CORAL REEF CONSERVATION PROGRAM

Draft Programmatic Environmental Impact Statement

2019

COVER SHEET

a. Title:	Coral Reef Conservation Program
b. Subject:	Draft Environmental Impact Statement (DEIS)
c. Lead Agency:	Office of Coastal Management (OCM), National Ocean Services (NOS), National oceanic and Atmospheric Administration (NOAA)
d. Cooperating Agency:	No cooperative agency
e. Abstract:	NOAA is preparing a Draft Programmatic Environmental Impact Statement (DPEIS) for continued implementation of its Coral Reef Conservation Program (CRCP) which provides for coral reef conservation and restoration consistent with its strategic plan throughout the U.S. jurisdictions of the Atlantic Ocean, which includes the Gulf of Mexico, South Atlantic and Caribbean Sea, the Pacific Ocean, which includes the Pacific Island Region, and priority international areas (i.e., the wider Caribbean, the Coral Triangle, the South Pacific, and Micronesia). NOAA proposes to continue implementing the CRCP through coral reef conservation and restoration activities such as internal, agency-funded and executed activities and by providing financial and technical assistance to Federal, State, and local agencies, private organizations, and academic institutions. The CRCP would continue to focus funding and activities on combating strategic threats to and restoration of coral reefs, guided by the *Coral Reef Conservation Program Strategic Plan* (CRCP Strategic Plan; NOAA 2018a), and future iterations of a programmatic strategic plan.
f. Contact:	Elizabeth Fairey National Marine Fisheries Service Office of Habitat Conservation (OHC/1) NOAA Coral Reef Conservation Program 1315 East-West Highway Silver Spring, MD 20910
g. Transmittal:	This Draft EIS on the continued implementation of NOAA's CRCP is being made available to the public on or about December 13, 2019, as required by the National Environmental Policy Act of 19691.[1]

[1] National Environmental Policy Act of 1969, as amended (42 U.S.C.§§ 4321–4347)

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ARMS	Autonomous Reef Monitoring Structures
AUV	Automated underwater vehicle
BMP	Best management practices
CEQ	Council on Environmental Quality
CNMI	The Commonwealth of the Northern Mariana Islands
CRCP	Coral Restoration Conservation Program
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DAWR	Guam Division of Aquatic and Wildlife Resources
DCMMs	Discretionary conservation and mitigation measures
DPEIS	Draft Programmatic Environmental Impact Statement
EEZ	Exclusive economic zone
EFH	Essential fish habitat
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FGBNMS	Flower Garden Banks National Marine Sanctuary
FMG	Florida Middle Grounds
FMP	Fishery Management Plan
FONSI	Finding of no significant impact
GDP	Gross domestic product
GHG	Greenhouse gas
HAPC	Habitat area of particular concern
HMS	Highly migratory species
LAA	Likely to Adversely Affect
LID	Low Impact Development
MMA	Marine Managed Areas
MMPA	Marine Mammal Protection Act

MSA	Magnuson-Stevens Fishery Conservation and Management Act
NEPA	National Environmental Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service
NHO	Native Hawiian Organization
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NRHP	National Register of Historic Places
NGLA	Northern Guam Lens Aquifer
OAR	Office of Oceanic and Atmospheric Research
OCS	Office of Coast Survey
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PDARP	Programmatic Damage Assessment and Restoration Plan
PEIS	Programmatic Environmental Impact Statement
PRIMNM	Pacific Remote Islands Marine National Monument
PWC	Personal watercraft
PVC	Polyvinyl chloride
ROV	Remotely operated vehicle
SCUBA	Self-contained underwater breathing apparatus
SHPO	State Historic Preservation Officer
TEV	Total economic value
THPO	Tribal Historic Preservation Officer
USCRTF	U.S. Coral Reef Task Force
USFWS	U.S. Fish and Wildlife Service
USVI	U.S. Virgin Islands

Executive Summary

The National Oceanic and Atmospheric Administration (NOAA) is preparing a Draft Programmatic Environmental Impact Statement (DPEIS) for continued implementation of its Coral Reef Conservation Program (CRCP). The CRCP funds and conducts coral reef conservation and restoration activities throughout the U.S. jurisdictions of the Atlantic Ocean, including the Gulf of Mexico, South Atlantic and Caribbean Sea, the Pacific Ocean, including the Pacific Island Region, and priority international areas (i.e., the wider Caribbean, the Coral Triangle, the South Pacific, and Micronesia).

The Council on Environmental Quality regulations recognize the discretionary preparation of PEISs for agency programs (40 C.F.R. § 1502.4(b)), and NOAA has decided to exercise its discretion to prepare a PEIS for the continued operation of the CRCP. Based on early internal agency scoping, NOAA identified the potential for significant impacts to certain resources, impacts that could result in public controversy as the result of implementing program activities. In addition, the CRCP is a nationwide program extending across seven state and territorial jurisdictions with the potential to affect multiple sensitive marine resources as well as socio-economics. NOAA further intends for the PEIS to create efficiencies by establishing a framework for future "tiering." As CRCP activities are proposed for implementation, to the extent additional NEPA review is required, it will rely on the analysis set forth in the PEIS and focus on location specific effects. (40 C.F.R. § 1508.28, 1502.20).The programmatic scope of this document and its intended future use in CRCP environmental decision making are described more fully in Chapter 1, Sections 1.6 through 1.8. NOAA's decision to prepare a PEIS for the CRCP is a program specific decision and does not reflect a broader agency policy.

The CRCP seeks to address an increasing number of threats faced by coral reefs, including pollution, unsustainable fishing practices, and global climate change. According to the World Resources Institute, more than 60% of the world's reefs are under threat from local stressors, like fishing and land-based pollution (Burke et al., 2011). That number jumps to 75% when local threats to reefs are combined with the threat of thermal stress from a changing climate. As a result of increasing threats to coral reef resources, 22 species of coral found in U.S. waters are now listed as threatened under the Endangered Species Act of 1973 (ESA) (16 U.S.C. §1531 *et seq*.). Given their economic, cultural, and ecological value, it is now more important than ever to address and attempt to mitigate or reverse the threats impacting coral reef ecosystems.

Pursuant to the Coral Reef Conservation Act of 2000 (CRCA), 16 U.S.C. § 6401, *et seq.*, the proposed action is to preserve, sustain, and restore the condition of coral reef ecosystems; to promote the wise management and sustainable use of coral reef ecosystems to benefit local communities and the nation; and to develop sound scientific information on the condition of coral reef ecosystems and the threats to these ecosystems. NOAA proposes to continue implementing the CRCP in accordance with the CRCA, as guided by the *Coral Reef Conservation Program Strategic Plan* (CRCP Strategic Plan; NOAA 2018a) and future iterations of a programmatic strategic plan. This DPEIS addresses the direct, indirect, and cumulative environmental effects of the CRCP until 2040, which aligns with the planning horizon of the CRCP Strategic Plan.

The types of activities the CRCP anticipates implementing are described further in Chapter 2 of this document, but include:

- Monitoring, mapping, and research (e.g., scuba surveys, use of underwater autonomous vehicles, coral sampling, fish sampling and tagging, and bathymetric echosounders);
- Coral restoration and interventions (e.g., coral nursery and outplanting, removal of invasive and nuisance species, and addressing coral disease);
- Watershed management and restoration (e.g., small-scale construction projects designed to minimize sediment and pollutant runoff to coral habitats, such as restoring vegetative cover and use of, rain gardens, culvert repair, stream bank stabilization, retention ponds, or constructed wetlands);
- Reduction of physical impacts to coral reef ecosystems (e.g., buoy installation and marine debris removal); and
- Outreach/education and program operations.

Projects implemented or funded by the CRCP vary in terms of their size, complexity, and geographic location. CRCP projects often benefit coral species and habitats found within coral reef ecosystems and the communities that rely on the coral reef ecosystem for nutrition, recreation, and shoreline protection. The CRCP conducts monitoring to gather data on the condition of coral reef ecosystems to support conservation and restoration efforts and related management decisions. NOAA facilitates CRCP activities in coordination with its non-federal partners through grants and cooperative agreements. The CRCP works with a variety of partners that include other federal agencies, state and territorial governments and agencies, research and academic institutions, non-governmental organizations, and community groups in both the Pacific and Atlantic Oceans to conserve tropical/subtropical coral reef ecosystems across multiple states and territories using a targeted approach focused on local issues. These activities are prioritized based on available funding and the effectiveness of each activity at responding strategically to threats to coral ecosystems.

NOAA also conducts its own CRCP activities using appropriated funds. This work brings together expertise from across NOAA for a multidisciplinary approach to studying these complex ecosystems toward the goal of more effective management. The CRCP works closely with NOAA scientists in the National Ocean Service (NOS); National Marine Fisheries Service (NMFS); Office of Oceanic and Atmospheric Research (OAR); and National Environmental Satellite, Data and Information Service (NESDIS). The CRCP also supports capacity building in other nations that have coral ecosystem resources. The CRCP is leading efforts in the U.S. to study and conserve the coral reef ecosystem for current and future generations. (See Sections 2.2, 2.2.1, and 2.2.5 and Figure 1-2.)

As noted, this document will assess the direct, indirect, and cumulative environmental impacts of NOAA's proposed action to continue funding and otherwise implementing coral reef conservation and restoration activities through its existing programmatic framework for implementing the CRCP consistent with its obligations under the CRCA and Executive Order 13089, Coral Reef Protection, of 1998. As explained below, the analysis in this DPEIS is programmatic (i.e., more general) in nature and does not purport to evaluate the environmental impacts of project-level activities. It identifies a suite of coral reef conservation activities that CRCP supports to conserve and restore coral reef ecosystems. This DPEIS evaluates the potential impacts to the human and natural environments expected to be caused by the implementation of these activities. As such, it sets the stage so that future decisions by NOAA at the project-specific level can be reviewed and included under, or effectively tiered from, this programmatic analysis. The DPEIS is also intended to include information that may be incorporated by reference in other NOAA NEPA reviews and documents.

This document provides a programmatic-level environmental analysis to support NOAA's proposal to continue implementation of the CRCP. The DPEIS takes a broad look at issues and programmatic-level alternatives (compared to a document for a specific project or action) and provides guidance for future activities to be carried out by NOAA. In addition to providing a programmatic analysis, NOAA intends to use this document to approve future project-specific actions, so long as the activity being proposed is within the range of alternatives and scope of potential environmental consequences, and does not have significant adverse impacts. Any future project-specific activities proposed by NOAA that are not within the scope of alternatives or environmental consequences considered in this DPEIS will require additional analysis under NEPA but may rely, as appropriate, on analyses and information included herein.

In addition to providing a programmatic, tiered approach to NEPA, NOAA also intends for this DPEIS to establish a framework for programmatic compliance with other environmental statutes such as the ESA, Magnuson-Stevens Act (MSA), National Marine Sanctuaries Act (NMSA), Coastal Zone Management Act (CZMA), Marine Mammal Protection Act (MMPA), and other applicable statutes, acknowledging that specific activities may require development of more focused and refined analysis. To this end, NOAA has initiated ESA Section 7 consultations on a programmatic level with NMFS and the U.S. Fish and Wildlife Service. Similar approaches are being explored for consultations to address Essential Fish Habitat (EFH), National Marine Sanctuaries Act, and National Historic Preservation Act (NHPA) compliance.

This DPEIS also relies on and incorporates by reference several pre-existing NEPA documents and other relevant analyses that have considered effects of activities on coral ecosystems. Where the document incorporates by reference, the information incorporated is summarized and the relevant document and location of the information within the document are cited.

This DPEIS contains four chapters:

Chapter 1 - ***Introduction and Purpose and Need*** describes the purpose and need for the action, as well as background information on the CRCP and its activities.

Chapter 2 - Alternatives describes the three alternatives considered in this DPEIS. The "no action" alternative is the continued implementation of the existing CRCP Strategic Plan, which seeks to reduce land-based sources of pollution, improve fisheries sustainability, increase resilience to climate change, and restore viable coral populations**.** A second alternative and third alternative, Alternatives 1 and 2, respectively, as well as those alternatives considered but rejected from further analysis, are also described.

Chapter 3 - Affected Environment generally describes the baseline physical, biological, and social environments of areas likely to be affected by the CRCP. The affected environment associated with the proposed action is substantial, including all coral reef habitats in U.S. state and territorial waters, plus offshore habitats and coastal areas that influence or affect coral reef ecosystems within the U.S. Exclusive Economic Zone, and coral reef habitats in some tropical and subtropical countries outside of the United States. This chapter is a snapshot of existing conditions and provides the context related to the present condition of resources.

Chapter 4 - Environmental Consequences describes the potential direct, indirect, and cumulative environmental impacts of Alternative 1 and Alternative 2 when compared with the No Action Alternative. NOAA is also required by other statutes to ensure that these actions are analyzed for their impact to the natural and human environment, including, but not limited to, ESA-listed species and their designated critical habitats, managed fisheries, and EFH. This chapter also identifies and describes other applicable legal requirements.

Appendices to the document describe, among other things, the proposed discretionary conservation and mitigation measures (DCMMs) associated with Alternative 2 as well as mitigation measures and best management practices (BMPs) currently implemented under the CRCP and common to all alternatives.

Alternatives

The National Environmental Policy Act (NEPA) requires that any federal agency proposing a major action (that is not categorically excluded) consider reasonable alternatives. To warrant detailed evaluation by NOAA, an alternative must be reasonable and meet the purpose and need (see Section 1.5). Screening criteria are used to determine whether an alternative is reasonable. After applying the screening criteria to an identified range of considered alternatives, only three alternatives were brought forward for detailed review in the DPEIS.

Based on the purpose and need for action (see Section 1.5), an alternative for implementation of the CRCP must meet the following criteria to be considered a reasonable alternative carried forward for detailed consideration. Each alternative must:

- Seek to meet NOAA's duties and obligations and be consistent with the authorities specified by Congress in the CRCA;
- Seek to meet one or more goals established by the CRCP Strategic Plan;
- Be implemented in a manner that ensures compliance with applicable statutory requirements protecting natural and cultural resources; and
- Be implemented in a manner that is practicable from economic, technological, and policy standpoints.

No Action Alternative – Continued operation of the CRCP based on addressing the three primary threats (i.e., fishing impacts, land-based sources of pollution, and climate change) and supporting research, coral restoration, and intervention techniques to respond rapidly to imminent threats, such as increased bleaching and disease, to corals and coral reef ecosystems. CRCP operations currently include monitoring, mapping and research activities, watershed and coral reef restoration, reduction of physical impacts to coral reef ecosystems, outreach and education, and program support. The No Action Alternative would continue to require implementation of avoidance, minimization, and mitigation measures listed in Appendix A, whereas the DCMMs listed in Appendix B may be implemented on a project-by-project basis but not as a requirement. Because this is a programmatic analysis of the CRCP's continued implementation (where program activities are being analyzed as opposed to a single specific project action) with no change in management direction, the No Action Alternative is interpreted herein as "no change from current management" (CEQ 1981).

Alternative 1 – Operation of the CRCP to address the three primary threats (i.e., fishing impacts, land-based sources of pollution, and climate change) through monitoring, mapping, and research (see Section 2.3.1) and watershed management and restoration (see Section 2.3.3). Alternative 1 does not include activities to restore viable coral populations (i.e., coral restoration and interventions [see Section 2.3.2], and reduction of physical impacts to coral reef ecosystems [see Section 2.3.4.]). This alternative would refocus CRCP's resources and efforts solely on the three primary threats to corals. Alternative 1 would continue to require implementation of avoidance, minimization and mitigation measures listed in Appendix A. The DCMMs listed in Appendix B may be utilized on project-by-project basis.

Alternative 2 – No Action Alternative plus required implementation of the DCCMs in Appendix B. Alternative 2 differs from the No Action Alternative in that the DCMMs (Appendix B) will cease to be discretionary. The DCMMs would be required for all projects funded or conducted by the CRCP. The CRCP would have one required set of avoidance, minimization, and mitigation measures that consists of Appendix A and Appendix B.

