertebrates such as sea urchins, squid, crustaceans, and tunicates (USFWS, 2015a). Marine invertebrates in turn feed upon phytoplankton and zooplankton. Many cnidarians, mollusks, sponges, and crustaceans are filter feeders, playing a major role in ecosystem function (NAP, 2019; Burge et al., 2016; Sánchez et al., 2016). They help filter and clean estuaries and bays along the coast by removing suspended particles and reducing the turbidity of the water column.

Figure 3.8-2. Jellyfish in the Order Limnomedusae

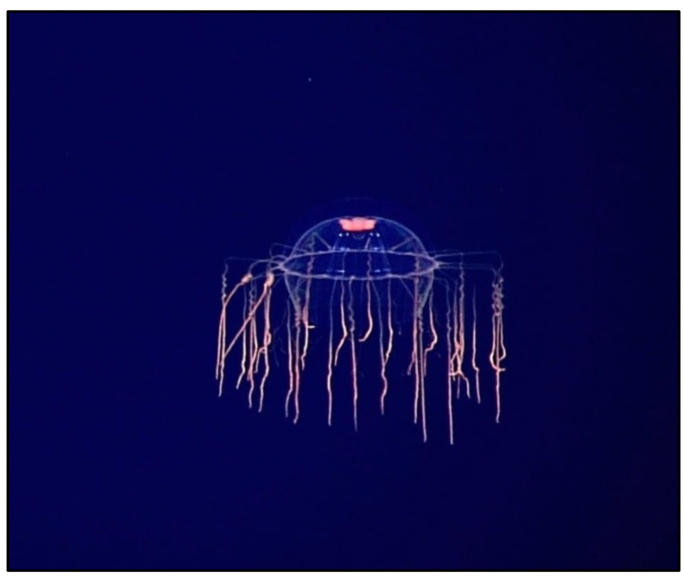

Photo Credit: NOAA Okeanos Explorer Program

The sessile, soft-bodied coral polyps attached to the ocean floor secrete a hard, external skeleton of limestone (calcium carbonate or $CaCO_3$), constructing tropical coral reefs in the process. These reefs represent the largest structures of biological origin on the planet; the structure, complex three-dimensional geometry, and hard surfaces they provide are the basis for biologically diverse ecosystems (NOAA, 2018a). Coral reefs are increasingly at risk around the world from increasing ocean temperatures and acidification related to increased atmospheric carbon dioxide levels and related global warming, as well as from more localized threats such as sedimentation, overfishing, dynamiting, and damage from anchors.

A number of marine macroinvertebrates support economically and socially important industries, both commercial and sport, along the nation's coasts and estuaries, especially crustaceans (e.g., lobster, crab, shrimp) and mollusks (e.g., clam, mussel, oyster, scallop, squid, octopus). In 2015 alone, total U.S. landings revenues were $618 million for lobster, $489 million for shrimp, and $439 million for sea scallop, in comparison to $509 million for walleye pollock and $461 million for Pacific salmon, the two most important fin fisheries (NMFS, 2017d). Harvest of these shellfish is regulated by the federal and state governments, and management of the harvest of cephalopods like the octopus has also begun (Conners et al., 2017; Conners and Conrath, No Date).

3.8.1.2 Freshwater Macroinvertebrates

The most important freshwater aquatic macroinvertebrates are bivalve mollusks (clams and mussels), crustaceans (crayfish), and arthropods (aquatic insects and their larvae). Clams and mussels are often so inconspicuous and immobile that they can be mistaken for cobblestones; they are found on the bottom of waterbodies and feed by filtering water for microscopic plant and animal food particles (plankton). Like marine macroinvertebrates, freshwater macroinvertebrates are very important both ecologically and economically (MDC, No Date). They are a vital food source for vertebrates, conveying nutrients from producers (plants and algae) to higher-order consumers in the aquatic food web. Many species of mammals, birds, reptiles, amphibians, and fish feed on aquatic macroinvertebrates in freshwater bodies. Some kinds of aquatic macroinvertebrates are indicators of water quality. Still others, notably mosquitoes (whose larvae are aquatic), are disease vectors.

3.8.1.2.1 Freshwater Macroinvertebrate Stressors

North America has the highest freshwater mussel diversity in the world, but an estimated 70 percent of these are extinct or imperiled (USFWS, 2019a). A number of species are listed as threatened or endangered because of changes to hydrology caused by dams, reservoirs, and channelization, and because of turbidity, sedimentation, and pollution (Platt, 2018) as well as invasive species (USFWS, 2004). Aquatic macroinvertebrates are so sensitive to water quality and susceptible to water pollutants that certain kinds are frequently used as reliable indicators of freshwater quality in waterbodies (Gaufin and Tarzwell, 1952; USU, 2018). Some species of macroinvertebrates can survive degraded water quality, but others survive only under nearly pure or pristine conditions (NPS, 2018a).

Among the "indicator species" of water quality and pollution are the benthic (bottom-dwelling) macroinvertebrates: small, fully aquatic animals and the aquatic larval stages of insects (which may be non-aquatic as adults). They include snails, worms, beetles, and the larvae of dragonflies, mayflies, and stoneflies (**Figure 3.8-3**). Benthic macroinvertebrates are typically found attached to rocks, vegetation, sticks, and logs, or within burrows in bottom sand and sediments (EPA, 2016).

Photo Credit: G. Carter via NOAA/GLERL

Figure 3.8-3. Variety of Freshwater Benthic Macroinvertebrates

Non-native, invasive macroinvertebrates like the zebra mussel (*Dreissena polymorpha*) (**Figure 3.8-4**), a native to Eurasia introduced inadvertently into the Great Lakes ecosystem from ship ballast water (USFWS, 2019a), have affected the aquatic ecology of entire lake and river systems (USGS, 2018) including the Great Lakes, Mississippi River Basin, and other watersheds, where they have threatened native freshwater mussel species (USFWS, 2004). Since the early 1990s, more than 95 percent of the native clams once found in Lake Erie have disappeared because of the zebra mussel, which attaches itself to native clams in large numbers, impeding the ability of the clams to feed and burrow (Nichols and Wilcox, 2004). Zebra mussels have spread rapidly and now infest the entire Great Lakes ecosystem (Egan, 2017).

Photo Credit: Amy Benson, USGS

Figure 3.8-4. Zebra Mussel

In addition to its ecological impacts, the invasive zebra mussel has also become an extremely costly nuisance to industries and municipalities, such as water and electrical utilities, which withdraw water or discharge effluent, because of the mussel's tendency to completely clog water intake and effluent outfall pipes. Invasion of the zebra mussel has cost billions of dollars in the last three decades because of the need to invent, design, construct, and maintain water treatment systems that use chemicals, heat, and ultraviolet light to clear pipelines, intakes, and outfalls, and to keep water and effluent flowing through them (Egan, 2017).

The closely related quagga mussel (*Dreissena bugensis*), an invasive native to the Dnieper River basin in the Ukraine, was first discovered in Lake Erie in 1989 and has also spread very rapidly, proving even more ecologically destructive in the Great Lakes than the zebra mussel. Quaggas are such effective filter feeders that they remove substantial quantities of phytoplankton from the water column. By depleting phytoplankton, quaggas in turn reduce food for zooplankton, thereby co-opting and diverting energy flows at the base of the aquatic food pyramid into their own growth and biomass (IMC, 2018). The biomass of quagga mussels in Lake Michigan in one recent year was estimated to be about seven times greater than the entire biomass of the schools of prey fish upon which the lake's salmon and trout depend (Egan, 2017). Under favorable conditions, these mussels can now filter all of Lake Michigan's water in less than two weeks. Removal of suspended particles increases water clarity (decreasing turbidity) and reduces chlorophyll (phytoplankton) concentrations. In turn, increased light penetration leads to a proliferation of certain aquatic plants, altered species dominance, and changes in the entire aquatic ecosystem.

Pseudofeces (mucous-coated grit expelled by filter-feeding gastropod mollusks, distinct from actual feces) produced by quagga mussels from filtering water accumulate and foul the underwater environment (USGS, 2019). As these waste particles decompose, DO is depleted and the water becomes very acidic; additionally, toxic byproducts are generated. Moreover, quagga mussels magnify organic pollutants within their tissues to concentrations 300,000 times greater than in the environment; these toxins can be passed up the food chain, increasing exposure of wildlife to organic pollutants (Snyder et al., 1997).

3.8.1.3 Sound Production and Hearing

The science of how aquatic macroinvertebrates, with their exceptional morphological and physiological diversity, use sound or are affected by anthropogenic sources of underwater sound is in its infancy (Mooney et al., 2010; Acoustical Society of America, 2017; Hawkins and Popper, 2017; Hawkins and Popper, 2012; NSF and USGS, 2011). Certain macroinvertebrates, such as cnidarians, annelids, arthropods, and mollusks, are known to have external sensory cilia (hair-like structures) and/or internal statocysts (sac-like organs with sensory cilia) to detect vibrations in the water (Navy, 2015).

Similar to the way that some fish sense sound, scientists believe that macroinvertebrates are able to sense vibrations and particle motion – rather than sound pressure, which is detected by and affects marine mammals (DOSITS, 2017; Nedelec et al., 2016; Edmonds et al., 2016). Because any acoustic sensory capabilities in aquatic macroinvertebrates, to the extent they exist at all, are limited to detecting particle motion, and this decreases rapidly with distance from the sound source, invertebrates are probably restricted to detecting sound sources in close proximity rather than sound caused by pressure waves from distant sources (Navy, 2015). Due to their commercial importance, most attention has focused on the acoustic capabilities and sensitivities of marine crustaceans (e.g., lobsters, shrimp, crabs). While crustaceans are known to detect, produce, and respond to sound, their sensitivity to sound is unknown (Edmonds et al., 2016).

The hearing range of macroinvertebrates is uncertain and likely varies from phylum to phylum. At present, no acoustic frequency or sound intensity thresholds exist above which there are known or observed impacts (Edmonds et al., 2016). All of the NOS underwater sound sources, such as echo sounders and ADCPs, associated with the project alternatives should be well above the hearing range of macroinvertebrates (Hawkins and Popper, 2012). However, certain macroinvertebrates can probably detect low-frequency sounds from ship movement (Mooney et al., 2010), though scientists still lack an understanding of what that means to them. To date, there are no studies indicating whether masking occurs in aquatic macroinvertebrates or suggesting that anthropogenic sounds would have any impact on invertebrate behavior (Hawkins and Popper, 2012).

3.8.1.4 Regional Distribution

Aquatic macroinvertebrates are found in all regions of the action area, though different phyla and taxa predominate in different regions and habitats. In the freshwater navigable rivers throughout the continental U.S., as well as the Great Lakes, mollusks, in particular mussels, are ecologically predominant. Native insect larva and crustaceans such as amphipods and crayfish (which are all arthropods), as well as annelids (segmented worms), are also present in these freshwater habitats. Brachiopods, bryozoans, Cnidaria (jellyfish and corals), echinoderms (sea stars, etc.), Porifera (sponges), and tunicates are some of the prominent macroinvertebrates not found to any extent or at all in freshwater environments.

It is in the marine environment that macroinvertebrate diversity and abundance reach their zenith, especially in warmer waters and the tropics. All five marine regions of the EEZ support abundant macroinvertebrate populations, biomass, and species diversity.

Tropical coral reefs of any significance, and the diverse animal assemblages and ecosystems they support, occur only in the Southeast Region and Pacific Islands Region. The economic value of particular commercially important macroinvertebrates varies substantially from region to region. Shrimp are particularly important in the Gulf States (Southeast Region), while lobster support an important fishery in the Greater Atlantic Region. Oyster harvest in Chesapeake Bay (on the boundary between the Greater Atlantic Region and Southeast Region) used to support a major industry that is now much diminished, but crabs continue to be economically and culturally important. Crabs also support a large commercial fishery in the Alaska Region.

3.8.1.5 Threatened and Endangered Species

NMFS and the USFWS have listed a number of imperiled aquatic macroinvertebrates as either threatened or endangered under the ESA.

3.8.1.5.1 Marine Macroinvertebrates

A total of 17 ESA-listed or candidate species of marine macroinvertebrates, 15 coral species and two species of abalone (a marine gastropod mollusk), potentially occur in the action area (**Table 3.8-1**). The corals are all within the Southeast Region and the Pacific Islands Region, while the abalones are found in the West Coast Region. Two species of ESA-listed coral have designated critical habitat.

Table 3.8-1. ESA-Listed Marine Macroinvertebrates Occurring in the Action Area

Common Name	Scientific Name	ESA Status	Lead Agency	Region*	Critical Habitat
Staghorn coral	*Acropora cervicornis*	Threatened	NMFS	SER	Yes
Coral: no common name	*Acropora globiceps*	Threatened	NMFS	PIR	No
Coral: no common name	*Acropora jacquelineae*	Threatened	NMFS	PIR	No
Elkhorn coral	*Acropora palmata*	Threatened	NMFS	SER	Yes

Common Name	Scientific Name	ESA Status	Lead Agency	Region*	Critical Habitat
Coral: no common name	*Acropora retusa*	Threatened	NMFS	PIR	No
Coral: no common name	*Acropora speciosa*	Threatened	NMFS	PIR	No
Pillar coral	*Dendrogyra cylindrus*	Threatened	NMFS	SER	No
Coral: no common name	*Euphyllia paradivisa*	Threatened	NMFS	PIR	No
Black abalone	*Haliotis cracherodii*	Endangered	NMFS	WCR	No
White abalone	*Haliotis sorenseni*	Endangered	NMFS	WCR	No
Coral: no common name	*Isopora crateriformis*	Threatened	NMFS	PIR	No
Rough cactus coral	*Mycetophyllia ferox*	Threatened	NMFS	SER	No
Lobed star coral	*Orbicella annularis*	Threatened	NMFS	SER	No
Mountainous star coral	*Orbicella faveolata*	Threatened	NMFS	SER	No
Boulder star coral	*Orbicella franksi*	Threatened	NMFS	SER	No
Coral: no common name	*Pocillopora meandrina*	Candidate	NMFS	PIR	--
Coral: no common name	*Seriatopora aculeata*	Threatened	NMFS	PIR	No

*SER = Southeast Region (includes Gulf of Mexico, the Caribbean, and the Atlantic seaboard from North Carolina to Florida); WCR = West Coast Region (includes Washington, Oregon, and California); PIR = Pacific Islands Region (includes the Hawaiian, Marianas, and American Samoa archipelagos, Wake Island, and the Remote Pacific Islands).

3.8.1.5.1.1 Acropora cervicornis (Staghorn Coral)

Staghorn coral (**Figure 3.8-5**) is considered one of the most important corals in the Caribbean Sea because it furnishes crucial habitat for other reef animals, especially fish. It lives in a number of coral reef habitats: spur and groove, bank reef, patch reef, transitional reef habitats, limestone ridges, terraces, and hard bottom. Along with elkhorn and star corals, staghorn coral gradually built Caribbean coral reefs across millennia. However, in the early 1980s, a severe epidemic of white band disease swept across its range, and now the surviving staghorn population is a tiny fraction (less than three percent) of its former abundance. Staghorn populations now comprise isolated colonies compared to the vast thickets that once predominated across its range. Thickets remain a prominent feature at just a few known locations. Staghorn coral populations have difficulty reproducing because of white band disease and other stressors (NMFS, No Date-ab).

Figure 3.8-5. Staghorn Coral and Fish for Which They Furnish Habitat

Photo Credit: NMFS

The greatest single threat now facing staghorn coral is a warming ocean. This forces the corals to expel the photosynthetic algae (zooxanthellae) living in their tissue that provide them with food, causing "coral bleaching" and often leading to death. A related threat is ocean acidification, a decrease in water pH caused by increased carbon dioxide in the atmosphere, which dissolves in the surface water to form carbonic acid. This makes it harder for corals to build their skeletons. Other threats are unsustainable fishing practices, which deplete the herbivorous fish that clean the reef, and pollutants originating on adjacent lands such as sediments and nutrients (NMFS, No Date-ab).

In 2014, staghorn coral was listed as ESA-threatened throughout its range, which includes the Bahamas, Caribbean, Florida, and Gulf of Mexico. NMFS has designated four critical habitat areas recognized as providing critical recruitment habitat for staghorn corals off the coast of Florida and off the islands of Puerto Rico and the U.S. Virgin Islands (NMFS, No Date-ab).

3.8.1.5.1.2 Acropora globiceps

Within the action area, this species of coral (which lacks a common name) occurs in the central and western Pacific Ocean. Within the EEZ, it is found in Guam, the Commonwealth of the Northern Mariana Islands, American Samoa, and the Pacific Remote Island Area (NMFS, No Date-k).

A. globiceps coral has branches resembling fingers; their size and shape depend on the degree of wave action to which they are exposed. Colonies subject to strong wave action have pyramid-shaped branchlets. Colonies can range in color from uniform blue to cream, brown, or fluorescent green.

A. globiceps is susceptible to the three major threats identified for many corals, namely ocean warming, disease, and ocean acidification, as well as many of the other threats common to corals, such as unsustainable fishing, land-based pollution sources, small population size, and habitat degradation. Despite its widespread geographic distribution, this species occurs primarily in a limited depth range of 0 to 8 m (0-26 ft). Shallow reef areas like these can be complex and physically diverse but are often vulnerable to multiple stressors, both localized and global in nature.