Table E-1 summarizes the suite of activities the CRCP would implement under each of the proposed alternatives.

Table E-1. Alternatives Summary

	No Action Alternative	Alternative 1	Alternative 2
Monitoring, mapping, and research	X	X	X
Coral restoration and interventions:	X	--	X
Watershed management and restoration	X	X	X
Reduction of physical impacts to coral reef ecosystems	X	--	X
Outreach/education and program operations	X	X	X
Continued compliance with mandatory mitigation measures (Appendix A)	X	X	X
Requirement of discretionary conservation and mitigation measures (Appendix B)	--	--	X

Under all alternatives, the CRCP would continue to be implemented using available appropriations, across four NOAA line offices, using a mix of internal and external funding, across existing geographic areas, and in collaboration with similar partners. The CRCP would continue to conduct program activities in compliance with mandatory mitigation measures developed in compliance with applicable environmental laws such as the ESA and CWA.

Analysis

A brief comparison summary of adverse impacts and benefits among alternatives is provided in the table below (E-2). The summary provides context and intensity of potential impacts using D for direct, I for indirect, S for short-term, L for long-term, etc., and combining these indicators of context, followed by the range of anticipated impact intensity (i.e., negligible to moderate). For example, an adverse impact that is expected to be direct, short- to long- term in duration, local, and negligible to minor, will appear in the table as D/S-L/L, negligible to minor, with further explanation of the potential impact(s).

The CRCP anticpates the adverse environmental impacts for all of the alternatives range from negliable to major. Many of the impacts would be temporary and local. While table E-2 provides a full summary of impacts, the primary adverse impacts from CRCP activities by activity category are:

- Monitoring, mapping, and research: direct injury and/or mortality to corals and fish from sampling and temporary changes in species behavior due to in-water activities;
- Coral restoration and interventions: risk of spread of pathogens and invasive species from transplanting corals and in-water intervention activities, and direct injury and possible mortality to corals due to collection used in nurseries and for intervention development/research;
- Watershed management and restoration: temporary disturbance of terrestrial species and sedimentation due to earthmoving activities; and
- Reduction of physical impacts to coral reef ecosystems: temporary disturbance from installation of buoys and the removal of marine debris.

No Action Alternative, Alternative 1, and Alternative 2. All three alternatives would result in benefits from monitoring, mapping, and research activities that will support data collection and perform research critical to managing corals and associated coastal and marine resources. All three alternatives would implement watershed restoration and management activities that would reduce erosion, stormwater runoff, and sediment and other pollutant loading into downstream and coastal waters. Benefits would be direct and indirect, both short- and long-term, and local to the specific project location. Stabilized sediments (e.g., trails and roads) would restore natural hydrology and reduce sedimentation and erosion in terrestrial, aquatic, wetland, and floodplain habitats; restore flood storage capacity of wetlands and floodplains; and restore habitat for listed species. Reductions in sediments and pollutants in coastal waters would improve water quality and benefit coastal and marine habitats such as corals, seagrasses, mangroves, fish, and fisheries. No differences in beneficial impacts are expected among the three alternatives for “monitoring, mapping, and research” and “watershed management and restoration” activities.

No Action Alternative and Alternative 2. Only the No Action Alternative and Alternative 2 would implement “coral restoration and interventions” and “reduction of physical impacts” activities to directly address impacts to corals from climate change and benefit corals and associated habitats and biota. Both alternatives include transplanting and outplanting corals, development of coral nurseries, reducing invasive species and diseases associated with corals, and reducing physical impacts to corals from marine debris and vessel anchoring. Benefits would be direct and indirect, long-term, local to larger scale, and minor to major, depending on the project. Because coral reefs are not expected to recover without intervention, these alternatives are the only two that would support the recovery and restoration of coral reefs.

Alternative 1. Alternative 1 would likely have the fewest beneficial impacts because it eliminates the activities to restore viable coral populations (i.e., "coral resotation and interventions" and "reduction of physical impacts to coral reef ecosystems'). While some adverse of impacts related to implementing "coral restoration and interventions" and "reduction of physical impacts to coral reef ecosystems" would be avoided by not conducting these activities, it is expected that this avoidance in adverse impacts would not outweigh the benefits gained by implementing activites to restore corals and reduce physical impacts.

Alternative 2. Alternative 2 includes required implementation of all DCMMs in Appendix B. Mandating these measures will further reduce potential impacts of many of the proposed activities. DCMMs (Appendix B) would be implemented in addition to mitigation measures and BMPs that are currently implemented by the CRCP listed in Appendix A and would be expected to further benefit coral reefs and associated habitats and biota. Expected benefits to coral reefs would be the same as for the No Action Alternative, with potentially greater, albeit negligible, benefits.

The three alternatives' potential adverse impacts range from direct to indirect, short- to long-term, local to larger in scale, and from negligible to major. Benefits under the No Action, Alternative 1, and Alternative 2 are anticipated to be both direct and indirect, both short and long term, and potentially both local and large scale, depending on the project.

Table E-2. Summary of the impacts to resources anticipated under the alternatives. The CRCP's discretionary conservation and mitigation measures (DCMMs) are provided in Appendix B. Resources are analyzed for both terrestrial and coastal and marine environments where relevant. Context factors are abbreviated as: Direct and/or Indirect (D-I)/Short- to Long-term (S-L)/Local to Large Scale (L-LS), followed by intensity descriptions of negligible to major.

Resources	**No Action Alternative** *Continued Implementation of the Current CRCP*	**Alternative 1** *Current CRCP without Coral Reef Restoration/Intervention and Reducing Physical Impacts to Coral Reefs*	**Alternative 2** *Current CRCP with Addition of Required DCMMs*
Physical Environment			
Sediments and Soils	**Adverse Impacts.** Terrestrial - D/S/L, negligible to minor due to erosion, sedimentation, compaction, potential introduction of pollutants into soils during monitoring, construction, herbicide use, other watershed proposed activities. Coastal waters: D/S/L, negligible to minor due to sediment resuspension and deposition during vessel	**Adverse Impacts**. Terrestrial - same as for the No Action. Coastal - D/S-L/L, negligible to moderate. Combined adverse impacts to sediments under this alternative are due to continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor, due to	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible benefits due to DCMMs such as additional dive and vessel training, seafloor habitat avoidance, decontamination of equipment, use of mooring buoys or live boating, etc.

	and other in-water activities. Additional long-term, negligible to moderate impacts possible from large projects such as stormwater ponds, road stabilizations, and vessel removals. **Benefits.** D-I/S-L/L-LS, negligible to major due to reduced erosion and land loss, sediment and other pollutant loadings to coastal waters, improved soil and sediment quality, stabilized substrates, reduced debris and contamination, and acquisition of data critical to resource management.	elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	that reduce the amount of disturbance.
Terrestrial Habitats and Biota	**Adverse impacts.** D/S/L, negligible to minor displacement of fish, wildlife, and vegetation due to sound, runoff, altered hydrology, herbicide use, habitat loss due to construction and other watershed proposed activities; invasive species introduction and loss of native species. **Benefits.** D/S-L/L, negligible to moderate benefits due to potential increased quality of native habitat for foraging, nesting, and migratory stops for birds and other terrestrial wildlife; restored habitat due to reduced erosion and improved water quality for instream fish and wildlife.	**Adverse impacts.** D/S/L, negligible to minor, same as No Action, due to watershed proposed activities in terrestrial habitats. **Benefits.** D-I/S-L/L, negligible to moderate, due to continued mapping, monitoring, and research, and watershed restoration and management activities.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible water quality and habitat improvements due to DCMMs such as erosion and sediment controls and reduced herbicide concentrations.

Wetlands and Floodplains	**Adverse impacts.** D/S/L, negligible to minor impacts to wetlands and floodplains due to temporary construction activities and introduction of sediments, other pollutants, and invasive species. **Benefits.** D-I/S-L/L-LS, negligible to moderate due to potential for restored flood capacity, soil rehydration, and increase in native habitat due to reduced erosion and improved water quality.	**Adverse impacts.** D/S/L, negligible to minor same as No Action, negligible to minor due to watershed proposed activities in terrestrial habitats. **Benefits.** D-I/S-L/L-LS, same as No Action, negligible to moderate due to information available to support future conservation and management efforts.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible water quality and habitat improvements due to DCMMs such as erosion and sediment controls and reduced herbicide concentrations.
Water Resources	**Adverse Impacts.** Terrestrial: D/S/L, negligible to minor due to potential for erosion and transport of sediments/other pollutants generated from construction and other activities (see sediments and soils above) and conveyed into downstream and coastal waters. Coastal waters: same as terrestrial with additional impacts from land-based sediments and pollutants, resuspension of sediments due to vessels and other in-water activities associated with monitoring and coral transplanting, and potential contamination from debris. **Benefits**. D-I/S-L/L, negligible to major due to reduced sediments and other pollutant loadings to downstream waters, potential contamination from marine	**Adverse impacts.** Terrestrial. D/S/L, negligible to minor impacts. Same as No Action. Coastal waters: D/S/L, negligible to minor impacts due to potential resuspension of sediment from anchoring and marine debris into the water column. **Benefits.** D-I/S-L/L, and negligible to moderate due to watershed restoration and management activities and continued monitoring, mapping, and research activities.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible, benefits due to DCMMs such as additional dive and vessel training, seafloor habitat avoidance, use of mooring buoys and live boating, and others that reduce the opportunity for resuspension of sediments into the water column.

	debris, and major benefits due to acquisition of data critical to management.		
Biological Environment			
Seagrasses	**Adverse impacts.** D/S/L, negligible to minor due to temporary disturbance during monitoring/surveying, other in-water activities (esp. propeller scars), debris removal, installation of mooring buoys, and coral proposed activities. **Benefits.** D-I/L/L-LS, negligible to moderate due to reduced sediment and nutrient loading from watershed, reduced disturbance/damage from permanent moorings and debris/contamination, habitat stabilization due to potential coral reef recovery.	**Adverse Impacts.** D/S-L/L, negligible to moderate due to continued damage from anchoring and accumulation of marine debris, as well as potential loss of buffering effects of coral reefs. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible, benefits due to DCMMs such as additional dive and vessel training, seafloor habitat avoidance, use of mooring buoys and live boating, and others that reduce contact with resource.
Mangroves	**Adverse impacts.** D-I/S/L, negligible to minor, similar to disturbances described in sediment and soils. **Benefits**. D-I/S-L/L-LS, negligible to moderate to native mangroves due to reduced sediment and nutrient loadings from the watershed, reduced wave energy and sedimentation due to coral recovery, reduced disturbance and contamination due to permanent moorings and debris removal.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible benefits due to a reduction of indirect adverse impacts of sediment and pollutant loadings into coastal waters, potential impacts from anchors and marine debris, and erosion as a result of required DCMMs.

Corals and other associated invertebrates and algae	**Adverse impacts.** D-I/S-L/L, negligible to moderate from temporary disturbance during monitoring, surveying, research, mooring buoy, coral reef restoration, and debris removal activities; potential for disease, corallivores, and invasive species that may increase due to transplanting and outplanting activities. **Benefits.** D-I/S-L/L-LS, negligible to major due to reduced invasive species, acquisition of data available for recovery and management; reduced runoff from watershed, debris removal, reduced anchoring, and increased recovery due to transplanting and outplanting of corals, control of disease, corallivores, and invasive species, other activities that increase the potential for recovery of coral reefs.	**Adverse impacts.** D-I/S-L/L-LS, negligible to major due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible, benefits due to DCMMs such as additional restrictions on the amount of coral removed for transplants, additional decontamination protocols, and further reductions in physical contact with coral to reduce potential for physical damage, disease, corallivore, and invasive species impacts to corals.
Fish	**Adverse impacts.** D-I/S/L, negligible to minor impacts due to temporary disturbance and loss of habitat during monitoring, surveying, research, mooring buoy installation, debris removal, and coral reef restoration. **Benefits.** D-I/S-L/L-LS, negligible to major due to reduced watershed runoff, improved water quality and habitat; potential for restored reef habitat and increase in data for resource management.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to continued damage from coral reef habitat loss and anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional, negligible benefits due to DCMMs such as additional sediment and erosion control to improve water quality, reduced physical contact with habitats, and sound protocols to further reduce potential sound impacts.

Invasive Species	**Adverse impacts.** D-I/S-L/L-LS, negligible to moderate due to potential increases in invasive species due to disturbance and incidental introductions via revegetation materials, transplants, vessels, equipment, trucks, etc. **Benefits.** Terrestrial: D-I/S-L/L-LS, negligible to major due to opportunities for native species to re-establish due to reduced erosion or revegetation. Coastal and marine waters: interventions to reduce invasive species would support recovery of corals and associated biota.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to discontinued coral restoration efforts and continued disturbance from anchoring and accumulation of marine debris, resulting in continued introduction and establishment of invasive species. **Benefits.** D/S-L/L, negligible to minor due to the elimination of CRCP components that address invasive species.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible benefits due to required DCMMs to reduce the concentration of herbicides used for vegetation management and to reduce the risk of introducing invasive species (as well as disease and corallivores) during coral restoration and intervention activities.
Regulatory Environment			
Essential Fish Habitat	**Adverse impacts.** D/S/L, negligible to minor disturbance and loss of habitat for fisheries during monitoring, surveying, research, mooring buoy installation, debris removal, and coral reef proposed activities. **Benefits.** D-I/S-L/L-LS, negligible to major due to restoration of reef and associated habitats (mangroves and seagrasses) due to reduced sediment loading, improved water quality, reduced derelict fishing gear and other debris, and additional data for EFH management.	**Adverse impacts.** D-I/S-L/L-LS, negligible to moderate due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D-I/S-L/L-LS, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional, negligible benefits due to DCMMs such as additional sediment and erosion control to improve water quality, reduced physical contact with habitats, and sound protocols to further reduce potential sound impacts.

Protected Species	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to disturbance/displacement of organisms or habitat due to water quality, hydrologic alteration, or excavation during watershed proposed activities, temporary disturbance during surveying and research activities; potential use of herbicides; other potential impacts would require consultation. **Benefits.** D-I/L/L-LS, negligible to major due to proposed activities that reduce erosion and sedimentation; negligible to major due to invasive species control, road and trail stabilization, and habitat improvements for listed species.	**Adverse impacts.** D-I/S-L/L-LS, negligible to moderate due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S/L, negligible to minor due to the elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible water quality benefits and reduced impacts to habitats from in-water activities due to DCMMs such as additional protocols to reduce physical contact with sea floor and potential sound/echosounder impacts, monitor vessel speeds, use of BMPs.
Socioeconomic Environment			
Cultural Resources	**Adverse impacts.** D-I/S-L/L, permanent, negligible to minor due to section 106 SHPO consultation to identify resources and subsequent unlikely disturbance except to remove or document an object or structure that is discovered. **Benefits.** D/L/L-LS, negligible to moderate due to the potential discovery and/or acquisition of data to support protection of these resources and protection from erosion and runoff.	**Adverse impacts.** D-I/S-L/L, negligible to minor due to the prior consultation with SHPO to avoid impacting these resources. **Benefits.** D-I/L/L, negligible to moderate due to potential documentation, recovery, and protection of cultural resources.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts, due to DCMMs. **Benefits.** Same as No Action, with additional negligible benefits due to required DCMMs protocols to reduce sedimentation into or physical contact with potential resources.

Public Health and Safety	**Adverse impacts.** D-I/S-L/L, negligible to minor due to closure of public and private areas for safety during periods of monitoring or research activities. **Benefits.** D-I/S-L/L-LS, negligible to moderate due to benefits to coastal storm surge and shoreline protection.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to continued accumulation of debris and the potential for adverse impacts to public health and safety. **Benefits.** D-I/S-L/L, negligible to minor, due to the elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action alternative. **Benefits.** Same as No Action alternative.
	Adverse impacts. D-I/S-L/L, negligible to minor due to potential interruptions in activities. **Benefits.** D-I/S-L/L, negligible to moderate include data acquisition and information to improve public health and safety.	**Adverse impacts.** D-I/S-L/L, negligible to major due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to moderate, due to the elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action alternative. **Benefits.** Same as No Action alternative.

1. INTRODUCTION

1.1 NOAA's Role in Conserving Coral Reef Ecosystems

Healthy coral reef ecosystems are among the most biologically diverse, culturally significant, and economically valuable on Earth. They provide billions of dollars in food, jobs, recreational opportunities, coastal protection, and other important goods and services to people around the world.

Coral reefs face an increasing number of threats, including pollution, unsustainable fishing practices, and global climate change. More than 60% of the world's reefs are under threat from local stressors, like fishing and land-based pollution (Burke et al., 2011). That number jumps to 75% when local threats to reefs are combined with the threat of thermal stress from a changing climate. As a result of increasing threats to coral reef resources, 22 species of coral found in the United States (U.S.) waters are now listed as threatened under the Endangered Species Act (ESA) (Burke et al., 2011).

The National Oceanic and Atmospheric Administration (NOAA) established the Coral Reef Conservation Program (CRCP) in 2000 to carry out the policies and purposes of the Coral Reef Conservation Act (CRCA), 16 U.S.C. § 6401, *et seq*. In compliance with the CRCA, the CRCP strives to protect, conserve, and restore the nation's coral reefs by maintaining healthy ecosystem function. The CRCP brings together expertise from across NOAA for a multidisciplinary approach to studying these complex ecosystems toward the goal of more effective management of coral reefs. The CRCP works closely with NOAA scientists in the National Ocean Service (NOS); National Marine Fisheries Service (NMFS); Office of Oceanic and Atmospheric Research (OAR); and National Environmental Satellite, Data, and Information Service (NESDIS). The CRCP also works with a variety of partners that include other federal agencies, state and territorial governments and agencies, research and academic institutions, non-governmental organizations, and community groups in both the Pacific and Atlantic Oceans to conserve tropical/subtropical coral reef ecosystems across multiple states and territories using a targeted approach focused on local issues. Finally, the CRCP supports capacity building in other nations that have coral ecosystem resources.

The CRCP is leading efforts in the U.S. to study and conserve the coral reef ecosystem for current and future generations. A more detailed description of the CRCP's history, framework and management is provided below.

1.2 Programmatic Scope

NOAA is preparing a Draft Programmatic Environmental Impact Statement (DPEIS) for coral reef conservation and restoration activities as part of the implementation of the CRCP Strategic Plan throughout the U.S. jurisdictions of the Atlantic Ocean, which includes the Gulf of Mexico, South Atlantic and Caribbean Sea, and the Pacific Ocean, which includes the Pacific Island Region (Figure 1-1), and priority international areas (i.e., the wider Caribbean, the Coral Triangle, the South Pacific, and Micronesia; Figure 1-2).

The CEQ regulations expressly recognize and encourage the discretionary preparation of PEISs for agency programs (40 C.F.R. § 1502.4(b)), and NOAA has decided to exercise its discretion to prepare a PEIS for the continued operation of the CRCP. Based on early internal agency scoping, NOAA identified the potential significant impacts to certain resources, including some activities that may be highly controversial, as the result of implementing program activities. In addition, the CRCP is a nationwide program extending across seven State and Territorial jurisdictions with the potential to affect multiple sensitive marine resources as well as socio-economics. NOAA further intends for the PEIS to create efficiencies by establishing a framework for future "tiering." As CRCP activities are proposed for implementation, to the extent additional NEPA review is required, it will rely on the analysis set forth in the PEIS and focus on location specific effects (40 C.F.R. §§ 1508.28, 1502.20). The programmatic scope of this document and its intended future use in CRCP environmental decision making are described in Sections 1.6 through 1.8. NOAA's decision to prepare a PEIS for the CRCP is a program-specific decision and does not reflect a broader agency policy.

This document will assess the direct, indirect, and cumulative environmental impacts of NOAA's proposed action to continue funding and otherwise implementing coral reef conservation and restoration activities through its existing programmatic framework for implementing the CRCP consistent with its obligations under the CRCA and Executive Order 13089, Coral Reef Protection. Projects implemented or funded by the CRCP vary in terms of their size, complexity, and geographic location. CRCP projects often benefit coral species and habitats found within coral reef ecosystems and the communities that rely on the coral reef ecosystem for nutrition, recreation, and shoreline protection. The CRCP conducts monitoring to gather data on the condition of coral reef ecosystems to support conservation and restoration efforts. NOAA facilitates CRCP activities in coordination with its non-federal partners through grants and cooperative agreements. These activities are prioritized based on available funding and the effectiveness of each activity at restoring coral reefs or responding strategically to threats to coral ecosystems. This DPEIS identifies and evaluates the general environmental impacts, issues, and concerns related to the comprehensive management and implementation of the CRCP, and includes potential mitigation. NOAA analyzed the No Action Alternative and two Alternatives in this DPEIS (Section 2.4.3).

NOAA anticipates that environmental effects will be caused by site-specific, project-level activities implementing the CRCP. Therefore, this DPEIS will support tiered, site-specific National Environmental Policy Act (NEPA) reviews by narrowing the spectrum of environmental impacts to focus on project-level reviews as needed. NOAA also intends for this DPEIS to establish an environmental decision-making framework for compliance with other environmental statutes such as the ESA and the MMPA. For example, NOAA will use the information and analysis in this DPEIS to initiate ESA Section 7 consultation with NMFS for listed marine species and the U.S. Fish and Wildlife Service (USFWS) for terrestrial species and freshwater fish species that may be affected by CRCP implementation. NOAA is conducting a programmatic review to ensure that the underlying activities would not adversely impact essential fish habitat, protected species, or other species. In addition, information generated from CRCP activities will enable NOAA and other managers to determine which strategies can protect corals and coral reef ecosystems throughout the seven U.S. jurisdictions and identified international priority areas.

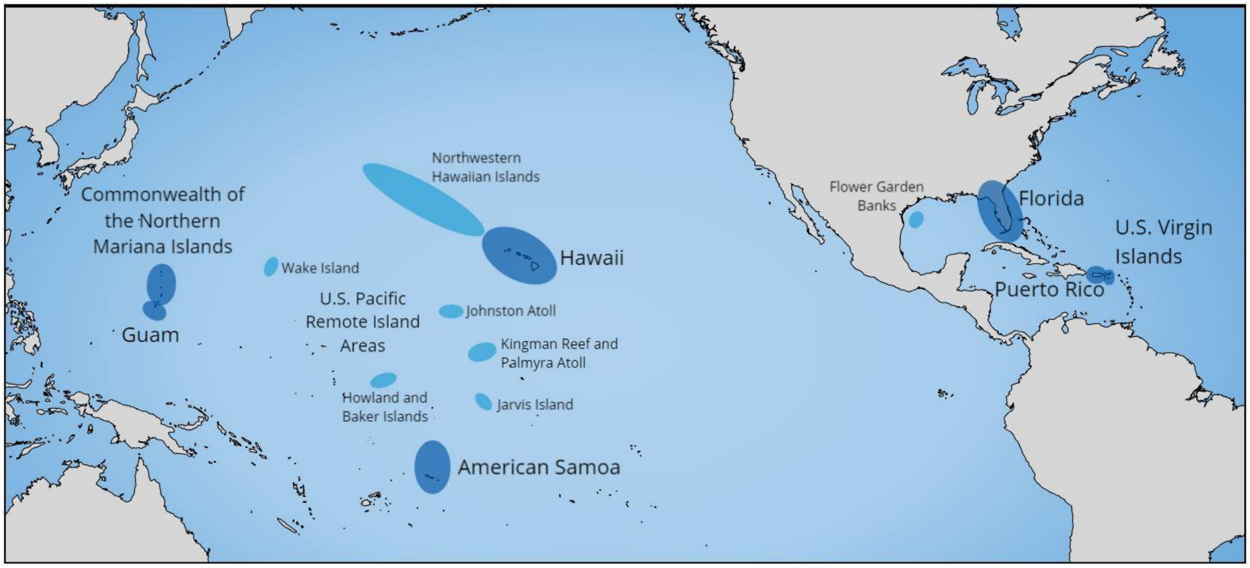

Figure 1-1. The CRCP's U.S. Coral Areas. The dark blue areas highlight the U.S. States and territories where the bulk of the CRCP's activities take place. The lighter blue areas highlight the remote areas where the CRCP mainly supports periodic monitoring and assessment.

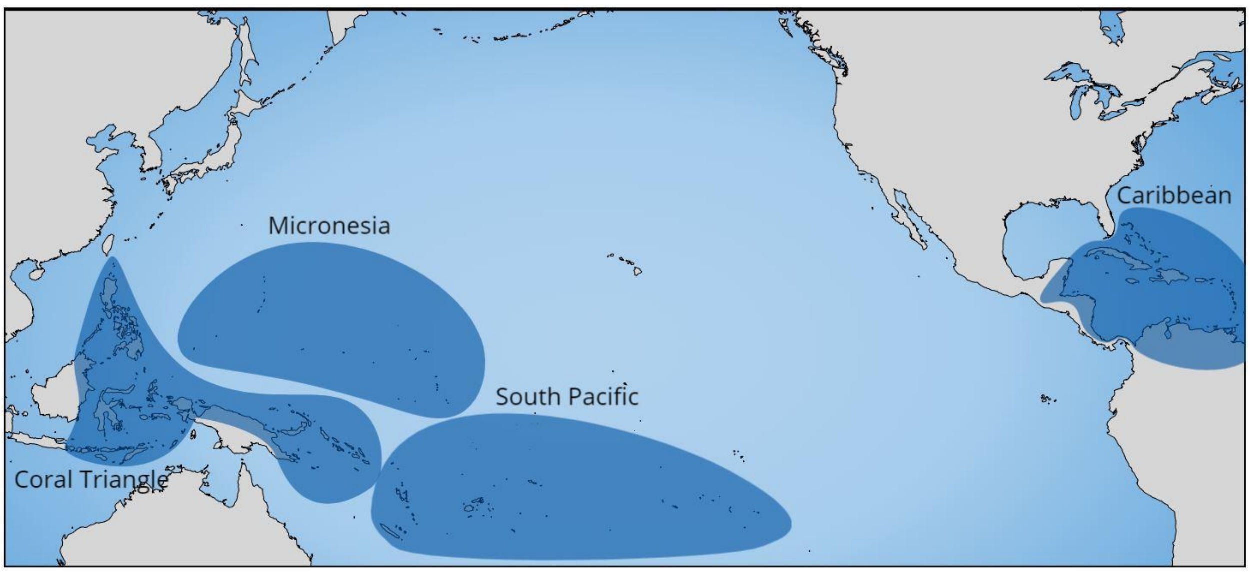

Figure 1-2. The CRCP's International Priority Areas. The dark blue areas highlight the general international regions where the CRCP mainly supports capacity building

1.3 History of the CRCP

The following is a brief history[1] of the establishment and implementation of the CRCP, including its plans and policies. As noted above, NOAA established the CRCP in 2000 to help fulfill NOAA's

[1] The following is a list of reference documents that have been developed and guided management of the CRCP over the years: National Action Plan to Conserve Coral Reefs (2000, http://www.coralreef.gov/about/CRTFAxnPlan9.pdf); National Coral Reef Action Strategy (2002, http://www.coris.noaa.gov/activities/actionstrategy/); 2007 External Review Panel Final Report, https://repository.library.noaa.gov/view/noaa/479/noaa_479_DS1.pdf; Roadmap for the Future (2008) https://www.coris.noaa.gov/activities/roadmap/crcproadmap.pdf; NOAA Coral Reef Conservation Program Goals &

responsibilities under the CRCA and Executive Order 13089, Coral Reef Protection. NOAA is responsible for providing external funding through the Coral Reef Conservation Grant Program and the Coral Reef Conservation Fund, as authorized under Sections 204 and 205 of the CRCA, respectively, and implementing the National Program, as authorized under Section 207. These programs primarily target activities that are in tropical/subtropical coral reef ecosystems including colonized hard bottom habitats (e.g., spur-and-groove reefs, individual and aggregated patch reefs, and gorgonian-colonized pavement and bedrock); uncolonized hardbottom (e.g., reef rubble and uncolonized bedrock); mesophotic reefs (30-150 meters [m], ~100-500 ft) that are linked to shallow-water coral reefs (<30 m; ~100 ft) (i.e., have a meaningful ecological connection between the mesophotic area and associated shallow-water coral reefs); submerged vegetation (e.g.+, seagrass and macroalgae); mangroves and other emergent vegetation; and unconsolidated sediments (e.g., sand and mud).

In addition to the CRCA, the CRCP has been guided by a series of national strategy, planning, and guidance documents. Initially the CRCP addressed the priorities and objectives laid out in the *National Action Plan to Conserve Coral Reefs* (USCRTF, 2000) and the *National Coral Reef Action Strategy* (NOAA, 2002). The *National Action Plan* was produced by the U.S. Coral Reef Task Force (USCRTF) pursuant to Executive Order 13089, and the *National Coral Reef Action Strategy* was developed by NOAA, through the CRCP, pursuant to section 203 of the CRCA. Both documents identified two overarching goals: (1) understand coral reef ecosystems and the natural and anthropogenic processes that determine their health and viability and (2) reduce the adverse impacts of human activities. These two goals encompassed the following 13 conservation strategies: (1) create comprehensive maps of all U.S. coral reef habitats, (2) conduct long-term monitoring and assessments of trends, (3) support strategic research to respond to major threats, (4) incorporate human dimensions into coral reef conservation strategies, (5) create an expanded network of coral reef marine protected areas, (6) reduce impacts of extractive uses, (7) reduce habitat destruction, (8) reduce pollution, (9) restore damaged reefs, (10) reduce global threats, (11) reduce impacts from international trade, (12) improve Federal accountability and coordination, and (13) create an informed public.

In 2002, the USCRTF called for each of the seven U.S. jurisdictions containing coral reefs (i.e., U.S. Virgin Islands [USVI], Puerto Rico, Florida, Hawaii, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands [CNMI]) to develop *Local Action Strategies*, which were locally-driven roadmaps addressing fishing impacts, land-based sources of pollution, recreational overuse and misuse, lack of public awareness, climate change and coral bleaching, and disease, as well as additional locally-relevant threats (i.e., invasive species and over population). These *Local Action Strategies* documents contained a variety of projects to be implemented over a three-year period (roughly 2004-2006). From 2000 through 2008, the CRCP funded and/or implemented a variety of projects that addressed the goals and objectives of the *National Action Plan*, the *National Coral Reef Action Strategy*, and the jurisdictional LASs.

Objectives 2010-2015, https://permanent.access.gpo.gov/lps124467/3threats_go.pdf; NOAA Coral Reef Conservation Program International Strategy 2010-2015, ftp://ftp.library.noaa.gov/noaa_documents.lib/CoRIS/intl_strategy_2010-2015.pdf); Jurisdictional Management Priority Setting Documents, https://www.coris.noaa.gov/activities/management_priorities/); Jurisdictional Capacity Assessments, https://www.coris.noaa.gov/activities/capacity_assessment/.

In 2007, the CRCP conducted its first external review, during which a panel of experts provided an independent assessment of the CRCP's effectiveness in achieving its mandates and provided recommendations for improving its impact and performance in the future. The review panel recommended that the CRCP (1) retain the mission of supporting effective management and sound science; (2) consolidate and sharpen its place-based goals and objectives; (3) increase emphasis on management-relevant science; (4) focus more on addressing impacts related to climate change and unsustainable fishing; and (5) expand the CRCP's international presence. To address the findings of the external review, the CRCP developed the *Roadmap for the Future* (2008) document, which outlines CRCP's principles and priorities and National-level responsibilities.