The projected impact of climate change to coral reef ecosystems indicates that the shallow depth range that characterizes this species, in conjunction with other biological, demographic, and spatial elements, threaten it with extinction in the foreseeable future. In 2014, *A. globiceps* was listed as ESA-threatened throughout its range (NMFS, No Date-k).

3.8.1.5.1.3 Acropora jacquelineae

Within the action area, this species of coral (which lacks a common name) is found in the central and western Pacific Ocean. Within the EEZ, it is considered to be present in American Samoa. In addition, its current known geographic range is mostly confined to the Coral Triangle, a roughly triangular region of the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste. The Coral Triangle contains at least 500 species of reef-building corals and is considered a biodiversity hotspot (Allen, 2007). A number of ocean-warming events have already happened in recent years within the western equatorial Pacific, including the Coral Triangle, suggesting that future ocean warming events may be more severe than average in this part of the world.

Figure 3.8-6. *Acropora jacquelineae*

Photo Credit: NMFS

Closely related to the previous species (*A. globiceps*), *A. jacquelineae* consists of gray-brown or pinkish flat plates up to 1 m (3 ft) in diameter (**Figure 3.8-6**). Its upper surface has many smooth-sided thin projections called corallites (NMFS, No Date-l). *A. jacquelineae* occurs in many subtidal reef slope and back-reef habitats, including lower reef slopes, walls and ledges, mid-slopes, and upper reef slopes protected from wave action. Its depth range is 10 to 35 m (33 to 115 ft). Like *A. globiceps*, *A. jacquelineae* is vulnerable to the three major threats facing corals, including ocean warming, disease, and ocean acidification. This combination of factors contributes to a risk of extinction within the foreseeable future for *A. jaquelineae.* Accordingly, in 2014 it was listed as ESA-threatened throughout its range (NMFS, No Date-l).

3.8.1.5.1.4 Acropora palmata (Elkhorn Coral)

Elkhorn coral is in the same taxonomic genus as fellow Caribbean reef-builder staghorn coral (*Acropora*) and is threatened by the same factors. Elkhorn coral typically occurs in clear, shallow water 0.3 to 4 m (1 to 15 ft) deep on coral reefs throughout the Bahamas, Florida, and the Caribbean. It lives in high-energy zones with substantial wave action (NMFS, No Date-e).

Elkhorn coral colonies are golden tan or pale brown in color, with white tips. Like other corals, they derive their color from the symbiotic algae (zooxanthellae) that reside within their tissue and convert sunlight into food. Elkhorn corals have flattened frond-like branches, which typically angle upward from a central trunk. Individual elkhorn colonies can grow to at least 2 m (6 ft) in height and 4 m (12 ft) in diameter, as well as in dense stands with interlocking frameworks known as thickets. Due to their tree-like form, elkhorn corals furnish valuable, spatially complex habitat for fish and other coral reef organisms. In addition, dense thickets of elkhorn corals help prevent shoreline erosion from storm-generated waves (NMFS, No Date-e).

In 2014, elkhorn coral was listed as ESA-threatened throughout its range. NMFS has designated four critical habitat areas recognized as providing critical recruitment habitat for elkhorn corals off the coast of Florida and off the islands of Puerto Rico and the U.S. Virgin Islands.

3.8.1.5.1.5 *Acropora retusa*

A. retusa (which lacks a common name) is a species of coral found within the EEZ at Guam, American Samoa, and the Pacific Remote Island Area, occurring at relatively shallow depths ranging from 0 to 5 m (0 to 17 ft). Colonies of *A. retusa*, typically brown or green in color, are composed of flat plates with short, thick finger-like branches. These branches appear rough and spiky because their radial corallites vary in length. *A. retusa* is characterized as rare even where it is found. This species is vulnerable to the same global threats as other coral species (ocean warming, disease, and acidification).

Projections of climate change impacts to coral reef environments indicate that the shallow depth range of A*. retusa*, in combination with its other biological, demographic, and spatial factors, contributes to a risk of its extinction within the foreseeable future. Accordingly, in 2014 *A. retusa* was listed as ESA-threatened throughout its range (NMFS, No Date-m).

3.8.1.5.1.6 *Acropora speciosa*

This species of coral (which lacks a common name) is likely distributed from Indonesia to the Marshall Islands in the western and central Pacific. Within the EEZ, it might be found in the Pacific Remote Island area and American Samoa. Its colonies, which are cream or light brown in color with delicately colored branch tips, form thick cushions or bottlebrush branches (**Figure 3.8-7**). A*. speciosa* is found on lower reef slopes and walls, especially those with clear water and high *Acropora* diversity, at a depth ranging 12 to 40 m (40 to 132 ft) (NMFS, No Date-n).

This species is threatened by the same global factors as other coral species (ocean warming, disease, and acidification). Due to the widespread nature of these threats, any one threat event has the potential to adversely affect many coral colonies simultaneously. Thus, a species with a relatively small effective population size, like *A. speciosa*, may have a high proportion of genetically unique individuals harmed by threats at any given time within the foreseeable future. This, in combination with other biological, demographic, and spatial elements, contributes to a risk of extinction for this species within the foreseeable future. Accordingly, in 2014 A*. speciosa* was listed as ESA-threatened throughout its range (NMFS, No Date-n).

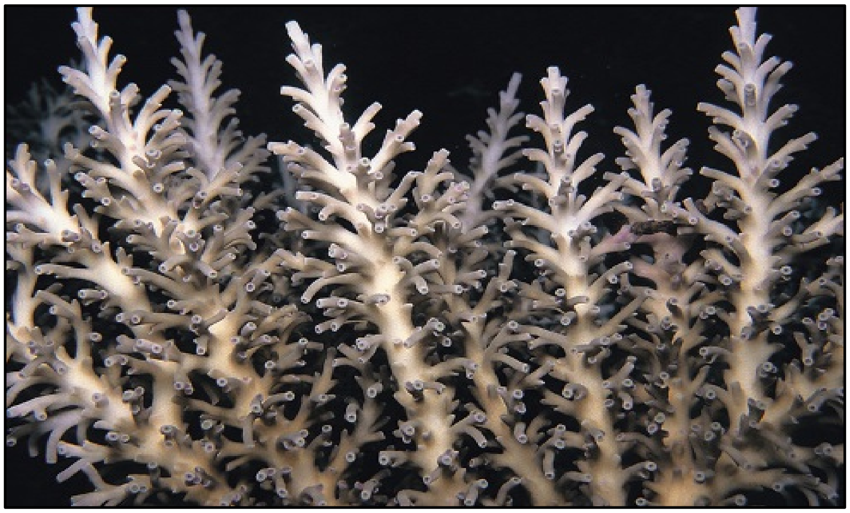

Figure 3.8-7. *Acropora speciosa*

Photo Credit: NMFS

3.8.1.5.1.7 Dendrogyra cylindrus (Pillar Coral)

Pillar coral (**Figure 3.8-8**) is a hard coral found in the western Atlantic Ocean and the Caribbean Sea. It often resembles a cluster of cigars or fingers protruding from the ocean floor (NMFS, No Date-u). Pillar coral colonies occur on flat or gently sloping back reef and fore reef environments from 1 to 25 m (3 to 83 ft) in depth. Pillar coral colonies are resistant to heavy wave surge, but colonies will occasionally topple due to erosion at the bases. However, upper portions of the colonies generally survive, and they produce multiple new pillars which continue to grow upward.

Pillar coral is imperiled throughout its range by climate change, including ocean warming and ocean acidification. Diseases, land-based sources of pollution from residential and commercial development, overfishing, and habitat degradation are also threats (NMFS, No Date-u). In 2014, pillar coral was listed as ESA-threatened throughout its range.

Figure 3.8-8. Pillar Coral

Photo Credit: NMFS

3.8.1.5.1.8 Euphyllia paradivisa

This species of coral (which lacks a common name) is native to the Indo-Pacific islands, occurring mostly in the Coral Triangle area, but is also found in the waters around American Samoa. It favors underwater habitats sheltered from surface wave action on fringing reef crests, mid-slope terraces, and lagoons at depths ranging from 2-25 m (6-82 ft). Like *A. globiceps* and *A. jacquelineae* discussed above, *Euphyllia paradivisa* faces a variety of global and localized threats that in aggregate contribute to a risk of extinction for this species within the foreseeable future. In 2014, it was listed as ESA-threatened throughout its range (NMFS, No Date-o).

3.8.1.5.1.9 Haliotis cracherodii (Black Abalone)

The black abalone is an herbivorous marine snail that was once widespread and abundant along the California coast but is now endangered. For millennia before modern commercial fisheries appeared to exploit it, indigenous Californians harvested and ate abalone. Large piles of abalone shells called middens document human settlement dating back more than 7,000 years. Abalone shells were even traded by Native Americans along routes that began in southern California and extended east of the Mississippi River (NMFS, No Date-c).

The black abalone continues to survive in rocky intertidal pools and subtidal reefs along the California and Baja California coasts. Their oval-shaped shells protect them from predators, while their strong, muscular “foot” attaches to rocks and other hard substrates, from which they release eggs and sperm into the water by the millions when prompted by the right environmental conditions. Harvesting black abalone has been illegal in California since 1993, but the high price of abalone meat, considered a delicacy, maintains poaching pressure. This endangered species has declined significantly along the Southern California coast because of historical overharvest and poaching, and more recently, mass mortality has occurred from a disease known as withering syndrome. In 2009, black abalone was listed as ESA-endangered throughout its range (NMFS, No Date-c).

3.8.1.5.1.10 Haliotis sorenseni (White Abalone)

Closely related to the black abalone, in 2001 the white abalone (**Figure 3.8-9**) was listed as ESA-endangered throughout its range along the California coast because of overharvest and poaching. Although harvest of white abalone has been illegal in California since 1997, the high price of abalone meat on the black market makes them a continuing target of poachers. Surveys in southern California show a 99 percent decline in the white abalone stock since the 1970s. In 2001, NMFS determined that it would be imprudent to designate critical habitat because identification of such habitat might increase the threat of poaching for white abalone (NMFS, No Date-ae).

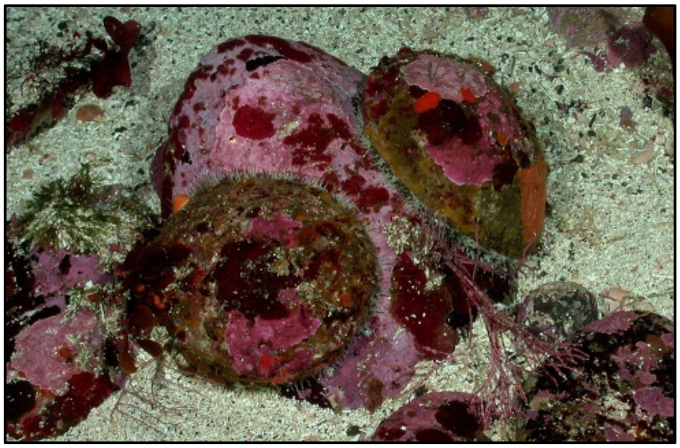

Figure 3.8-9. White Abalone

Photo Credit: NMFS

3.8.1.5.1.11 Isopora crateriformis

This coral (which lacks a common name) is believed to be distributed within the Coral Triangle, in addition to some of the western Pacific, including American Samoa and the Marshall Islands. It forms brown, fattened, solid encrusting plates which can reach over 1 m (3 ft) in diameter. When a colony grows on a slope, the lower edge is usually lifted as a plate. Its main habitats are shallow, high-wave-energy environments, including reef flats and lower crests, as well as upper reef slopes. It has been reported from low tide to at least 12 m (40 ft) deep. Its abundance is characterized as "rare" (NMFS, No Date-p).

I. crateriformis is threatened by the same global and localized factors as the other species in the Coral Triangle and western Pacific, including ocean warming, disease, and ocean acidification. Thus, in 2014 it was listed as ESA-threatened throughout its range (NMFS, No Date-p).

3.8.1.5.1.12 Mycetophyllia ferox (Rough Cactus Coral)

Rough cactus coral is distributed in the Caribbean, southern Gulf of Mexico, Florida, and the Bahamas. It usually exhibits shades of grey or brown, but may also be reddish or green (NMFS, No Date-y). This species is most abundant in fore reef environments from 5-30 m (17-100 ft), but it is also found at low abundance in certain deeper back reef habitats and deep lagoons (IUCN, 2019).

Rough cactus coral is threatened by many of the same factors that threaten other corals: residential and commercial development, transportation corridors, fishing and harvesting of aquatic resources, human intrusions and disturbance (recreational activities), invasive species, pollution, and climate change. In 2014, rough cactus coral was listed as ESA-threatened throughout its range (IUCN, 2019; NMFS, No Date-y).

3.8.1.5.1.13 Orbicella annularis (Lobed Star Coral)

This species is one of the dominant corals in the reefs of the Caribbean Sea and Gulf of Mexico, where it can form extremely large colonies. However, it is ESA-listed as threatened due to sharp population declines. The size of this species makes it an ecologically and structurally important component of coral reefs. It provides refuge for reef-dwelling fish and other animals and can alter marine microclimates to suit other coral species (EDGE, No Date).

Lobed star coral is threatened by residential and commercial development, shipping lanes, fishing and harvesting of aquatic resources, human intrusions and disturbance (recreational activities), invasive species, pollution, and climate change. In 2014, lobed star coral was listed as ESA-threatened throughout its range (NMFS, No Date-q).

3.8.1.5.1.14 *Orbicella faveolata* (Mountainous Star Coral)

Mountainous star coral (**Figure 3.8-10**) is found in the Caribbean Sea and Gulf of Mexico. It is usually pale brown but may be deep brown with fluorescent green highlights (NMFS, No Date-s). Befitting its name, colonies of mountainous star coral are massive, forming large rounded domes and becoming plate-like at the edges (Corals of the World, No Date). While this species is one of the most important reef-building corals in the Caribbean Sea, its populations have recently declined severely (Rippe et al., 2017).

Figure 3.8-10. Mountainous Star Coral

Photo Credit: NMFS

The mountainous star coral is threatened by a combination of climate change, including ocean warming and ocean acidification, diseases, land-based sources of pollution, and habitat degradation. Accordingly, in 2014 it was listed as ESA-threatened throughout its range (NMFS, No Date-s).

3.8.1.5.1.15 *Orbicella franksi* (Boulder Star Coral)

This coral species is native to shallow waters in the Caribbean, Gulf of Mexico, Bahamas, Bermuda, and Florida. Colonies of boulder star coral generally form very large clumps with uneven surfaces; they sometimes form plates. Boulder star coral is usually orange-brown, greenish-brown or greyish-brown. However, extremities of the lumps are frequently pale or white (NMFS, No Date-d).

The boulder star coral, like its close relative the mountainous star coral, is threatened by a combination of climate change, including ocean warming and ocean acidification, diseases, land-based sources of pollution, small population size, and habitat degradation. In 2014, it was listed as ESA-threatened throughout its range (NMFS, No Date-d).

3.8.1.5.1.16 *Pocillopora meandrina* (Cauliflower Coral)

This coral species (sometimes called cauliflower coral) occurs at depths of 1-27 m (3-89 ft) in shallow reefs exposed to strong wave action. It is distributed on coral reefs across the Pacific, with a range extending from the Seychelles Islands in the Indian Ocean to the west coast of Central America in the eastern Pacific. It is found in all U.S. Pacific Islands jurisdictions (NMFS, No Date-w).

Colonies of *P. meandrina* are usually cream colored but can also be green or pink; they resemble small upright bushes (**Figure 3.8-11**), with branches radiating outward from the initial point of growth. These branches are flattened and are covered by bumps called verrucae (NMFS, No Date-w).

P. meandrina is threatened by climate change, including ocean warming and ocean acidification, habitat degradation, diseases, and unsustainable fishing. It is an ESA-candidate species for listing through its entire range (NMFS, No Date-w).

Figure 3.8-11. ***Pocillopora meandrina***

Photo Credit: NMFS

3.8.1.5.1.17 Seriatopora aculeata

This coral species (which lacks a common name) is likely distributed mostly within the Coral Triangle, as well as adjacent areas in the western Pacific Ocean including the Mariana Islands and Guam. Colonies of *S. aculeata* are pink or cream in color and have short, tapered branches, about the width of a pencil, usually in fused clumps (NMFS, No Date-aa).

This species is found in a wide range of habitats, both on the reef slope and back reef. It occurs on upper reef slopes, mid-slope terraces, lower reef slopes, reef flats, and lagoons at a depth range of 3-40 m (10-132 ft).

S. aculeata is vulnerable to the three major, interrelated global threats documented for corals: ocean warming, disease, and ocean acidification. A number of ocean warming events have already taken place within the western equatorial Pacific, an indication that future ocean warming events in this part of the planet may be more severe than average. A substantial portion of its current known geographic range is located within the Coral Triangle, which over the 21st century, is predicted to experience the most rapid and severe impacts on the world's coral reefs both from global climate change and localized human actions. In aggregate, these stressors contribute to a risk of extinction within the foreseeable future for *S. aculeata.* In 2014, this coral was listed as ESA-threatened throughout its range (NMFS, No Date-aa).

3.8.1.5.2 Freshwater Macroinvertebrates

A total of three ESA-listed species of aquatic macroinvertebrates, all mussels, have been documented in the Great Lakes (**Table 3.8-2**).