To make the most of limited resources and to reverse the general decline in coral reef ecosystem health that has occurred over the past several decades, the CRCP narrowed the focus of its National Program to address three threats: fishing impacts, land-based sources of pollution, and climate change. These three threats were widely accepted as having the largest influence on coral decline at the time the roadmap was prepared and continue to be some of the top threats facing the ecosystem. The National-level CRCP responsibilities included providing maps of all U.S. coral reef ecosystems appropriate for management and conducting biophysical and socioeconomic monitoring and assessments to track coral reef status and trends over time and in jurisdictions.

To implement the proposed changes, the CRCP created three working groups made up of NOAA and non-NOAA experts, who provided recommendations to address each of the three threats. The results of this collaborative effort was the *NOAA Coral Reef Conservation Program Goals & Objectives 2010-2015* document, which outlined priorities for the domestic component of the CRCP, and the *NOAA Coral Reef Conservation Program International Strategy 2010-2015* document, which outlined priorities for the international component of the program. Additionally, the CRCP worked with each of the seven U.S. coral reef jurisdictions to develop a set of strategic coral reef management priorities and conducted capacity assessments to identify the support needed to address the identified priorities.

In 2016, the CRCP completed a second review of its science and changes were suggested to better balance existing and emerging priorities that optimize coral reef conservation outcomes as a part of its adaptive management cycle. This resulted in a new strategic plan: the CRCP Strategic Plan. The CRCP Strategic Plan focuses on improving fisheries sustainability, reducing land-based sources of pollution, addressing climate change impacts, and restoring viable coral populations. The CRCP supports activities to reach conservation goals for corals, coral recruitment habitat, key fishery taxa, and water quality. NOAA's CRCP must be implemented in accordance with legal and policy requirements. These compliance requirements generally fall into two categories: those that are necessary to meet the requirements of the CRCA as implemented by agency strategies, plans, and policies; and those necessary to meet the requirements of other NOAA mandates (e.g., ESA, MMPA, Magnuson-Stevens Fishery Conservation and Management Act, Coastal Zone Management Act, etc.) and other Federal mandates (e.g., National Historic Preservation Act, National Environmental Policy Act, etc.). While the goals and objectives of the CRCP are intended to lead to short- and long-term conservation benefits to the coral reef ecosystem, activities implementing the program to achieve conservation benefits may affect natural and cultural resources. Effects often need to be addressed through applicable regulatory processes and associated mitigation measures.

1.4 Summary of NOAA's Proposed Action

NOAA proposes to continue implementing the CRCP through coral reef conservation and restoration activities such as internal, agency-funded and executed activities and by providing financial and technical assistance to Federal, State, and local agencies, private organizations, and academic institutions. This proposed action would enable the CRCP to continue focusing its funding and activities on the conservation of coral reefs, guided by the CRCP Strategic Plan and future iterations of a programmatic strategic plan. The types of activities the CRCP anticipates implementing are described further in this document. The CRCP will continue to be implemented across multiple coral reef ecosystems located in the seven U.S. jurisdictions, the U.S. Pacific Remote Islands Marine National Monument, the Gulf of Mexico, and targeted international areas (i.e., the wider Caribbean, Coral Triangle, the South Pacific, and Micronesia). The geographic extent is depicted in Figures 1 and 2, above, and program structure and activities are described in detail in the description of the proposed action and alternatives (Sections 2.2 and 2.3). This DPEIS addresses the environmental effects of the CRCP until 2040 to align with the planning horizon of the CRCP Strategic Plan. NOAA identifies in this document a suite of conservation and restoration activities that NOAA believes will most effectively conserve and restore coral reefs, habitats, and ecosystems guided by the CRCP's foundational documents for the next couple of decades. This DPEIS evaluates the potential impacts to the human and natural environment of implementing these activities and provides a framework so that future decisions by NOAA at the project-specific level can be covered by or effectively tiered from this programmatic analysis.

1.5 Purpose and Need

1.5.1 Purpose

The purpose of the proposed action is for NOAA, though the CRCP, to effectively and efficiently conserve coral reef ecosystems and work to ensure their continued existence and sustained use for the Nation and future generations pursuant to the CRCA.

NOAA must implement the program according to the CRCA, other NOAA and Federal mandates, internal NOAA policy and guidance, and the strategic plan priorities, implementation of which may shift and evolve over time. Implementation activities identified through collaboration and coordination with partners will minimize risks, mitigate threats, and restore function to coral reef ecosystems. In sum, NOAA needs to manage the CRCP through an efficient management framework designed to ensure that maximum program funding is devoted to coral reef conservation and recovery.

1.5.2 Need

Coral reef ecosystems are rapidly declining in health globally. Widespread acute and chronic threats to coral habitats adversely affect their ecosystem functions and services. Threats, such as impacts from climate change, unsustainable fishing practices, and land-based sources of pollution alter and degrade, and in certain circumstances, lead to the mortality of coral reef ecosystems. Thus, there is an urgent need for NOAA to evaluate and implement activities to support long-term conservation and recovery of coral reef ecosystems. The vulnerability (or danger) of not acting aggressively is to risk losing, perhaps catastrophically, the globally and highly substantial ecological, societal, and economic benefits provided by coral reef ecosystems.

1.6 Scope of this Document

This DPEIS provides a programmatic-level assessment of the potential impacts of NOAA's CRCP and its implementation on the human environment, including biological and physical resources. A programmatic approach is used when initiating or reevaluating a federal program for compliance with NEPA. It takes a broad look at issues and alternatives, and provides a baseline for future management actions. Programmatic documents are often intended to ensure NEPA compliance, as well as facilitate compliance with other applicable laws and regulations such as the ESA, for management and other activities over a certain period before a formal review is again initiated. This DPEIS assesses the potential direct, indirect, and cumulative impacts of the alternatives. The chapters that follow describe the activities proposed for continued implementation of the CRCP and potential alternatives (Chapter 2), the affected environment as it currently exists (Chapter 3), and the probable direct, indirect, and cumulative impacts on the human environment that may result from the continued implementation of the proposed CRCP activities and alternatives (Chapter 4). The scope of this DPEIS covers coral reef conservation activities funded, authorized, or conducted by the CRCP that:

- Contribute to coral reef conservation in accordance with Federal statutes, Executive Orders, and NOAA strategies and policies;
- Generally take place in shallow and mesophotic marine waters of USVI, Puerto Rico, Florida, Hawaii, American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, Flower Garden Banks National Marine Sanctuary, Papahanaumokuakea Marine National Monument, the Pacific Remote Islands Marine National Monument (see Figure 1-1), and targeted international regions including the wider Caribbean, the Coral Triangle, the South Pacific, and Micronesia (see Figure 1-2);
- Involve the transiting of these waters in various-sized research vessels, the deployment of divers and instruments into the water to characterize, sample, and monitor living marine resources and their environmental conditions and conduct in-water conservation and restoration activities, and/or use active acoustic devices for navigation and remote-sensing purposes.

The program and its supported activities are described in detail in the Description of the Proposed Action (Sections 2.2 and 2.3).

The DPEIS covers both short-term and long-term environmental effects generally expected to occur as a result of implementing typical CRCP activities. This DPEIS does not cover activities other than those included in the description of the proposed action. Any information not included in this DPEIS may need to be captured in project-level, tiered NEPA documents. Therefore, some proposed activities may require further environmental impact assessments and compliance with other consultation, approval, or permitting requirements before a decision on whether to proceed is made. The analysis provided by this DPEIS is intended to support and integrate compliance with the ESA, Magnuson-Stevens Act (MSA) (pertaining to EFH), National Marine Sanctuaries Act (NMSA), Coastal Zone Management Act (CZMA), MMPA, and other applicable statutes, acknowledging that specific activities may require development of more focused and refined analyses.

This DPEIS also relies on and incorporates by reference several pre-existing NEPA documents and other relevant analyses that have considered effects of activities on coral reef ecosystems. Where the document incorporates by reference, the information incorporated is summarized and cited.

1.7 Tiering

As discussed, this DPEIS establishes a tiered environmental review process for the CRCP. Tiering refers to the coverage of general matters in broader or programmatic NEPA documents (such as national program or policy statements) with subsequent narrower statements or environmental analyses (such as regional or basin-wide program statements or, ultimately, site-specific statements) by incorporating by reference the general discussions in the broader or programmatic NEPA documents and concentrating solely on the issues specific to the statement subsequently prepared (40 C.F.R. § 1508.28). If the impacts of a site-specific action are fully covered in this DPEIS, no further NEPA review would be required, and such determination would be documented in a memorandum for the record. If the impacts are not fully covered, a project-specific NEPA review would be required. The programmatic analysis included in this DPEIS provides a comprehensive analysis of the CRCP's activities by evaluating programmatic activities and impacts, thereby allowing decision-makers to tier future project-specific analyses from the DPEIS. Tiering future project-specific analyses would reduce or eliminate duplicative documentation by focusing future project analyses, if needed, on project-specific issues. For example:

- When decision-makers review a proposed coral reef conservation project and determine that it falls within the scope of the proposed action and impacts in the DPEIS, the decision-makers may prepare a memorandum for the record in accordance with NOAA's NEPA procedures, NOAA Administrative Order 216-6A and its Companion Manual (NAO 216-6A), documenting that the impacts of the proposed action are included in the scope of the DPEIS, and proceed without further NEPA review. The criteria for making this determination are set forth in the Companion Manual at Section 5.A and include verifying that the existing analysis is valid in light of any new information or circumstances and the direct, indirect, and cumulative effects that would result from implementation of the new proposed action are similar to those analyzed in this PEIS;
- When decision-makers from another NOAA program office review a proposed action that is substantially similar to the actions evaluated in the DPEIS and determine that it falls within the scope of the proposed action and impacts in the DPEIS, the decision-makers may prepare a memorandum for the record in accordance with NOAA's NEPA procedures, NOAA Administrative Order 216-6A and its Companion Manual (NAO 216-6A), documenting that the impacts of the proposed action are included in the scope of the DPEIS, and proceed without further NEPA review;
- When decision-makers review proposed coral reef conservation activities and determine that project-specific impacts may require additional environmental analysis, they would prepare NEPA documents for the activities that tier from this DPEIS if the conditions and environmental effects described in the DPEIS are still valid and address any exceptions or additional information beyond the scope of the DPEIS;
- If a NEPA analysis for a subsequent activity differs from the analysis provided at the programmatic level (e.g., best practices that were assumed in this analysis are not incorporated as part of a proposed project), that difference would be described in the tiered NEPA analysis to indicate whether the significance of impacts differs from the significance presented in this DPEIS. If the impacts of a future project are analyzed in an EA tiered to this DPEIS, and found to be not significant, the environmental assessment would produce a Finding of No Significant Impact (FONSI) and proceed;

- If the impacts of an activity were found to be significant and/or beyond the scope of impacts disclosed in this DPEIS, those impacts would be evaluated in a tiered or independent NEPA document; and
- When decision-makers from other NOAA program offices review proposed actions to which the impacts analyses and mitigation measures evaluated in this document are relevant, they may incorporate the analyses by reference to streamline environmental review.

1.8 Scope of Environmental Resources, Impacts, and Issues

Based on coordination and consultation with internal agency subject matter experts, expert Federal and State agency staff, and other stakeholders, as well as public comments received during scoping, NOAA has identified the important environmental resources, impacts, issues, and concerns. NOAA has given these important environmental resources, impacts issues, and concerns detailed evaluation in this DPEIS. Given the nature of the CRCP and its activities, certain elements of the biological and physical environment were removed from detailed evaluation as NOAA determined that these would either not be affected by program activities or that the impacts would be negligible or discountable (Section 4.2.2). Chapter 3, which provides a detailed Description of the Affected Environment, provides an explanation of our approach. Where the CRCP decided not to carry elements of the biological and physical environment forward for detailed description and analysis, the CRCP provides a summary explanation in Chapter 4 of this document. Elements that receive no further consideration are not evaluated in the environmental impacts discussed in Chapter 4.

1.9 Public Involvement

On July 11, 2018, NOAA published a Notice of Intent (NOI) to prepare an EIS in the Federal Register 83 FR 32099. NOAA reviewed and addressed comments received in preparing this DPEIS. This DPEIS will be circulated to relevant Federal agencies and stakeholders with an interest in coral reef conservation and restoration and then filed with the Environmental Protection Agency (EPA). A Notice of Availability (NOA) will be published in the Federal Register which will initiate a 45 day public comment period. Public comments submitted during the comment period will be reviewed and appropriate responsive changes will be included in the Final PEIS. NOAA will include a chapter explaining how it addressed public comments.

1.10 Statutory/Regulatory Compliance Requirements

Pursuant to the CRCA, NOAA is the federal agency that administers the CRCP and its activities evaluated in this DPEIS. These activities may trigger a broad range of regulatory compliance processes because they may cause adverse impacts to public trust resources that are regulated by various statutes. Table 1-1 presents a brief summary of some of these applicable laws. This information is provided to aid the reader in understanding the material presented later in the DPEIS and is not intended to be a complete listing of all statues, orders, or regulations applicable to the proposed action and alternatives. All activities will be reviewed to determine whether other statutory compliance requirements are triggered, and compliance would occur on a case-by-case basis as necessary (Devaney Memo, 2014; Friedman Memo, 2017).

Table 1-1. Primary Laws Applicable to the CRCP

Law	Summary of Law
Coral Reef Conservation Act of 2000 (CRCA)	The purpose of the CRCA is to: (1) preserve, sustain, and restore the condition of coral reef ecosystems; (2) promote the wise management and sustainable use of coral reef ecosystems to benefit local communities and the Nation; (3) develop sound scientific information on the condition of coral reef ecosystems. and the threats to such ecosystems; (4) assist in the preservation of coral reefs by supporting conservation programs, including projects that involve affected local communities and nongovernmental organizations; (5) provide financial resources for those programs and projects; and (6) establish a formal mechanism for collecting and allocating monetary donations from the private sector to be used for coral reef conservation projects.
Marine Mammal Protection Act (MMPA)	The MMPA protects all marine mammals, including cetaceans (i.e., whales, dolphins, and porpoises), pinnipeds (i.e., seals and sea lions), sirenians (i.e., manatees and dugongs), sea otters, and polar bears within the waters of the U.S. The MMPA requires that an incidental take authorization be obtained for the unintentional "take" of marine mammals incidental to activities.
Endangered Species Act (ESA)	The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. Under the ESA, species may be listed as either endangered or threatened. "Endangered" refers to a species that is in danger of extinction throughout all or a significant portion of its range. "Threatened" refers to a species that is likely to become endangered within the foreseeable future. ESA also provides for the designation and protection of critical habitat, specific geographic area(s) that contains features essential to the conservation of a threatened or endangered species. Section 7 (a)(2) requires the agencies, through consultation with the U.S. Fish and Wildlife Service or the NMFS, to ensure their activities are not likely to jeopardize the continued existence of listed species, or destroy or adversely modify their critical habitat.
Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act or MSA)	The MSA is the primary law governing marine fisheries management in U.S. federal waters. First passed in 1976, the MSA fosters long-term biological and economic sustainability of our nation's marine fisheries out to 200 nautical miles from shore. Key objectives of the MSA are to (1) prevent overfishing, (2) rebuild overfished stocks, (3) increase long-term economic and social benefits, (4) use reliable data and sound science, (5) conserve essential fish habitat (under the 1996 amendment Sustainable Fisheries Act), and (6) ensure a safe and sustainable supply of seafood. The MSA includes provisions concerning the identification and conservation of Essential Fish Habitat (EFH),

	which is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS, and NMFS must provide conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH.
The National Marine Sanctuaries Act (NMSA)	The NMSA authorizes the Secretary of Commerce to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or esthetic qualities as national marine sanctuaries. Section 304(d) Act requires interagency consultation between NOAA and federal agencies taking "likely to injure" a sanctuary resource. A permit or other approval is required to conduct an activity within a sanctuary that is otherwise prohibited.
Coastal Zone Management Act (CZMA)	The CZMA provides for the management of the nation's coastal resources, including the Great Lakes. The goal is to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone." The CZMA requires that federal actions which have reasonably foreseeable effects on any coastal use (land or water) or natural resource of the coastal zone be consistent with the enforceable policies of a state's federally approved coastal management program.
National Historic Preservation Act (NHPA)	The NHPA requires Federal agencies to take into account the effects of their undertakings, such as construction projects, on properties covered by the NHPA, such as historic properties, properties eligible for listing on the National Register of Historic Places, or properties that an Indian Tribe regards as having religious and/or cultural importance.
Clean Water Act (CWA)	The CWA regulates surface water quality in states, territories, and authorized tribal lands. Under Section 404 of the CWA, the U.S. Army Corps of Engineers requires that an interested party obtain a permit before filling, constructing on, or altering a jurisdictional wetland (33 U.S.C § 1344).
Fish and Wildlife Coordination Act	The Fish and Wildlife Coordination Act requires that federal agencies consult with the USFWS, the NMFS, and State agencies for activities that affect, control or modify waters of any stream or bodies of water, in order to minimize the adverse impacts of such actions on fish and wildlife resources and habitat.

2. DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

2.1 Proposed Action

Pursuant to the CRCA, NOAA proposes to continue implementing the CRCP activities in order "to preserve, sustain, and restore the condition of coral reef ecosystems; to promote the wise management and sustainable use of coral reef ecosystems to benefit local communities and the Nation; and to develop sound scientific information on the condition of coral reef ecosystems and the threats to these ecosystems." The CRCP Strategic Plan focuses CRCP's efforts to ensure compliance with the CRCA. The CRCP Strategic Plan includes four areas of work, which are described below in Section 2.2. Section 2.3 describes the activities the CRCP conducts in furtherance of these four areas of work. The existing CRCP framework, which consists of external grants, contracts, and internal funding for NOAA programs and offices, supports these coral reef conservation activities**.** This DPEIS includes a description of the proposed action appropriate to the programmatic decision being made. It, therefore, does not describe the number, scale, and location of projects as decisions regarding funding and project proposal, approval, and implementation vary over time. Rather, the description of the proposed action clearly describes the component activities that would predictably be implemented over time and the jurisdictions in which the program is implemented. Therefore, the description is qualitative, not quantitative. Chapter 3 describes the current condition of the resources in which these activities would likely be implemented, and Chapter 4 predicts the types of impacts that could occur as a result of implementing the described activities. This approach is programmatic and provides sufficient information to predict the general impacts anticipated from implemtnation of the CRCP. Project-specific impacts, as explained below, will be evaluated, as necessary on a case-by-case basis where the specific parameters of the scope and scale of each proposed action would be clearly described. Describing the proposed action in this way provides a foundation to properly evaluate the context and intensity of impacts at a programmatic scale.

The types of activities the CRCP anticipates implementing are described further in Chapter 2.3 of this document, but include these five categories of activities:

- Monitoring, mapping, and research (e.g., scuba surveys, use of underwater autonomous vehicles, coral sampling, fish sampling and tagging, and bathymetric echosounders);
- Coral restoration and interventions (e.g., coral nursery and outplanting, removal of invasive and nuisance species, and addressing coral disease);
- Watershed management and restoration (e.g., small-scale construction projects designed to minimize sediment and pollutant runoff to coral habitats, such as restoring vegetative cover and use of, rain gardens, culvert repair, stream bank stabilization, retention ponds, or constructed wetlands);
- Reduction of physical impacts to coral reef ecosystems (e.g., buoy installation and marine debris removal); and
- Outreach/education and program operations.

2.2 Overview of the CRCP Strategic Plan

The CRCP Strategic Plan focuses efforts on four areas of work, which are supported through cross-cutting functions. These four areas are improving fisheries sustainability, reducing land-based sources of pollution, increasing resilience to climate change impacts, and restoring viable coral populations. The cross-cutting functions of the CRCP include research, mapping, monitoring, social science, communications, and capacity building. Domestically, the CRCP supports on-the-ground and in-the-water actions (described in Section 2.3, below) to meet the Strategic Plans's goals and objectives and to conserve coral reef ecosystems through resilience-based management in the seven U.S. coral reef jurisdictions. Internationally, the CRCP focuses its support and effort on capacity building under four focus areas: (1) working with regional initiatives to build marine protected area networks and strengthen local management capacity to improve and maintain resilience of coral reef ecosystems and the human communities that depend on them; (2) developing and implementing tools and practices to more effectively observe, predict, communicate, and manage climate change; (3) strengthening local and national capacity and policy frameworks to reduce impacts of fishing on coral reef ecosystems; and (4) strengthening policy frameworks and institutional capacities to reduce impacts to coral reef ecosystems from pollution due to land-based activities.

2.2.1 Improve Fisheries Sustainability

To improve fisheries sustainability, the CRCP is working closely with the fisheries management agencies of the seven states and territories, four regional fishery management councils, as well as NOAA Fisheries to support sustainable coral reef fisheries in U.S. waters. Sustainable fisheries management also depends on the engagement and cooperation of fishers, local communities, and other key stakeholders, which the CRCP helps facilitate. U.S. fisheries management is a model for the world and best practices will be shared to build capacity for sustainable management in foreign governments located within the four regions that are connected to U.S. coral reef ecosystems. The CRCP focuses on advancing ecosystem-based approaches and improving essential data collection and capacity building activities to support the effective use of existing coral reef fisheries management and enforcement tools.

This will be accomplished by:

- Focusing on key fishery taxa that are ecologically important for reef conditions and particularly vulnerable to overfishing;
- Filling priority data gaps for fisheries' managers, aiming to better understand ecological sustainability for coral reef ecosystems, and promptly delivering data and results;
- Connecting management partners with successful tools and strategies for adaptive management and sufficient enforcement and compliance; and
- Improving the way CRCP works, including increasing comparability and sharing of data, engaging more partners, and developing more effective communication products.

2.2.2 Reduce Land-Based Sources of Pollution

The second area of focus is reducing land-based sources of pollution such as sediment, nutrients, and other pollutants transported in surface waters, runoff, groundwater seepage, and atmospheric deposition into coastal waters that degrade water quality. The health of U.S. coral reef ecosystems depends on effective management of land-based activities in adjacent coastal and upland regions. The CRCP utilizes an integrated watershed management approach that includes comprehensive management plans to identify sources, baseline characterizations to understand the full suite of impacts, prioritized management responses, and detailed plans regarding partner roles and responsibilities. The CRCP continues to support the installation of stormwater control BMPs and provides technical assistance to support performance monitoring and assessments. The CRCP also supports capacity building and multilateral coordination to advance watershed management efforts within the U.S. jurisdictions and, to a limited extent, internationally.

2.2.3 Increase Resilience to Climate Change

The third area of work addresses the impacts of climate change, including ocean acidification, on coral reef ecosystems, emphasizing a conservation approach that focuses on resilience-based management. Resilience refers to the capacity of a system to resist and recover from disturbance, and maintain structure and function to provide ecosystem services. Resilience-based management has recently been adopted as an effective approach for integrating climate change considerations into coral reef management by several international and domestic partners. As part of this effort, the CRCP is focusing on three concepts: (1) providing an understanding of past and present impacts, and projecting future impacts to coral reefs caused by climate change and associated responses such as coral bleaching; (2) assessing and understanding likely social and ecological responses to climate change; and (3) supporting the identification and prioritization of management actions to support ecosystem resilience and human well-being.

2.2.4 Restoring Viable Coral Populations

The fourth area of work is focused on maintaining and restoring viable, functioning coral reef ecosystems. To achieve this, the CRCP is implementing a multi-prong approach that addresses local stressors such as invasive species and anchoring impacts, while simultaneously repopulating key reefs. The CRCP supports research, on-the-ground actions to prevent additional losses of corals and their habitat, and coral restoration using intervention techniques (e.g., stress hardening and assisted gene flow) to create resilient, genetically diverse, and reproductively viable populations of key coral species. These intervention techniques are expected to facilitate the adaptation of coral reef ecosystems to evolving environmental conditions. Additionally, the CRCP will improve the use of regulatory mandates to prevent loss of coral and coral reef habitat through supporting technical knowledge transfer to permitting agencies, encouraging consistent use of BMPs, and informing mitigation options with appropriate restoration techniques.

2.2.5 Cross-Cutting Functions

In addition to the four areas of focus, the CRCP supports cross-cutting functions, including research, mapping, monitoring, social science, communications, and capacity building at a national and international scale. The CRCP:

- Supports topic-based research needs identified within the areas of work to meet our objectives and long-term conservation goals.
- Maps coral reefs throughout the seven jurisdictions for multiple purposes.
- Continues to implement the National Coral Reef Monitoring Program. This program documents and identifies the status and trends of U.S. coral reef ecosystems to provide an ecosystem perspective to support informed conservation and management via monitoring fish, benthic, climate, and socioeconomic variables in a consistent and integrated manner.

Historically, the National Coral Reef Mondiotining Program activities in the U.S. Pacific (American Samoa and U.S. Remote Pacific Island Areas, Mariana Archipelago (Guam and the Commonwealth of the Northern Mariana Islands, and Main Hawaiian Islands) occur on a triannual rotation. The Caribbean activities have taken place biannually rotating between Puerto Rico and U.S. Virgin Islands, and the activities in Florida take place every other year.

- Aims to apply advanced social science approaches, particularly the combination of bio-physical and human dimensions (social and economic) research to identify results and outcomes that will better inform decision-making and policy for coral reef conservation.
- Recognizes the value of an informed and engaged public, empowered to act for coral reef ecosystem conservation. The CRCP conducts outreach efforts and will utilize new, innovative tools to increase awareness and stewardship of coral reef ecosystem resources.
- Builds capacity by providing science for management support and by transferring knowledge among international and domestic partners.

2.3 CRCP Activities to Support the Strategic Plan

In order to meet the goals and objectives outlined in the Strategic Plan, the CRCP conducts monitoring, mapping, research, restoration, and outreach and education. This includes the broad-scale coral reef monitoring, which documents the status and trends of U.S. coral reef ecosystems and provides an ecosystem perspective to support informed conservation and management. Table 2-1 depicts how the activities listed below are mapped to the focus areas of the CRCP Strategic Plan.

Table 2-1. Implemented activities under the CRCP mapped to focus areas in the strategic plan

Activity	**CRCP Areas of Focus**			
	Improve Fisheries Sustainability	**Address Land-based Sources of Pollution**	**Address Climate Change**	**Restore Viable Coral Populations**
Monitoring, Mapping, and Research				
Biological Monitoring				
SCUBA and/or Snorkel Surveys	**X**	**X**	**X**	**X**
Stationary Cameras	**X**	**--**	**--**	**X**
Fisheries Monitoring and Detection Using Echosounder	**X**	**--**	**--**	**X**
Geological and Oceanographic Monitoring				
Moored Instruments, and Water Quality Monitoring	**X**	**X**	**X**	**X**
Antifouling and Lubricants for Instruments	**X**	**--**	**X**	**--**
Drifters	**X**	**--**	**X**	**X**
Automated Underwater Vehicles and Remotely Operated Vehicles	**X**	**--**	**X**	**--**
Marine Sediment Monitoring	**X**	**--**	**X**	**--**
Terrestrial Sediment Monitoring	**X**	**X**	**X**	**--**
Socioeconomic Monitoring	**X**	**X**	**X**	**X**
Coral Reef Mapping				
In-water Echosounder	**X**	**--**	**X**	**--**
Aerial	**X**	**X**	**X**	**X**
Satellite	**--**	**X**	**X**	**X**
Common Research Activities				

Tagging				
Fish	**X**	**--**	**--**	**--**
Shark	**X**	**--**	**--**	**--**
Corals	**--**	**--**	**X**	**X**
Collection of biological samples				
Coral	**--**	**X**	**X**	**X**
Fish and Other Invertebrates	**X**	**--**	**--**	**--**
Algae/Seagrass	**--**	**X**	**X**	**X**
Coral Restoration and Interventions				
Coral Restoration				
In-situ Nursery Development/ Enhancement	**--**	**--**	**--**	**X**
Nursery Maintenance	**--**	**--**	**--**	**X**
Coral Transplantation	**--**	**--**	**--**	**X**
Other Coral Interventions				
Urchin Propagation and Outplanting	**--**	**--**	**--**	**X**
Invasive and Nuisance Algae Control/Removal	**--**	**--**	**--**	**X**
Corallivore Control	**--**	**--**	**--**	**X**
Coral Disease Control	**--**	**--**	**--**	**X**
Coral Genomics, Stress Hardening, and Survival Analysis	**--**	**--**	**--**	**X**
Potential Future Coral Intervention Activities	**--**	**--**	**--**	**X**
Watershed Management and Restoration				

Technical Support for Watershed Management Plans	--	X	--	--
Vegetative Planting	--	X	--	--
Unpaved Road/Trail Stabilization	--	X	--	--
Stormwater Control Best Management Practices				
Bioretention Cells (Rain Gardens)	--	X	--	--
Baffle Boxes	--	X	--	--
Culvert Repair or Replacement	--	X	--	--
Curb/Grate Inlet Basket (with Filter)	--	X	--	--
Swale	--	X	--	--
Stormwater Pond/Sediment Basins	--	X	--	--
Constructed Wetlands	--	X	--	--
Low Impact Development	--	X	--	--
Streambank and Ghut Stabilization	--	X	--	--
Fencing	--	X	--	--
Elevated Boardwalks and Delimitation of Sensitive Areas	--	X	--	--
Reduce Physical Impacts to Coral Reef Ecosystems				
Boat Mooring Buoy Installation				
Recreational/Day Use Moorings	--	--	--	X
Storm Buoys	--	--	--	X
Marker Buoys	--	--	--	X
Debris Removal	--	--	--	X
Outreach/Education and Program Operations				

Outreach/Education				
Signage	**X**	**--**	**--**	**X**
In-situ Education Activities	**X**	**X**	**X**	**X**
Other Outreach Activities	**X**	**X**	**X**	**X**
Data Analysis and Modeling	**X**	**X**	**X**	**X**
Program and Interagency Coordination/Administration	**X**	**X**	**X**	**X**
Operational Activities (Vessels)	**X**	**X**	**X**	**X**

2.3.1 Monitoring, Mapping, and Research

The CRCP supports monitoring, mapping, and, research by supporting NOAA offices and programs and through its external grant program. This section describes these techniques in general terms, but for more information on the CRCP's current and historic monitoring efforts, see https://www.coris.noaa.gov/monitoring/.

2.3.1.1 Biological monitoring

Biological monitoring is the collection of observations related to biological indicators of coral reef ecosystem health. These indicators can include diversity, abundance, size, distribution, and habitat composition and complexity of benthic species, reef fish, and other motile invertebrates diversity, distribution, abundance, and size. These biological data are collected through different types of self-contained underwater breathing apparatus (SCUBA) diver/snorkeler-based, visual or photographic surveys or though the placement of cameras in strategic locations to collect images over a period of time.

SCUBA and/or Snorkel Surveys

Biological monitoring of coral reef ecosystems involving divers using in-water techniques (e.g., SCUBA and snorkel surveys) includes techniques such as roving surveys, stationary point counts, radial surveys, towed diver surveys, and belt transect surveys. These techniques are conducted in shallow-water coral reef and mesophotic ecosystems. For roving surveys, the diver/snorkeler hovers above the reef or swims along a predefined path and records the selected species on an underwater data sheet and/or with photographic/video documentation; diver contact with the bottom is rarely made. For stationary point counts, divers can stand or kneel in a particular area, preferably in sandy patches, as hovering may cause the fish community to remain low in the substrate hindering effective countability. Divers conducting radial surveys temporarily place a weighted (2-9 lb of dive weights tied together with a size about 10 cm x 15 cm [4 in x 6 in]) buoyed line (1-2m [3-6.5 ft] high) in an area that does not have live coral and then attach a 10 m (~33 ft) line to the top of the buoy. One diver swims the line out to its full extent and holds the end of the line for the survey; the divers constantly tend the line and move it over any areas of higher relief and return to the desired depth once over the higher relief area. This allows for the same distance from the center to be maintained even if the depth changes. The other diver "mans" the line at the midpoint, keeping it from snagging on the bottom, as they swim slowly around in a circle. Towed diver surveys (Figure 2-1) involve a boat towing divers, who visually collect information on the benthos and fish population while maintaining a certain height above contour of the reef. Belt transects (Figure 2-2) involve the deployment of lightweight fiberglass tapes. The organisms of interest are examined in a belt (a predetermined width on either side of and depth above the line), directly under the tape, or at certain points along the tape. Heavy-duty metal reels are placed on hard, non-living substrate or in sand to anchor one end of the line, while a lead weight anchors the other end. Once the weighted end is in place, researchers either deploy the tape prior to conducting the survey or count fish while swimming along the selected deployment path. The tape is used solely as a guide to determine the area of examination. In general, these surveys involve temporary deployment of the transect tape in a line parallel or perpendicular to depth gradients. The tapes, metal reels, and lead weights are removed from the reef once the transect observations are complete.


Figure 2-1. Two towed divers conducting coral reef surveys. (left) *Source: NOAA*
Figure 2-2. A diver laying out a measured transect line. (right) *Source: NOAA*

Additional monitoring techniques involve the temporary deployment of quadrats and light chains. Quadrats (i.e., polyvinyl chloride [PVC] or hollow aluminum squares of various sizes that may be subdivided into smaller areas by a grid) are laid randomly or at certain points along a transect tape, and the organisms are assessed within the quadrat. Most quadrats are made up of PVC pipe (Figure 2-3). Chains are generally brass or stainless steel, with very small links (e.g., a few mm to cm width) and are used to assess the rugosity (bathymetric relief) of the reef (Figure 2-4). These chains are deployed along the bottom similar to a transect tape, but unlike the transect tape, the chain follows the contour of the reef.


Figure 2-3. Diver conducting a temporary quadrat survey. (left) *Source: Kelli O'Donnell*
Figure 2-4. A weighted rugosity line. (right) *Source: Kelli O'Donnell*

For repeated surveys at fixed sites (permanent transects), researchers often mark the bottom with pins or other permanent landmarks secured in hard ground, rubble, or sediment areas where they will not impact living corals (Figures 2-5 and 2-6). The most permanent pins are rebar or stainless steel rods or pins (0.63-2.54 cm [0.25-1 in] diameter) and are either driven into the seabed by divers using hand-held hammers, or inserted into a hole (1.9-3.2 cm [0.75-1.25 in] diameter) in the seabed created by divers using a pneumatic drill. These holes may be filled with a marine epoxy to hold the pin in place. To assist with relocating the markers, the pins may also be marked with small floats on stainless steel leaders, and labeled with a tag.

Figure 2-5. A permanent transect marker is hammered into place in American Samoa.
Source: American Samoa Coral Reef Ecosystem Monitoring Program

Figure 2-6. A permanent transect marker with small float on a reef.
Source: The Nature Conservancy

During various monitoring activities to measure growth or spread of disease, divers used hand-placed calipers or flexible tapes. Hand-placed calipers and flexible transect tapes used for measuring and video monitoring purposes remain in contact with small portions of coral colonies for brief periods lasting 30 minutes or less.

Stationary Cameras (Not Moored to Seafloor)

Stationary cameras are designed to sample the distribution, relative abundance, and size composition of reef fish and associated characteristics of their habitat. One type of system can be deployed with weights that hold the camera at depth for a predetermined amount of time (30-60 min). The majority of stationary cameras are buoyed to the surface so the entire device can be recovered. A few systems are baited to attract fish, while other systems are passive. Another method involves temporarily securing small cameras, such as GoPro™ cameras, to non-living components of the reef using zip ties.

Fisheries Monitoring and Detection Using Echosounder

Fish spawning aggregations are commonly located with echosounder equipment; the CRCP incorporates by reference the activities described in Section 9 of Appendix A and Chapter 4.2.4 to 3.1.1 and 3.1.1.1 of the Draft Programmatic Environmental Assessment for Fisheries and Ecosystem Research Conducted and Funded by the Southeast Fisheries Science Center (SEFSC, 2016). This equipment generates sounds at frequencies between 12-300 kHz. The relatively low power echosounders are directed at the water column or the seabed directly beneath the vessel. For example, the CRCP has supported activities on the R/V Nancy Foster that have used the Kongsberg/Simrad EK60 split-beam echosounder operating at frequencies of 38, 120, and 200 kHz. When in use, the power is set to the lowest possible level, nominally 200 dB re: 1 PA, with a duty cycle of less than 10 Hz. Beam is maintained at less than 12 degree angle, which focuses the sound downward, with a small beam width.

2.3.1.2 Geological and Oceanographic Monitoring

Geological and oceanographic monitoring includes the analysis of chemistry/nutrients, water temperature, ambient sound level, ocean circulation, sedimentation, and pollution data to understand long-term natural processes and their effects on coral ecosystems and the analysis of episodic storms and other high energy events to understand their short-term impacts. Many of these analyses involve the use of temporarily moored instruments to passively collect data or the physical collection of samples for laboratory analysis.

Instruments Moored to the Seafloor

Moored instruments are typically deployed to passively measure oceanographic parameters at specific locations. Moored instruments may include cameras, wave and tide recorders, acoustic Doppler current profilers, salinity sensors, ecological acoustic recorders, fish acoustic tag receivers, subsurface temperature recorders, water samplers, carbon dioxide and pH sensors, sea-surface temperature recorders, bioerosion monitoring units (blocks of calcium carbonate), calcification accretion units, Coral Reef Early Warning System buoys, Moored Autonomous $p\mathrm{CO_2}$ buoys, autonomous reef monitoring structures, and subsurface ocean data platforms (Figures 2-7 and 2-8). These instruments passively collect information about water velocity and level, salinity, carbonate chemistry, natural ocean sounds, temperature, wind speed and direction, and light penetration. Many of these automated sensors are temporarily deployed by divers and are retrieved at a later time (hours to days to months up to 12 months); however, some instruments can be left for longer periods (years) or permanently, which requires periodic (i.e. monthly, quarterly, annual or biannual) maintenance (i.e., battery changes and sensor cleaning), retrieval, or replacement by divers. Divers conduct light cleaning *in-situ* using cloths to wipe off sensors. Those instruments that require more extensive cleaning are brought to land or aboard a ship to be cleaned. When an instrument is replaced, the new instrument is placed on the same footprint as the instrument that was removed.

In some cases, sensors are held in place by anchors composed of concrete, cement block, metal, or manufactured anchors, such as modular anchor for underwater instruments (MAUI) anchors. In other cases, sensors are cable-tied to stainless steel poles or to “sand anchors” screwed into the nonliving bottom, including non-living reef, rubble, or sand, or to mangrove prop roots. MAUI anchors are fabricated from metal and are encapsulated by a thick layer of polyurethane (e.g., Rhino Liner™) or PVC can also be used to hold instruments in place. A common metal used in anchor blocks is lead, because of its high density. Anchors typically weigh between 5 and 1200 lbs (2.2 and 544 kg, respectively) with a maximum seabed footprint of 91.44 cm x 121.92 cm (3 ft x 4 ft). The largest MAUI anchors that the CRCP uses in the Pacific are 400 lbs (181 kg) with a 91.44 cm x 30.48 cm (3 ft x 1 ft) footprint. In shallower water, divers place the anchors on the seabed. Anchors weighing more than a few pounds are lowered using lift bags so they can be precisely located on the seabed. While the anchors may support more than one type of instrument, they are not typically deployed close together and are usually deployed on separate sides of an island or embayment. Divers inspect, recover, service, and replace instruments used for long-term monitoring. During the inspections, anchors are replaced, if needed. Some sensors may have small floats to hold them up right.

Figure 2-7. Short-term and long-term moored instruments deployed at Jarvis Island by the NOAA Pacific Islands Fisheries Science Center. The yellow crates are the temporary deployment (1-3 days) of water sampling units) and the CTD and pH sensors (in the metal cage). The Calcification Accretion Unit and an Autonomous Reef Monitoring Structure (the square structures) towards the right in the photo are the longer-term deployments (~3 yrs). *Source: NOAA Pacific Island Fisheries Science Cetner*

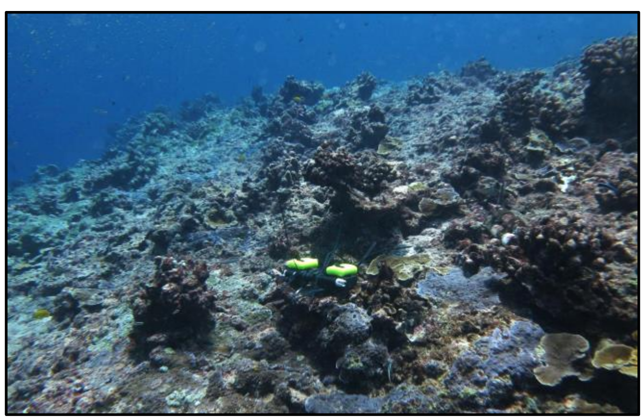

Figure 2-8. A subsurface temperature recorder (STR) zip-tied to the reef in the Pacific. This is also deployed for ~3 years*. Source: NOAA Pacific Island Fisheries Science Center*

The Coral Reef Early Warning System (CREWS) Network is a collection of marine environmental monitoring buoys (Figure 2-9). The buoys are Nexsens Model CB-950 with instruments chosen to measure certain environmental variables. The target depth range for the buoy anchor placement is approximately 9 m (30 ft) to 15 m (50 ft). To install the inverted U-anchor, divers use a core barrel drill to make two 6.4 cm (2.5 in) wide, 61 cm (2 ft) deep holes that are 30.5 cm (12 in) apart into the ocean bottom (dead coral of many years) in which stainless steel pins are inserted and surrounded by cement. When drilling, divers use a non-petroleum, vegetable based hydraulic oil, and reduced-weight, non-conductive hydraulic hoses to reduce hose sagging onto the bottom. The inverted U-anchor is cemented into the drilled holes and allowed to harden for five days before the installation of the surface buoy. The buoy installation involves pulling the buoy out by small boat, then attaching mooring lines, stretch-capable StormSoft™ lines attached to nylon lines-plus-chain near the ocean surface, to the two stainless steel pins on the bottom. This gives the buoys the capacity to move with the tide, as well as with large waves. The anchor pins have a very high tensile strength - up to 10,000 lb (4,536 kg)- and are unlikely to be pulled out by movement of the buoys. Local environmental management agency divers clean the buoyed sensors every two weeks using sponges.

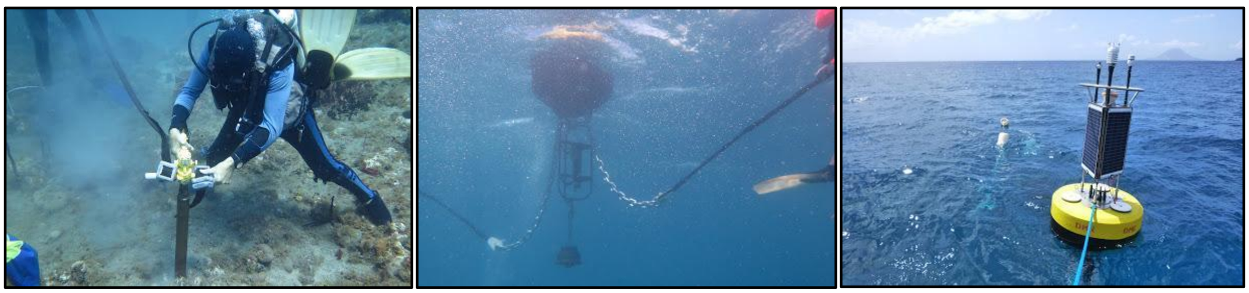

Figure 2-9. CREWS buoy installation. Left: The core barrel drill; Center: Buoy before attachment underneath the water; Right: buoy above water. *Source: NOAA Atlantic Oceanographic and Meteorological Laboratory*

Antifouling and Anti-corrosion agents

Some CRCP-supported projects use a petroleum-based lubricant and sealant that is compounded specifically to cling to metal and other surfaces, to provide long-term lubrication and prevent corrosion or rust on instruments. Lubricants seal out water and contaminants. The lubricant is particularly effective on bearings, water pumps, O-rings, gaskets, water filters, motors, and valves that must operate in hot or cold water, along seams, exposed to pool chemicals, or in salt water. Aqua Shield™ is applied to the moving metal parts (nuts and bolts) in moorings to prevent seizing and allows for functional use of the part during instrument replacement. Aqua Shield™ is insoluble, floats on water, and does not appear to degrade in salt water as instruments collected after deployment appear to have the same amount of Aqua Shield™ as when deployed years prior. Currently, ecological testing has not occurred on this product. When used in CRCP activities, only a small amount (< 1 oz [29 ml]) is applied to deployed instruments.

Drifters and Floats

The CRCP occasionally supports the use of drifters and floats to study ocean currents and eddies and verify satellite data. This information can be used in a variety of models such as those used to predict larval connectivity and dispersal or hydrodynamic connections between coral reef marine protected areas.

Drifters or floats typically have three to four major components: (1) body, (2) sails, (3) floats, and (4) a data collection/transmitter package. They can be made of non-biodegradable components such as plastic tubes and cloth or vinyl sails or made of biodegradable materials such as wood, hemp cloth, and rope. The collection/transmitter package tracks movement using a global positioning system (GPS) and may also collect other data such as surface temperature, salinity, wind speed, or other ocean properties. These shallow-water drifters are typically deployed from boats/ships and passively move with the currents for a period of time, days/weeks to indefinitely.

Automated Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs)

The CRCP occasionally supports the use of AUVs and ROVs. AUVs are programmed to follow a course of action, and ROVs are tethered to the ship and are under the active control of ship-based operators and observers.

The CRCP has supported and may support the use of AUVs, such as Slocum gliders. Past CRCP activities have included the deployment of gliders from NOAA vessels. The CRCP incorporates by reference this activity as described in Section 2.14 of the Environmental Assessment for National Center for Coastal Ocean Science (NCCOS) Surveying and Mapping Cruise Activities in Puerto Rico and the United States Virgin Islands (USVI) for April 5-26, 2016 (NOAA, 2016a) and Section 3.1.8.3 of the of the OCS PEA (2013), which provides a general description of AUVs used in survey activities.

ROVs are used for delineation and identification of seafloor habitats. Observers controlling ROVs monitor the vehicles during their deployment. ROVs are tethered to the boat and are lowered by a power winch into depths of 10-150 m. ROVs operate approximately 1 m above the seafloor along a predetermined transect for a set duration, which is controlled/maintained by an operator using thrusters. The ROV and ship speed is typically 0.5-1 kts during ROV deployments. The ship operates only using Z-drives (no propellers) during ROV deployment. The ROV provides real-time video display, navigation, and depths. When using a ROV the operator can maintain the height above the seabed by controlling the amount of tether deployed from the ship. Small ROVs may be launched by hand from shore or small boats. These small units will be used for small-scale exploration and site documentation and may also be used to collect water quality data.

Water Quality Monitoring

Water samples are used to collect information about vertical salinity, temperature structure, chlorophyll-*a*, nutrients, microbes, microscopic biota, carbonate chemistry, and contaminants. Monitoring of water quality involves the collection of seawater samples at various depths and locations either from a boat using a deployment water sample bottle using a line or a diver to collect samples from a certain depth. Depth casts from a boat collect water samples at various intervals and provide information about vertical salinity and temperature structure of the water column. The amount of water collected varies based on the intended analysis and typically ranges from 100 mL (3.38 oz) to 5 L (1.32 gallons) per sample.