Table 3.8-2. ESA-Listed Aquatic Macroinvertebrates Occurring in the Great Lakes

Common Name	Scientific Name	ESA Status	Lead Agency	Critical Habitat
Northern Riffleshell	*Epioblasma torulosa rangiana*	Endangered	USFWS	No
Snuffbox	*Epioblasma triquetra*	Endangered	USFWS	No
Rayed Bean	*Villosa fabalis*	Endangered	USFWS	No

3.8.1.5.2.1 *Epioblasma torulosa rangiana* (Northern Riffleshell)

This mussel occurs in both small and large streams, as well as in Lake Erie, although it now survives in less than five percent of its former range in the upper Midwest. It buries into substrates of firmly packed sand or gravel, leaving its feeding siphons exposed. Like many mussels, it has a complex life history. Its reproduction requires undisturbed habitat and adequate numbers of host fish necessary for the mussel's larval development. After male mussels discharge sperm into the water, females siphon in the sperm to fertilize their eggs, which they store in their gill pouches until larvae hatch and are expelled. Those larvae that find a fish host to fasten onto by means of tiny clasping valves grow into juveniles with shells of their own. At that stage they detach from the host fish and settle into the stream or lakebed, ready to begin a long life (up to half a century) as an adult mussel (USFWS, 2019d).

Dams and reservoirs have flooded most of the northern riffleshell's habitat. Reservoirs act as barriers that isolate upstream populations from downstream ones. Erosion from strip mining, logging, farming, and grading introduces sediments to many waterbodies. Suspended and deposited sediments can clog mussels' feeding siphons and smother them. Point-source and non-point-source pollution from agricultural runoff and industrial discharge is another threat. These toxins can accumulate and concentrate in the body tissues of filter-feeders like mussels, eventually poisoning them. In addition, the invasive zebra mussel poses a threat because they attach in great numbers to native mussels such as the northern riffleshell, suffocating and killing them. In 1993, this species was listed as ESA-endangered "wherever found" throughout its range (ECOS, No Date-b).

3.8.1.5.2.2 *Epioblasma triquetra* (Snuffbox)

The snuffbox is a small, triangular freshwater mussel with a yellow, green or brown shell that occurs in a number of states in the South and upper Midwest, as well as Pennsylvania and West Virginia. However, its range and numbers have decreased by at least 90 percent. It lives in small to medium-sized creeks with swift currents, although it also occurs in Lake Erie and some larger rivers (USFWS, 2019f). Males can grow up to 7.1 centimeters (cm) (2.8 in), with females reaching 4.6 cm (1.8 in). Adults often burrow deep in sandy, gravel, or cobble substrates, except when they are spawning or when the females are attempting to attract host fish. Snuffbox mussels are suspension feeders, feeding on algae, bacteria, detritus, microscopic animals, and dissolved organic material (USFWS, 2019f).

Adapted to living in currents, the snuffbox cannot survive in the lentic (still water) conditions created by dams. These mussels are also adversely affected by pollution, sedimentation, and invasive species like the zebra mussel. In 2012, the snuffbox mussel was listed as ESA-endangered "wherever found" throughout its range (ECOS, No Date-d).

3.8.1.5.2.3 Villosa fabalis (Rayed Bean)

The rayed bean (**Figure 3.8-12**) is a small freshwater mussel, typically less than 3.8 cm (1.5 in) long. Its shell is smooth-textured and green, yellowish-green, or brown with many dark-green wavy lines. It generally lives in smaller, headwater creeks, but is sometimes found in large rivers and wave-washed areas of glacial lakes, as well as Lake Erie. It prefers sand or gravel substrates, often in and around the roots of aquatic vegetation. Adult rayed beans spend their entire lives partially or completely submerged in the substrate, filtering water through their gills to feed upon algae, bacteria, detritus, microscopic animals, and dissolved organic material (USFWS, 2019e).

Figure 3.8-12. Rayed Bean Mussel

Photo Credit: Angela Boyer, USFWS

Historically, the rayed bean used to range across a wide area in the upper Midwest and eastern states, north to Ontario. Once found in at least 115 streams, canals, and lakes, it now occurs in only 31 streams and one lake, as well as Lake Erie. It has suffered a 73 percent reduction in the number of occupied streams and lakes. It has been extirpated entirely from three states but is still found in several others, as well as Ontario, Canada. After extirpation from Tennessee and West Virginia, reintroductions have restored the rayed bean to these states (USFWS, 2019e).

This mussel is endangered for the same reasons as the snuffbox mussel: dams and reservoirs, pollution, sedimentation, and invasive species. In 2012, the rayed bean mussel was listed as ESA-endangered "wherever found" throughout its range (ECOS, No Date-c).

3.8.1.5.2.4 Other ESA-Listed Freshwater Mussel Species

A number of other ESA-listed freshwater mussel species are found throughout navigable rivers of the U.S., particularly in the major tributaries of the Mississippi River System, including the Tennessee, Ohio, Illinois, Arkansas, and Red Rivers; these species are unlikely to be affected by NOS projects.

3.8.2 Environmental Consequences for Aquatic Macroinvertebrates

This section discusses the potential impacts of proposed activities associated with Alternatives A, B, and C on aquatic macroinvertebrates. ESA-listed endangered and threatened species are included as part of the discussion along with non-listed species because the potential impact mechanisms are the same. However, any impacts on managed species are of particular concern since they could affect commercially and recreationally important populations of these species. Effects determinations for ESA-listed species are presented at the end of this section after the analysis of impacts.

Activities described in Sections 2.1.1 through 2.1.13 that occur on NOS projects and that could be expected to impact aquatic macroinvertebrates include operation of crewed sea-going surface vessels; operation of remotely operated vehicles (ROVs) and autonomous vehicles; use of echo sounders, ADCPs, acoustic communication systems, and sound speed data collection equipment; anchoring; collection of bottom grab samples; operation of drop/towed cameras and video systems; installation, maintenance, and removal of tide gauges and GPS reference stations; and SCUBA operations.

3.8.2.1 Methodology

The factors from NOS activities that could impact aquatic macroinvertebrates in the action area include: (1) active underwater acoustic sources (e.g., echo sounders, ADCPs, and acoustic communication systems); (2) vessel sound (e.g., from surface vessels, ROVs, and autonomous vehicles); (3) vessel surface wake and underwater turbulence (e.g., from surface vessels; ROVs and autonomous vehicles; survey equipment; and anchors); (4) accidental leakage or spillage of oil, fuel, and chemicals into surrounding waters (e.g., from vessel operations); (5) disturbance of the sea floor (e.g., from anchoring and collection of bottom grab samples); and (6) air emissions (e.g., from smokestacks and outboard motors). These potential impact causing factors and their associated impacts on aquatic macroinvertebrates are discussed below for each alternative. Note that use of the term "sea floor" in the analysis below also includes lake and river bottoms where NOS activities could occur.

As discussed in Section 3.2.2, significance criteria were developed for each resource analyzed in this PEIS to provide a structured framework for assessing impacts from the alternatives and the significance of the impacts. The significance criteria for aquatic macroinvertebrates are shown in **Table 3.8-3**.

Table 3.8-3. Significance Criteria for the Analysis of Impacts to Aquatic Macroinvertebrates

Impact Descriptor	Context and Intensity	Significance Conclusion
Negligible	Impacts to aquatic macroinvertebrates would be limited to temporary (lasting up to several hours) behavioral and stress-startle responses to individual invertebrates found within the project area. Impacts on habitat would be temporary (e.g., temporary placement of an object on the sea floor or increased turbidity) with no lasting damage or alteration.	Insignificant
Minor	Impacts to aquatic macroinvertebrates would be temporary or short-term (lasting several days to several weeks) but would not be outside the natural range of variability of species' populations, their habitats, or the natural processes sustaining them. This could include temporary or repeated short-term stress responses without permanent physiological damage. Behavioral responses to disturbance by some individuals, groups, populations, or colonies could be expected, but only temporary disturbance of breeding, feeding, or other activities would occur, without any impacts on population levels. Displacement would be short-term and limited to the project area or its immediate surroundings. Impacts on habitat (e.g., short-term placement of an object on the sea floor, increased	