In-Water Sediment Monitoring

Marine sediment samples are used to quantify chemical contaminants in the sediments, toxicity of those sediments, and identification of benthic infaunal community. Collected sediments are analyzed in laboratory settings for grain size, mineral makeup, and/or contaminants. Sediments are collected using a variety of methods depending on layer of sediment targeted, surface, subsurface, or level of disturbance. Surface sediments are generally collected using grabs, which are deployed from the water surface, or by hand using a shovel or trowel. Subsurface sediments are generally collected with gravity corers and hand corers. For hand corers, a diver may push the core to the desired depth in soft sediment or use the metal cap and hammer to drive the core into firmer sediment. Sediment pore-waters are sometimes collected to characterize nutrient and/or carbonate chemistry dynamics, as well as measure potentially harmful toxins and contaminants. Small wells are placed within sediments to known depths, and interstitial waters are removed, either by submersible pump or suction, after wells have equilibrated with sediment pore waters (several hours to days).

The assessment of the accumulation of terrestrial-based sediments and resuspended marine sediments on the coral reef ecosystems can be measured using multiple techniques including: bulk optic instruments (transmissometers and nephelometers), data loggers, sediment traps, sediment pods, tiles, and probing a stainless steel ruler through the sediment. Bulk optic instruments are used to determine water clarity and estimate suspended sediment concentrations. Data loggers are deployed to measure turbidity over varied time periods to track changes in sedimentation over time. In-water sediment traps are containers deployed in the water column for the purpose of (a) acquiring a representative sample of the material settling vertically through the water column and (b) providing an integrated particle collection rate and particle properties over the time of deployment. Each of these techniques requires temporary (1-24 months) deployment of equipment (traps, pods, instruments) in soft sediments near or in coral reefs, seagrass beds, and/or stream mouths. Sediment traps are commonly made from PVC drain pipes (between 1-10 inches wide and 2-30 inches in length) closed at one end and attached to a length of rebar that is driven into the sediments. Sediment pods are typically made from cement-filled large PVC irrigation pipes (6-20 inches in diameter and 8-10 inches in length) with metal eye bolts screwed into the sides. Sediment pods and other instruments can be weighed down with cinder blocks or other weighted bases or held into place using rebar driven into soft sediments. The optic instruments and data loggers can be deployed along with the sediment tubes or pods and are also secured to the rebar, using the mooring methods described above (Section 2.3.2.1), or by attaching the instruments to existing structures (e.g., docks or bridges).

Terrestrial Sediment Monitoring

Loads of terrestrial sediment are estimated using a variety of methods often including erosion control pins, sediment traps, flumes/weir, water level data loggers, turbidity meters, and/or peak crest gages. Erosion control pins and similar methods measure the vertical erosion or accretion of sediment in specific locations, which can then be multiplied over a large area to provide a crude estimate of mass sediment eroded or accreted. Sediment traps are placed downgrade of bare soils or restoration actions to quantify sediment mass collected at these sites to understand contributions from the land cover/use. These traps are designed to accommodate the conditions of the site and come in various forms. Depending on the type of sediment trap used, it may require digging a small trench or installing silt fencing to collect the sediment. Flumes and weirs are also used to funnel surface runoff and sediments into a concentrated area to quantify the volume of runoff and the amount of sediment that may be eroded from drainage areas. Each of these techniques requires temporary deployment of equipment, which may also be accompanied by minor construction (impacting a small areas 1-8 cm [0.5-3 in]) to install the equipment (e.g., flume/weir, sediment trap). Placement of flume and weirs are site specific; in some cases they are placed on roads and other times in streams. Typically, they are installed on land, never in nearshore habitats, which may or may not be within the coastal zone. Water level data loggers, turbidity meters, and peak crest gages are installed to provide an understanding of the volume and rate of storm flows and sedimentation in streams. Deployment often includes the temporary installation of a PVC casing to either house the data logger or used to quantify peak stage in a stream. The equipment is then removed following completion of the study (typically within a year).

2.3.1.3 Socioeconomic Monitoring

Various methods are used to collect information from coral reef stakeholders including specific users and the general public. This involves the collection of socioeconomic variables, including demographics in coral reef areas, human use of coral reef resources, as well as knowledge, attitudes, and perceptions of coral reefs and coral reef management. Some of these methods include resident surveys (primary data collection) in U.S. coral reef jurisdictions. Other data collection approaches may include the collation of information (secondary data collection) from the U.S. Census Bureau and Bureau of Economic Statistics on coral reef-related economic activities.

2.3.1.4 Coral Reef Mapping

The CRCP continues to map U.S. coral reef resources, which supports the CRCP's efforts to manage and monitor coral reef ecosystems. To map U.S. coral reefs, the CRCP uses remote sensing (aerial and satellite imagery), multibeam echosounders, and side-scan echosounder. Divers or ROVs are used to ground truth the information and to assist in the characterization of benthic habitats. This information is then used to develop maps.

In-Water Echosounder Mapping

Some reef environments are characterized and mapped using a multibeam echosounder and backscatter system and/or towed side-scan echosounder. Multibeam and side-scan echosounder systems are attached to the research vessel and do not contact the benthos or any of the attached organisms. Ship-based multibeam echosounders collect bathymetric and acoustic imagery in depths 0 to 3,000 m (1.86 mi). The specifications described below and the activities to be conducted are also incorporated by reference from Section 3.1.1 and 3.1.1.1 of OCS PEA (2013), which generally describes how hydrographic surveys are performed and the functions (including sound frequency range) of echosounder technology.

The CRCP mapping activities typically use NOAA vessels equipped with a downward pointing multibeam echosounders manufactured by Kongsberg (e.g., EM2040, EM710) or Reson (e.g., Seabat). The frequency of the Reson echosounder is 200 or 400 kHz with a bandwidth of 1 kHz for operational depths from 10-100 m (32-328 ft). The Kongsberg frequencies are between 65-100 kHz with an effective operational depths of 100-2,000 m (0.06-1.24 mi). Both types of echosounder are downward-oriented from the hull and spread up to 140 degrees across the ship width and by only 1-3 degrees along the track. Power is set to the lowest possible level (approximately 190-210 dB re: 1 PA with a duty cycle or "ping rate" also set to the lowest possible level 10-30 Hz).

Aerial Mapping

Aerial mapping may involve hyperspectral sensors that are used on aircraft. One example is Light Detection and Ranging (LIDAR),which uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses, combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. A LIDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver. Airplanes and helicopters are the most commonly used platforms for acquiring LIDAR data over broad areas. Two types of LIDAR are topographic and bathymetric. Topographic LIDAR typically uses a near-infrared laser to map the land, while bathymetric LIDAR uses water-penetrating green light to also measure seafloor and riverbed elevations. The CRCP incorporates by reference this activity referenced in Section 3.1.2 of OCS PEA (2013).

Small drones can also be used to map and photograph coral reefs and other habitats. A drone is an unmanned aerial vehicle remotely controlled that can have on-board sensors or camera to record and transmit information/data. All drones used must be in compliance with the Federal Aviation Administration regulations.

Satellite Mapping

The primary source of data used to date for production of interpreted shallow-water benthic habitat maps with CRCP funding has been IKONOS imagery. The IKONOS satellite was launched in 1999 and has panchromatic, blue, green, red and near infrared bands and multiple 11 km (6.83 mi) wide swaths can be combined to cover thousands of km^2. The 3.2-4.0 m (10.5-13.1 ft) resolution multispectral imagery has been used for production of the CRCP shallow-water benthic habitat maps that were not produced using overflights by aircraft. Remote sensing via satellites is also used for biophysical, geological, and oceanographic monitoring.

2.3.1.5 Common Research Activities

The CRCP is also engaged in coral reef ecosystem research activities. These activities may involve the collection of coral fragments or cores for studies associated with coral health and disease; collection of samples of corals and other organisms for genetic analysis and identification, larval tracking, algal ecology studies, fish and invertebrate life history studies, assessment of the ornamental trade in reef organisms, climate change mitigation, and biodiversity studies; testing and development of mitigation/recovery actions; and research on the effects of sediment, nutrients, or pollution on coral reef organisms.

2.3.1.5.1 Tagging

Fin Fish

Fish caught for tagging are captured with fish traps, hook and line, or nets, with efforts taken to minimize deployment time and barotraumas (e.g., injuries caused by pressure changes). In general, traps are set for a few hours to a maximum of 24-48 hours to prevent fish from starving or preying upon each other, and nets are deployed for a few hours to minimize entanglement of other non-target species. The captured fish are measured and tagged with minimal exposure to air, and released, generally within a few minutes to avoid post-collection mortality. In some cases, an anesthetic may be used and fish may be held in surface pens up to 60 minutes to allow for recovery and to examine potential negative impacts associated with tagging. In most cases, divers can measure and tag fish at m of capture to reduce the stress of bringing the fish out of the water, barotrauma issues, and release mortality. Sharks are often captured using alternate methods than fin fish, such as drum lines with circle hooks. Depending on the shark species and location, nets or seines may be used, but the most common gear is a drum line.

Typical tags include coded wire tags (e.g., external spaghetti tags), elastomer T-bar anchor tags, 8.0 cm (3.1 in) serially numbered plastic (nylon) dart identification tags, visible implanted fluorescent elastomer tags, and acoustic transmitters. Coded wire, T-bar, and dart tags are external tags that are inserted into the fish near the dorsal fin.Visible implanted fluorescent elastomer tags are injected between the rays of the caudal fin, similar to a barcode. Each is comprised of four separate lines in differing colors that can be read underwater using an ultraviolet light source. Acoustic transmitter tags are implanted inside of the fish.

Projects tracking fish movement patterns involve the use of underwater acoustic telemetry transmitters that are of a small size for implanting into fish; the transmitters have a relatively long battery life, an adequate detection range, and a unique signal to allow differentiation of individuals. One of the most common approaches involves fitting of fishes with internal coded acoustic tags (e.g., tags are generally 8-25 mm (0.31-0.98 in) in size, 69 kHz, 144-158 dB with a battery life of 2-24 months). Tags are typically inserted into a small incision in the abdominal wall, which is closed using a surgical stapler or biodegradable suture; fish are bathed in aerated MS-222 (tricaine methanesulfonate, see below), an anesthetic solution to prevent stress during the surgery. These transmitters transmit a train of pings (pulses) per cycle at a frequency of 51-84 kHz depending on the size and type of transmitter used. Battery lifespan for transmitters varies with battery size, power output, and ping frequency. The acoustic signal undergoes rapid loss due to absorption properties of the water, requiring the fish to be within the range of the receiver to pick up the signal.

In addition to various internal and external tags, researchers may used chemically mark the otoliths of fishes with inorganic fluorescent substances such as oxytetracycline (OTC, oxytetracycline hydrochloride at 75 mg/kg fish body weight). OTC belongs to a group of antibiotics used chiefly in treating infections caused by streptococci, staphylococci, Gram-negative bacilli, rickettsiae, and certain protozoans and viruses, and is now the preferred chemical because of its high retention in bony structures. OTC is injected into the coelomic cavity or the fish are bathed in an OTC solution.

MS-222 may be used for the temporary immobilization of fish and is generally used at a concentration of 0.1 g/L. MS-222 is generally used during manual spawning (fish stripping), weighing, measuring, marking, surgical operations, transport, photography, and research. MS-222 is not used in-situ, but is used in captive situations, such as in a laboratory. Fish treated with MS-222 is not used in fish intended for human consumption.

Sharks

The two principal tags in use are a fin tag and a dart tag. One type of fin tag is a two-piece, plastic cattle ear type tag, which is inserted through the first dorsal fin using seawater resistant nylon cable tie. The second type is the dart tag, which is easily and safely applied to sharks in the water. The "M" tag is composed of a stainless steel dart head, monofilament line, and a plexiglass capsule containing a vinyl plastic legend with return instructions. These dart tags, in use since 1965, are implanted in the back musculature near the base of the first dorsal fin.

Coral

Corals may be tagged to determine growth rate, spawning potential, or to monitor individual colony health over time for a study. Corals are generally tagged with aluminum or plastic tags that are attached with nails, cable ties, or epoxy to the substrate adjacent to the coral colony. Markers that are directly attached to coral colonies are rarely used and, when used, coral colonies have shown rapid tissue growth over the marker.

Alizarin Red S, a hydroquinone dye, can be used to stain or tag corals in order to provide a baseline growth ring and assess calcification rates. The stain is incorporated into the outer skeletal layer of the coral. Generally, the coral is removed and placed in chemical solution either in the lab or on a boat, but the coral may also be exposed *in-situ* using a plastic bag to enclose the coral for a given period of time. Exposure time is limited to eight hours because stress bands form in skeletons of corals that have had longer exposures (Dodge, 1984). Alizarin Red S in large amounts is toxic to all living creatures. When applied with running seawater, Alizarin Red S caused mild stress to adult corals, which caused the release of planulae and/or withdrawal of tentacles. Doses higher than 10 ppm (10 mg/ml) will not be permitted (Lamberts, 1973). Once the Alizarin Red S exposure is complete, the coral that was removed to be treated may be placed back on the reef from where it was collected or affixed to a base and secured to the seafloor (as described in Section 2.3.1.2, Instruments Moored to the Seafloor) for a period of time (months up to two years) until removed for laboratory analysis.

2.3.1.5.2 Collection of Coral Reef Species

Coral

Large cores (e.g., 10-15 cm diameter x 0.5-5.0 m length [4-6 in x 19-197 in) and small cores (2.5 cm diameter x 0.5-1.0 m length [1 in x 0.2-20 in]) are removed from large massive colonies to assess rates and patterns of reef accretion, the composition or nature of fossil assemblages, coral growth for species with annual banding patterns, and generate a long-term record correlating environmental change with fossil records. Coring requires use of an underwater hydraulic drill, pumps, and coring equipment. A common practice to minimize potential environmental impacts (and to reduce the potential for colony mortality) involves the filling of holes left by coring with Portland cement, clay, epoxy or similar materials, which allows live tissue to grow over the part that was cored (Figures 2-10).

Branches or portions of colonies (e.g., fragments, small cores) are collected for disease and health research (e.g., genetic studies, physiology and growth studies, infection experiments, and histology), used in coral nurseries (discussed in Section 2.3.6), and assessed for coral contaminants. Tissue sampling involves the collection of one polyp (~1 cm^2 of tissue [0.4 in^2]) or larger (~2-10 cm branch tip [~0.8-4 in]) using hand tools such as a syringe, shears, hammer and chisel, or pliers. The collection of small tissue samples from branching corals generally occurs at the outermost portion of the branch tip (Figure 2-11).

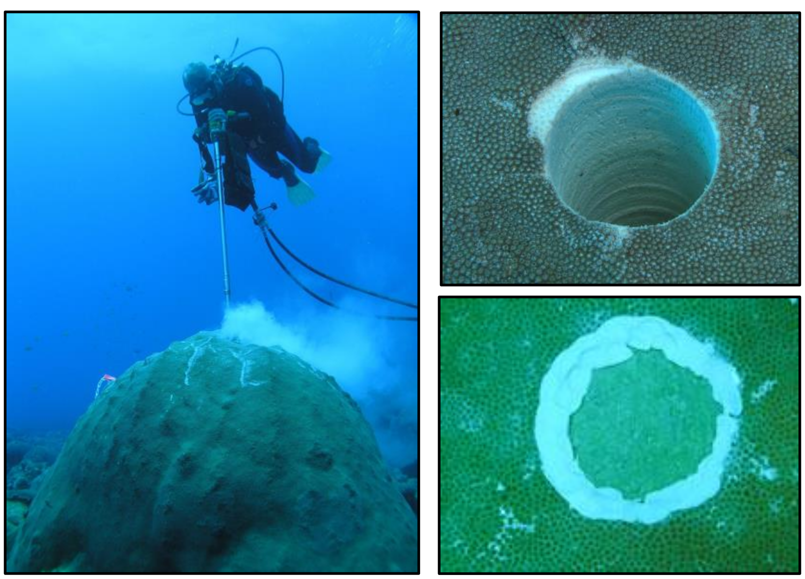

Figure 2-10. Coral coring (large cores). Left: A diver drills into coral; Upper Right: A hole left in a coral after drilling is complete; Lower Right: A cement plug with clay to seal the cored hole. *Source: Emma Hickerson/NOAA FGBNMS*

Figure 2-11. Divers collect a branch tip.
Source: NOAA CRCP/Coral Disease and Health Consortium

Additionally, researchers may collect naturally available coral fragments (e.g., picking up fragments from the seafloor by hand) or corals of opportunity (e.g., coral fragments or colonies that will be lost as a result of projects such as port expansions). Naturally available fragments are often reattached during restoration and transplantation experiments or cultured in a nursery for restoration and experimental use.