Impact Descriptor	Context and Intensity	Significance Conclusion
	turbidity, or loss of a small area of vegetation) would be easily recoverable, with no long-term or permanent damage or alteration.	
Moderate	Impacts to aquatic macroinvertebrates would be short-term or long-term (lasting several months or longer) and outside the natural range of variability of species' populations, their habitats, or the natural processes sustaining them. This could include physiological injury to individuals, repeated stress responses, or mortality. Behavioral responses to disturbance by numerous individuals could be expected in the project area, its immediate surroundings, or beyond. These could include negative impacts to breeding, feeding, growth, or other factors affecting population levels, including population-level mortality to or extended displacement (up to 1 year) of large numbers (e.g., population-level) of invertebrates. However, they would not threaten the continued existence of a stock, population, or species. Habitat would be potentially damaged or altered over the long term but would continue to support the species reliant on it.	
Major	Impacts to aquatic macroinvertebrates would be short-term or long-term and well outside the natural range of variability of species' populations, their habitats, or the natural processes sustaining them. Behavioral and stress responses would be repeated or permanent. Actions would affect any stage of a species' life cycle (i.e., breeding, feeding, growth, and maturity), alter population structure, genetic diversity, or other demographic factors, and/or cause mortality beyond a small number of individuals, resulting in a decrease in population levels. Displacement and stress responses would be short- or long-term within and well beyond the project area. Habitat would be degraded over the long term or permanently so that it would no longer support a sustainable fishery and/or would cause the population of a managed species to become stressed, less productive, or unstable.	Significant

3.8.2.2 Alternative A: No Action - Conduct Surveying and Mapping Projects for Coastal and Marine Data Collection with Current Technology and Methods, at Current Funding Levels

Under Alternative A, NOS survey effort would cover a total of 3,318,678 nm (6,146,191 km) across all five regions over the six-year period. Although the survey effort under Alternative A would vary by year (see **Table 3.4-6**), over the six-year period for proposed projects, the greatest number of nautical miles surveyed would be in the Southeast Region (over 50 percent). The survey effort in each of the other four regions is approximately 10 percent over six years, and perhaps slightly greater in the Alaska Region where the survey effort would be somewhat higher overall (approximately 16 percent). Additionally, survey effort in the Great Lakes would average 3,106 nm (5,752 km) annually, as compared to an annual average survey effort of 550,007 nm (1,018,613 km) for the remainder of the action area. In general, it is expected that level of effort and overall impacts trend together (i.e., greater impacts where the survey effort is higher), but there are other factors, such as location and depth of surveys, hearing frequency of aquatic macroinvertebrates, and population densities of aquatic macroinvertebrates, that add nuance to this trend.

Overall, vessel activity during NOS projects would comprise a negligible proportion of vessel traffic in the action area (not including recreational vessels as they are not generally included in the count). Additionally, whenever possible, the location and timing of a given project would be purposefully coordinated to ensure that areas are not repeatedly surveyed (although ONMS and IOOS surveys may occur multiple times in one year). This ensures that the potential environmental impacts directly resulting from NOS projects would not be exacerbated by repeated surveys within a given area.

3.8.2.2.1 Aquatic Macroinvertebrates

The analysis of impacts on aquatic macroinvertebrates considers all of the impact causing factors listed above, except for air emissions which are analyzed in Section 3.8.2.2.2. Potential impacts could occur in all of the geographic regions. Three of the regions (Southeast, West Coast, Pacific Islands) include one or more ESA-listed species, but only one region, the Southeast Region, includes designated critical habitat for aquatic macroinvertebrates. The Pacific Islands Region contains the greatest number of ESA-listed species (all corals), closely followed by the Southeast Region (also corals). The only designated critical habitat is for staghorn and elkhorn coral in the Southeast Region (see **Table 3.8-1**).

In addition to the impacts on aquatic macroinvertebrates discussed in this section, these organisms may also be indirectly affected by habitat modification, such as degradation of water quality and disturbance of benthos, aquatic vegetation, and sediments. These potential impacts are discussed in Section 3.8.2.2.2.

3.8.2.2.1.1 Active Underwater Acoustic Sources

As noted in Section 3.8.1.3, research into the effects of underwater sound waves on aquatic macroinvertebrates has barely begun and there are still many unknowns. While they lack ears and related structures associated with hearing, certain aquatic macroinvertebrates do possess morphological structures (external cilia sensory hairs, and internal statocysts), and at close range to a sound source, they are believed to be capable of detecting low-frequency vibrations and particle motion in water. However, unlike aquatic vertebrates, aquatic macroinvertebrates, lacking ears with which to hear, would not be vulnerable to potential hearing loss from loud underwater sounds. Furthermore, virtually all of the high-frequency underwater acoustic sources used during NOS projects should be above the detection range of macroinvertebrates.

Overall, active underwater acoustic sources including echo sounders and ADCPs, when considered with the mobile and temporary character of NOS projects, the limited low-frequency detection range of aquatic macroinvertebrates documented to date, as well as the small area of the water column and sea floor affected during the projects relative to the entire EEZ, would have **adverse, negligible** impacts on aquatic macroinvertebrates. Impacts on aquatic macroinvertebrates, both marine and freshwater (Great Lakes and major navigable rivers), including ESA-listed species, would continue to be **insignificant**.

3.8.2.2.1.2 Vessel Sound

As noted in earlier sections, all vessels generate low-frequency underwater sound in the 20 to 500 Hz range and are major contributors to the overall background sound in the sea, which has been increasing for decades. As indicated in Section 3.8.1.3, aquatic macroinvertebrates can probably detect low-frequency sound from ships, but scientists do not yet understand what, if anything, this sound at these levels means to them. It is likely that aquatic invertebrates found in locations with high vessel traffic have already habituated to this background sound. Underwater vessel sound could potentially disturb certain nearby aquatic invertebrates, interrupt feeding, cause other behavior modifications, and possibly mask biologically important signals; such impacts would vary among macroinvertebrate taxa. Impacts on invertebrate behavior are anticipated to be temporary and localized to areas of vessel activity.

ROVs also generate engine sound, and effects on macroinvertebrates would likely be similar to those from sound from surface vessels but likely at a reduced magnitude as ROVs are smaller, thus producing less sound, and they would not be used as extensively as surface vessels (see **Table 2.4-1**).

Given the proposed volume of vessel traffic associated with projects within the EEZ, the effects of vessel sound on aquatic macroinvertebrates, including ESA-listed species, would be **adverse** and **negligible**. Multiple activities in one area could lead to larger magnitudes and more widespread impacts, but they would still be considered **insignificant**.

3.8.2.2.1.3 Vessel Wake and Underwater Turbulence

Water disturbance by surface vessel and ROV wakes and underwater turbulence could temporarily disturb nearby invertebrates and displace mobile taxa. However, these impacts would be minimal as the vessel would quickly pass by or stop moving. Impacts could increase if the frequency of disturbance becomes greater (i.e., repeated passes). In any event, mobile aquatic macroinvertebrates would be expected to return to the area and resume normal activities once the vessel departs or the ROV is no longer present.

Equipment used in NOS projects, such as echo sounders and ADCPs, is typically attached to a crewed vessel, ROV, or an autonomous vehicle, thus effects on invertebrates due to water movement that is created would occur from the use of these carriers, rather than any disturbance from the equipment itself. An exception would be in the rare instances when echo sounders are placed directly on the sea floor or operated by divers, who would possibly disturb nearby invertebrates temporarily by moving through the water column.

Some equipment such as sound speed data collection equipment, bottom grab samplers, and drop/towed cameras is lowered and raised through the water column or falls through the water. This movement through the water could temporarily disturb and displace nearby macroinvertebrates such as crabs, shrimp, or lobsters, although it is not expected that most would move very far. These impacts would be temporary, as these organisms are expected to return once water column turbulence ceases.

Effects on aquatic macroinvertebrates, including ESA-listed species, from vessel wake and underwater turbulence would be **adverse** and **negligible**. Multiple activities in one area could lead to more widespread impacts of greater magnitude, but impacts would still be considered **insignificant**.

3.8.2.2.1.4 Accidental Leakage or Spillage of Oil, Fuel, and Chemicals

An accidental event could result in release of fuel or diesel by a survey vessel. Adverse impacts on aquatic macroinvertebrates could also occur from pumping of oily bilge water overboard, discharged wastewater/graywater that may contain nutrients and fecal coliform, and accidental oil, fuel, and chemical spills. Discharges other than accidental ones are regulated by the MARPOL 73/78 protocol, to which the U.S. is a signatory. Moreover, all hazardous or regulated materials would be handled in accordance with applicable laws and crew members would be appropriately trained in materials storage and usage.

Some macroinvertebrates (e.g., crustaceans) are mobile enough to avoid areas of higher concentrations of oil and other contaminants, while others such as corals, sea anemones, and sea urchins are sessile or immobile. Depending on the product, most oil would remain at or near the surface and typically would not impact macroinvertebrates in deeper water, where most are located. Lighter substances can disperse into the water column or might dissolve in water, potentially impacting sessile eggs and larvae, as well as more mobile juvenile macroinvertebrates and adult crustaceans.

Although the probability of an accidental oil or chemical spill from a vessel used by NOS is very low, if exposed, aquatic macroinvertebrates can be affected directly either by ingestion of oil or oiled prey, through uptake of dissolved petroleum compounds, and through effects on eggs and larvae survival. Sublethal effects may cause stress and could be transient and only slightly debilitating, but invertebrates may also be killed by coming into contact with oil and other contaminants. Recovery requires energy, and this could eventually lead to increased vulnerability to disease, diminished growth and reproductive success, and reduced fitness overall.

Aquatic macroinvertebrates can be affected indirectly by oil and chemicals via modifications of the ecosystem that affect their prey species and habitats. Many macroinvertebrates feed upon phytoplankton and zooplankton during various life stages. However, even if a large amount of plankton were affected, it can recover rapidly due to high reproductive rates, rapid replacement from adjacent waters, widespread distribution, and exchange with tidal currents. Moreover, the vessels used for NOS projects and the quantity of fuel and other chemicals they carry are extremely small compared to the extensive size of the action area. Thus, the impact on a pelagic phytoplankton community, and on macroinvertebrates, would not be substantial, widespread, or long-term.

The likelihood of an accidental spill from a vessel used for NOS projects would be very low, and thus impacts are expected to be **adverse** and **negligible** to **minor**. Impacts on aquatic macroinvertebrates, including ESA-listed species, would be considered **insignificant**. In the event that an accidental spill did occur, the volume of oil, fuel, and/or chemicals would be fairly small, so that the impact on macroinvertebrates would still be considered **insignificant**.

3.8.2.2.1.5 Disturbance of the Sea Floor

Water disturbance by anchors and chains moving in the water, and by collection of bottom grab samples, can temporarily disturb, displace, damage, or crush, injure, and kill nearby aquatic macroinvertebrates, both mobile (e.g., crustaceans) and immobile (e.g., corals, sea urchins, sea anemones, mollusks, sponges). Impacts would be minimal and extremely localized (BOEM, 2014b), and would cease with the removal of the grab sampler, with the anchoring system coming to rest, or with the equipment being taken out of the water. Any displaced benthic aquatic macroinvertebrates are expected to return to the area and resume normal activities as soon as water column turbulence ceases.

Dropping an anchor onto the seabed or lake/river bottom would disturb a very small area (1-2 m^2 [3-6 ft]). If anchor chains drag across the sea floor, they can create a circular scour hole. Anchor scour has the potential to create localized turbidity that could reduce water clarity and increase sediment deposition. Increased sedimentation can impact benthic macroinvertebrates by reducing feeding efficiency, altering reproductive cycles, and reducing response to physical stimulus. In cases where organisms are exposed to excessive turbidity, the suspended sediments can potentially limit gas exchange and possibly lead to asphyxiation. However, suspended sediments are expected to settle quickly and long exposures are not likely to occur. Furthermore, NOS personnel would be careful not to drag anchor chains and would generally avoid anchoring on coral reefs (OCS, No Date).

Samples would not be collected on coral reefs, shipwrecks, obstructions, or hard bottom areas, further minimizing direct impacts to macroinvertebrates. Overall effects on aquatic macroinvertebrates from disturbance of the sea floor would be **adverse** and **negligible**. Impacts on macroinvertebrates, including ESA-listed species, would continue to be **insignificant**.

3.8.2.2.2 Habitat for Macroinvertebrates

The analysis of impacts on habitat for aquatic macroinvertebrates does not consider active underwater acoustic sources or vessel and equipment sound, as these impact causing factors would not affect habitat characteristics.

3.8.2.2.2.1 Vessel Wake and Underwater Turbulence

Vessel wakes and turbulence can generate wave and surge effects on shorelines and stir up bottom sediments, increasing localized turbidity in shallow areas depending on the wake wave energy, the water depth, and the type of shoreline. Wakes can cause shoreline erosion, degrade wetland habitat, and increase water turbidity. Water column habitat gradients would be temporarily disrupted by wake action, including temperature, salinity, DO, turbidity, and nutrient supply. Stirring up lake sediment can re-suspend nutrients such as phosphorus, potentially contributing to harmful, DO-consuming algal blooms.

The suspension of disturbed sediments from wake action and shoreline erosion could minimize the light intensity that reaches aquatic vegetation which depends on light for photosynthesis. High turbidity that causes a substantial reduction in light availability can lead to sublethal adverse effects or mortality of aquatic vegetation. Suspended material may also react with DO in the water and result in short-term oxygen depletion to aquatic resources, including vegetation and benthic macroinvertebrates.

The movement of ROVs, such as sound speed data collection equipment, bottom grab samplers, drop/towed cameras, and anchors and chains through the water column could temporarily cause localized turbulence and disturb nearby prey species, as well as potentially cause damage to submerged aquatic vegetation. These impacts would be temporary as prey species are expected to return once water column turbulence ceases.

Equipment such as echo sounders, ADCPs, and acoustic communication systems, are typically attached to a crewed vessel, ROV, or autonomous vehicle, thus effects on habitat would occur from the use of these carriers, rather than any disturbance from the equipment itself. The one exception would be in the rare instances when echo sounders are placed directly on the sea floor or operated by divers. In such cases, divers would move through the water column temporarily disturbing prey species.

Effects on habitat, designated critical habitat, and other aquatic macroinvertebrate habitat, from vessel wake and underwater turbulence would be **adverse** and **negligible** to **minor**. Multiple activities in one area could lead to greater magnitudes and extents of impacts, but impacts would still be considered **insignificant**.

3.8.2.2.2.2 Accidental Leakage or Spillage of Oil, Fuel, and Chemicals

An accidental event could result in release of fuel or oil by a survey vessel. The accidental loss of a substantial amount of fuel or oil during projects could affect water quality, the water column, the sea floor, intertidal habitats, and associated biota (i.e., submerged aquatic vegetation) resulting in their mortality or substantial injury, and in alteration of the existing quality of aquatic macroinvertebrate habitats. Cleaning and inspecting vessels prior to use would reduce the risk of accidental spills. In addition, implementation of a spill prevention and recovery plan and shipboard emergency plans that outline measures to reduce the potential for spills and isolate accidental spills should they occur would further reduce the potential for adverse impacts on habitat. In addition, onboard and supporting equipment and the procedures specified in the spill plan are expected to reduce the effects of accidentally discharged fuel and other petroleum products (e.g., oil, lubricants) by facilitating rapid response and cleanup operations.

Vessel bilge water discharges, engine operations, bottom paint sloughing, boat washdowns, and other vessel activities or wear can also deliver debris, nutrients, and contaminants to waterways. This may degrade water quality, contaminate sediments, and alter benthic communities and other macroinvertebrate habitats. Vessel wash, including gray water, deck runoff and cooling water can damage aquatic vegetation and disturb benthos and sediments, which may increase turbidity and suspend contaminants. Any liquid contaminants are expected to be rapidly diluted.

The likelihood of occurrence of an accidental fuel or oil spill from a survey vessel would be very low, although the release of other contaminants is a little more likely. Thus, impacts are expected to be **adverse** and **negligible** to **minor**. Impacts on habitat, as well as designated critical habitat, would continue to be **insignificant**.

3.8.2.2.2.3 Disturbance of the Sea Floor

Adverse impacts on aquatic macroinvertebrate habitat can occur when vessels anchor in shallow nearshore waters and the anchor chain drags across the sea floor, destroying submerged vegetation and creating a circular scour hole. Anchor scour has the potential to create localized turbidity and affect soft-bottomed sea floor habitat and/or rocky substrates, potentially creating turbidity that could reduce water clarity and increase sediment deposition. NOS personnel would deploy anchors so as to minimize anchor drag and would not anchor on known coral reef areas.

Increased turbidity immediately following anchoring events could temporarily reduce foraging ability of prey due to decreased visibility in the water column; however, these conditions would be of short duration and would soon return to baseline. Suspended material may also react with DO in the water and result in short-term oxygen depletion to aquatic resources.

Collecting bottom samples could create localized turbidity and affect soft-bottomed sea floor habitat, potentially creating turbidity that could reduce water clarity temporarily. Such turbidity would likely be minimal as samplers are designed to close to contain the sediment and prevent sample washout. Samples would not be collected on coral reefs, shipwrecks, obstructions, or hard bottom areas, further minimizing impacts on macroinvertebrate habitat. Placement of equipment or moorings on the sea floor has the potential to create localized turbidity that could reduce water clarity temporarily, although this would be minimal.

Effects from disturbance of the sea floor would be **adverse** and **negligible** to **minor**. Impacts on habitats and designated critical habitat would be **insignificant**.

3.8.2.2.2.4 Air Emissions

Since the pre-industrial era, increased emissions of anthropogenic GHGs (CO_2, CH_4, and N_2O) have influenced changes in oceanic conditions (as well as atmospheric and terrestrial conditions) (Limpinsel et al., 2017). Higher atmospheric CO_2 levels increase dissolved CO_2 and bicarbonate ions in seawater, which subsequently leads to a decrease in carbonate ions and pH, termed "ocean acidification." Changes in seawater carbon chemistry may affect marine biota through a variety of biochemical, physiological, and physical processes.

Smokestack and two-stroke outboard motor emissions from survey vessels would release air pollutants which can be deposited on the water surface and contribute to such adverse effects as increasing water acidity in aquatic macroinvertebrate habitat. Adverse impacts can be reduced by such measures as integrating new technologies, operational controls, replacing old engine systems, and switching to low sulfur fuels. Furthermore, the amount of emissions from survey vessels would be a negligible fraction as compared to emissions from all other non-project related vessel activity.

Thus, impacts from air emissions are expected to be **adverse** and **negligible**. Impacts on habitat and designated critical habitat for aquatic macroinvertebrates would be **insignificant**.

3.8.2.2.3 Conclusion

Since the effects of impact causing factors on aquatic macroinvertebrates and their habitats range from negligible to minor, the overall impact of Alternative A on aquatic macroinvertebrates, including ESA-listed species, and designated critical habitat would be **adverse** and **minor**; thus, impacts of Alternative A would continue to be **insignificant**.

3.8.2.3 Alternative B: Conduct Surveying and Mapping Projects for Coastal and Marine Data Collection with Equipment Upgrades, Improved Hydroacoustic Devices, and New Tide Stations

The same impact causing factors for aquatic macroinvertebrates and habitat considered under Alternative A are considered under Alternative B. Under Alternative B, all of the activities and equipment operations proposed in Alternative A would continue but at a higher level of effort, although the percentage of nautical miles covered by projects in each region would be the same as under Alternative A. The greatest level of effort would occur in the Southeast Region (with over 50 percent of the survey effort); level of effort in the other four regions would occur at similar levels (approximately 10 percent of the survey effort in each region), and perhaps slightly greater in the Alaska Region, where the survey effort would be somewhat higher overall (approximately 16 percent). The level of effort in the Great Lakes would remain much lower as compared to the annual total marine survey effort. In general, it is expected that level of effort and overall impacts trend together (i.e., greater impacts where the survey effort is higher), but there are other factors, such as location and depth of surveys, hearing frequency of aquatic macroinvertebrates, and population densities of aquatic macroinvertebrates, that add nuance to this trend.

Survey activities under Alternative B would take place in the same geographic areas and timeframes as under Alternative A; however, Alternative B would include more projects and activities and thus more nautical miles traveled than Alternative A. Overall, survey effort would cover an additional 331,868 nm (614,619 km) under Alternative B as compared to Alternative A (see **Table 3.4-7**). The types and mechanisms of impacts would remain the same in Alternative B as discussed for Alternative A. Therefore, the difference between the two alternatives is a matter of scale with an increased activity level, although distributed unevenly among the different types of activities, leading to a corresponding, incremental increase in effects under Alternative B as compared to Alternative A.

Impacts of Alternative B on aquatic macroinvertebrates, including ESA-listed species, and on habitat and designated critical habitat, would be the same or slightly, but not appreciably, larger than those discussed above under Alternative A for each impact causing factor. Overall, impacts on aquatic macroinvertebrates and habitat would be **adverse, minor,** and **insignificant**.

3.8.2.4 Alternative C: Upgrades and Improvements with Greater Funding Support

The same impact causing factors for aquatic macroinvertebrates and habitat considered under Alternative A are considered under Alternative C. Under Alternative C, all the activities and equipment operation proposed in Alternative A would continue but at a higher level of effort, although the percentage of nautical miles in each region would be the same as under Alternative A. In addition, there would be an overall funding increase of 20 percent relative to Alternative B, thus the level of survey activity would increase. The greatest level of effort would occur in the Southeast Region (with over 50 percent of the survey effort); in the other four regions level of effort would occur at similar levels (approximately 10 percent of the survey effort in each region), and perhaps slightly greater in the Alaska Region where the survey effort would be somewhat higher overall (approximately 16 percent). The level of effort in the Great Lakes would remain much lower as compared to the annual total marine survey effort. In general, it is expected that level of effort and overall impacts trend together (i.e., greater impacts where the survey effort is higher), but there are other factors, such as location and depth of surveys, hearing frequency of aquatic macroinvertebrates, and population densities of aquatic macroinvertebrates, that add nuance to this trend.

Survey activities under Alternative C would take place in the same geographic areas and timeframes as under Alternatives A and B; however, Alternative C would include more projects and activities and thus more nautical miles traveled, than Alternatives A and B. Overall, there would be an additional 331,868 nm (614,619 km) covered by survey vessels under Alternative C (see **Table 3.4-8**) as compared to Alternative B, and an additional 663,736 nm (1,229,238 km) as compared to Alternative A. The types and mechanisms of impacts would remain the same in Alternative C as discussed for Alternatives A and B. Therefore, the difference between the alternatives is a matter of scale with an increased activity level, although distributed unevenly among the different types of activities, leading to a corresponding, incremental increase in effects under Alternative C as compared to Alternatives A and B.

Impacts of Alternative C on aquatic macroinvertebrates, including ESA-listed species, habitats, and designated critical habitat, would be the same or slightly, but not appreciably, larger than those discussed above under Alternative A for each impact causing factor. Overall, impacts on aquatic macroinvertebrates and their habitats would be **adverse, minor,** and **insignificant**.

3.8.2.5 Endangered Species Act Effects Determination

Federal agencies are required under the ESA to determine whether their actions may affect ESA-listed species or their designated critical habitat. Effects determinations divide potential effects into three categories: No Effect; May Affect, but Not Likely to Adversely Affect; and May Affect, and is Likely to Adversely Affect. Actions receiving a “No Effect” designation do not impact listed species or their designated critical habitat (hereafter listed resources) either positively or negatively and is typically only used in situations where no listed resources are present in the action area. Actions receiving a “May Affect, but Not Likely to Adversely Affect” designation have only beneficial, insignificant, or discountable effects to listed resources. Insignificant effects under the ESA relate to the size of the impact and should never reach the scale where take occurs; they are of low relative impact, not measurable, or cannot be evaluated. Adverse effects are considered discountable if they are extremely unlikely to occur. Actions designated as “May Affect, and is Likely to Adversely Affect” will negatively impact any exposed listed resources in a manner that is not insignificant or discountable.

ESA-listed aquatic macroinvertebrate species – all of which are bottom-dwelling corals and mollusks (abalone and mussels) – are not believed to detect the mid-to-high frequencies emitted by active underwater acoustic sources. Additionally, due to the mobile and temporary nature of NOS projects and the small area of the sea floor affected during the projects relative to the entire EEZ, the response to underwater sound exposure from active underwater acoustic sources would be discountable.

The proposed volume of sound from vessel traffic associated with projects would be very small in comparison to sound from all the other non-project related vessel traffic within the EEZ. Additionally, there is no indication that ESA-listed corals and mollusks are susceptible to adverse effects from sound emitted by vessels. Because sound disturbance would be of temporary or short duration and would occur infrequently in any given area, the response by ESA-listed taxa to sound from survey vessels would be discountable.

Although water disturbance by surface vessel and ROV wakes and underwater turbulence could temporarily disturb and nearby corals and mollusks, effects would be temporary and minimal; thus, the response by ESA-listed aquatic macroinvertebrates would be discountable.

The likelihood for an accidental spill is very low, and exposure of ESA-listed macroinvertebrate species and critical habitats to oil, fuel, and other contaminants is not expected. Thus, effects from chemical contamination on ESA-listed species are, therefore, reasonably certain not to occur.

Given the minimal amount of potential turbidity and fine sediment created by disturbance of the sea floor, the effect on ESA-listed species would be discountable.

Thus, NOS concludes that the Proposed Action “May Affect, but [is] Not Likely to Adversely Affect” any of the ESA-listed aquatic macroinvertebrate species occurring in the action area, in particular those listed in **Tables 3.8-1** and **3.8-2**. Additionally, these aquatic macroinvertebrate species serve as prey to marine mammals, and thus, effects on them would constitute indirect effects to marine mammals. Thus, the “May Affect, but Not Likely to Adversely Affect” determination for ESA-listed aquatic macroinvertebrates also applies indirectly to ESA-listed marine mammals.

Since NOS projects may occur in some areas within or adjacent to designated critical habitats for elkhorn and staghorn coral in the Caribbean Sea, there is the potential for impacts on critical habitat characteristics that support these two ESA-listed species. Critical habitat may be minimally disturbed but would remain functional to maintain viability of the species reliant on it. Due to the potential for effects that could be negligible or minor, the Proposed Action “May Affect, but [is] Not Likely to Adversely Affect” the designated critical habitat occurring in the action area (as listed in **Tables 3.8-1** and **3.8-2**).