Multiple coral fragments or cores are not typically collected from the same coral colony or the same location. Researchers try to distribute the sample load across colonies and areas. In some cases, more than one sample may be taken from the same colony; for example; when conducting coral disease research, scientists may sample the healthy tissue and the infected tissue from the same colony.

Coral gametes may be collected for culture and used in restoration efforts or for research related to early life stages of corals or for cryopreservation. When collecting gametes from broadcast spawning corals, such as *Acropora* spp. and *Orbicella* spp., collections are made *in situ* via tent-like nets that are placed carefully by divers over individual spawning coral colonies (Figures 2-12 and 2-13). These nets are temporarily placed (< 24 hours) over the spawning colonies and can be secured to the seafloor using nails. The coral larvae produced from collected gametes can be released to the field after settlement or reaching the planktonic stage or they can be used for research. Additionally, divers can use syringes to collect sperm and eggs released from gonochoric broadcast spawning corals, such as *Dendrogyra cylindrus*. Sperm or eggs are released from individual colonies, and the sperm dilutes immediately if not packaged with buoyant eggs. The syringes used to collect sperm or eggs do not directly contact the coral only the water surrounding the colonies. To collect gametes from brooding corals, such as *Porites spp*. and *Agaricia spp.*, researchers “borrow” the whole coral colony from a reef, bring it into a lab tank for a few days while the planulae are released, and then epoxy the parent coral back on the reef where it came from. In rare cases when field collection is not possible, a limited number of parent colonies may be “borrowed” from the reef to facilitate the gathering of gametes in the lab during broadcast spawning events. Parent colonies will be brought into the lab up to two weeks prior to spawning and returned to the reef after the spawning event. These brooding species are generally smaller and hardier, making this possible to do.


Figure 2-12. A diver collects spawning coral gametes using a tent net. (left) *Source: NOAA*
Figure 2-13. Collected coral gametes in a tube. (right) *Source: Kelli O'Donnell*

Settlement plates can be biologically conditioned by placing them on the reef for a short period of time (two to three months) to be colonized by coralline algae and bacterial biofilm that serve as settlement cues for corals. The plates are primarily secured to the benthos using stainless steel or rebar rods; however, other methods have been used such as egg crates cable-tied to the non-living reef framework. Newly settled corals can be collected using these settlement plates/tiles. Settlement plates are man-made devices that are designed to simulate the natural strata that corals settle on and are generally made up of ceramic/limestone tiles (2.5-25 cm x 2.5-25 cm [1-10 in x 1-10 in]) but can also have other shapes (e.g., round, three-dimensional). Conditioned settlement plates can be used in the laboratory to settle larvae from collected gametes or they can be placed *in-situ* within coral reefs, using the methods described above, for a short period (weeks to months) or a longer period (one to two years) to assess natural coral recruitment. At the end of the *in-situ* period, plates are removed and analyzed in a lab.

Additionally, coral mucus samples are collected with a syringe without the needle attached or with swabs (Figure 2-14). Mucus samples are typically used for various monitoring purposes (e.g., disease) or for coral-bacteria symbiont research.

Figure 2-14. A snorkeler collects mucus for coral disease and health research.
Source: Mote Marine Laboratory

Fish and Other Invertebrates

In most instances, researchers conduct non-lethal sampling such as fin clips or scales collection for genetic analysis, or collect samples from fish previously harvested by fishermen to characterize life history stage, fecundity, growth rates, and diet. However, limited lethal collection of fish and motile invertebrates is undertaken to characterize life history stage, fecundity, growth rates, diet, or to understand corallivore impacts on corals or to assess contaminant exposure. This includes collection of fishes and invertebrates using hook and line, spearfishing, traps, or nets. Nets and traps are usually placed in areas near reefs, but not on the corals themselves. Hand collection can be used to collect slow-moving species. Hand collection includes small hand held nets, brushing off live rock or rubble, hand picking specimens from substrate, or suctioning of burrowed organisms. Traps are baited and temporarily placed (up to 24 hours) in mud or sand adjacent coral reefs, mangroves, or in seagrass areas. Bottom type is visually confirmed from the surface or by free divers prior to deployment. Collected organisms are either tagged and released or killed in the process of doing research.

In addition, Autonomous Reef Monitoring Structures (ARMS) or other structures, which are intended to mimic the structural complexity of coral reefs, are deployed for a determined amount of time (months to years) to attract colonizing macroinvertebrates. The ARMS currently used by the CRCP are 36 cm x 46 cm x 20 cm (14 in x 18 in x 8 in) and contain nine layers, which are 23 cm x 23 cm (9 in x 9 in) each, for colonization. ARMS are made of non-caustic PVC type 1 plastic and consist of layers that alternate between an open surface that contains triangular-shaped colonization sites. The top layer is a convoluted filter layer designed to provide a multitude of colonization sites and a large surface to volume ratio. ARMS are placed by divers on sites identified as uncolonized pavement or sand in proximity to natural coral reef structures to avoid coral damage. ARMS are anchored using stainless steel stakes and weights to ensure the ARMS stay in place during the duration of deployment.

Algae/Seagrass

For CRCP projects, algae/seagrass are typically collected during photoquadrat surveys. After divers take a photograph and visually quantify algae/seagrass, they collect representative samples of turf algae, crustose coralline red algae, and fleshy macroalgae by hand for laboratory identification or quantification of biomass. Samples collected for identification consist of individual plants, likely including blades, stipe and holdfast, as applicable.

2.3.1.5.3 Coral Measurements

Coral colonies are often measured using hand-placed calipers, rulers, or flexible tapes, which briefly (< 5 min) remain in contact with a portion of the coral colony (Figure 2-15 and 2-16).

Figure 2-15. A diver measures corals in a block style nursery. *Source: Kelli O’Donnell*

Figure 2-16. A diver inspects corals that were grown in a nursery and outplanted. *Source: Kelli O'Donnell*

2.3.2 Coral Restoration and Interventions

2.3.2.1 Coral Nursery

Reared or collected coral fragments are attached to bases and then attached to a growing rack in benthic or land-based nurseries, or attached to a tree or rope line in mid-water nurseries. *In-situ* nurseries are generally kept in areas near coral reefs where environmental conditions are appropriate for rearing corals (high water quality, circulation, presence of herbivores, etc.). Corals can also be grown *ex-situ* in land-based facilities. Corals grown in all nurseries can be used for coral restoration through transplantation or outplanting (attaching nursery grown corals back onto coral reefs), fragmentation to grow additional corals, and as a supply for laboratory research related to restoration and resilience.

In-situ Coral Nursery Development/Expansion

In order to set up a new nursery, a site-specific nursery operational plan is developed. The CRCP will work with grantees to identify options for nursery siting. Sites for new nurseries will be based on several selection factors: (1) avoiding impacts to existing benthic habitats including coral and seagrass; (2) areas with minimal predators; (3) appropriate water quality and substrate conditions for coral growth; and (4) logistics such as accessibility from land. Once a site is selected, the grantee will obtain all permits from applicable federal, state/territorial, and local permitting agencies.

In-situ coral nurseries are either floating/midwater nurseries or bottom-placed structures. There are a variety of structural forms for *in-situ* coral nurseries including lines, trees, and tables for floating nurseries, and blocks, PVC blocks, wire cages, and A-frames for bottom-placed nurseries. Floating nurseries, such as lines and trees, have four main components: an anchor, floats, lines, and coral attachment devices. Structures can be anchored to the bottom using duckbill anchors, helix ground anchors, rebar, anchor screws, heavy weights, or eye bolts cemented into hard-bottom. Horizontal lines or frames are held taut with floats. For line-style structures (Figure 2-17), vertical lines run between or through the middle of the horizontal line or lines may run parallel to the bottom supported by PVC pipes and floats at the middle and ends. Tree-style structures (Figure 2-17) have a PVC pipe or a fiberglass rod that runs up the center with branches (usually wooden, PVC, or fiberglass) coming off the center stem. The branches of tree-style nurseries may also support trays made of PVC and plastic mesh to hold microfragments. Floating table-style structures (Figure 2-18), have a flat surface typically made of PVC pipes or a plastic mesh that is floated vertical to the bottom. In some cases, during bleaching events, shade cloths can be deployed about 0.6 m (2 ft) above the coral table. The shade cloths are held taut with floats and removed when the bleaching event ends. Corals are attached to the lines or branches using vinyl-coated wires, cable ties or monofilament fishing line, or may be inserted into the braids of the line itself or held in place with small pieces of hemp or rope. Bottom-placed structures include block or frame nurseries that are fixed to the bottom with cinder blocks or anchors and do not include floats. This type of nursery has three main components: an anchor, a constructed unit, and a coral attachment device. For the block grow-out structures, cinder blocks are the base of the construction unit and are anchored in place using rebar (Figure 2-19). Pedestals (usually cut PVC pipes) are attached to the top of the cinder block using epoxy (Figure 2-20). Corals can be attached to the pedestal on the top of the cinder block via cement disks, cones, or pyramids using plastic ties, wires, or epoxy. Frame grow-out structures are made in a variety of shapes: tables, triangles, circles, or domes and are typically metal (stainless steel rebar with wire mesh) coated with epoxy, fiberglass to reduce fouling, or PVC pipes (Figure 2-20). Novel biodegradable materials such as bamboo with hemp ties are also being tested. Frames are anchored to the bottom using cinder blocks, weights, or rebar. Corals are then attached to the frames using wire or plastic ties.

Figure 2-17. Examples of floating/midwater coral nurseries: Horizontal line setup (left) and tree style nurseries (right).
Source: Mote Marine Laboratory

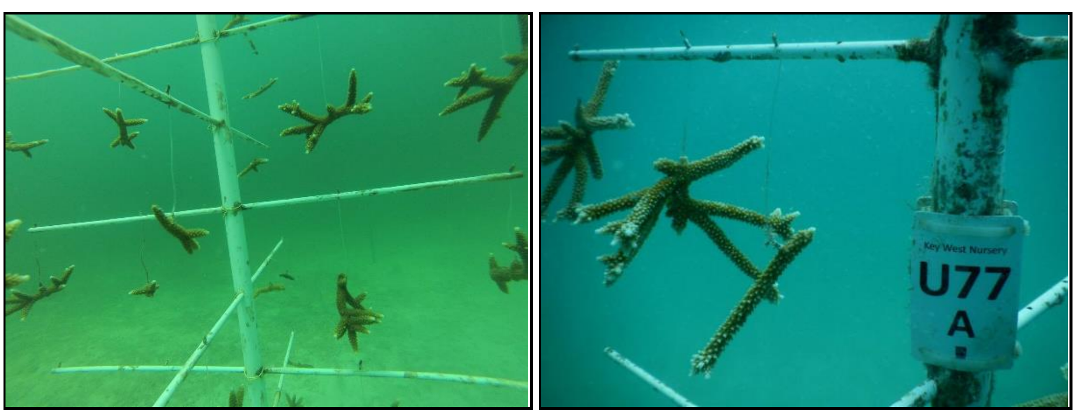

Figure 2-18. Coral trees made from PVC. Monofilament lines dangle Acroporid corals from the trees to allow them to grow.
Source: Kelli O'Donnell

Figure 2-19. Example of anchor for nursery trees. A short float marking where a duckbill anchor for coral nursery tree with fish nearby. A float is put on a short line to make it easier to find where the duckbill is anchored. *Source: Kelli O'Donnell*

Figure 2-20. Examples of benthic coral nurseries. The left photo shows the block style nursery where Acroporid corals are affixed on top of blocks to grow and the right photo is an example of an A-frame nursery with Acroporid coral attached. *Source: Mote Marine Laboratory (left); University of Miami (right)*

Corals grown in an *in-situ* nursery setting are usually "fragments of opportunity" that have previously broken from the donor colony during natural events or ship groundings, or have been "rescued" from areas where construction or other activities would have impacted the corals. However, fragments can also be collected from large healthy colonies using the method described in Section 2.3.1.5.2, Collection of Coral Reef Species. Collected fragments are either transported underwater to nearby nurseries or placed in bins with seawater on a vessel or vehicle if they need to be transported some distance to nursery sites (Figure 2-20). The seawater is changed regularly, and the bins remain shaded during transit. Typically, after establishment of a nursery during the first year of operation, no additional coral collection is needed to expand the nurseries, as the nursery itself will produce enough coral tissue *in-situ* for both expansion by fragmenting and for outplanting. However, in some cases, additional collections are made to increase genetic diversity within a nursery or to house corals salvaged from groundings, natural disasters, or construction projects.

Temporary nurseries can also be set up at the same reef location where transplanting/outplanting would occur such as following a vessel grounding. Once outplanting to restore the site is complete, the nurseries are removed from the site. This ensures corals never leave the water, which helps increase daily outplanting (restoration efforts), and reduces the handling and transport time of corals. Maintaining temporary nurseries allows corals to acclimate to the outplanting site's local microbiota and environmental condition or to remain acclimated to the site.

Coral Nursery Maintenance

Regular maintenance of nurseries is needed to maintain the health of the corals and to ensure the structures are stable. Typical nursery maintenance is done by divers and includes the removal of fouling organisms (algae, tunicates, sponges, and hydroids), use of wire or plastic brushes (Figure 2-21), removal of corallivores (snails, worms, and damselfish) by hand (see Section 2.3.2.3, Nuisance Species Control), repair of broken nursery components (lines, wires, and anchoring materials), removal or treatment of diseased corals such as administering a "break" (see Section 2.3.2.3, Coral Disease Control/Management), monitoring of coral health and growth (length, branch tips, width, condition, and mortality), and continued propagation (fragmentation) of corals to maintain nursery and transplanting/outplanting stock.

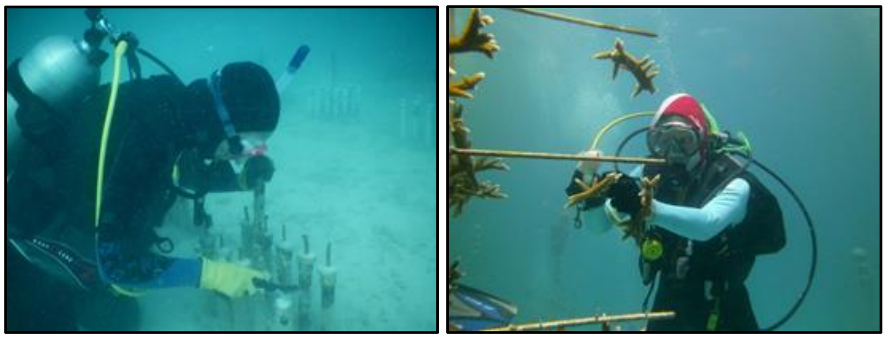

Figure 2-21. Divers clean the *in-situ* coral nursery structures as part of the maintenance routine.
Source: Kelli O'Donnell and Dave Seeley

2.3.2.2 Coral Transplantation/Outplanting

Transplantation of corals can be used to: (1) rehabilitate a degraded reef that has been impacted by an environmental disturbance such as disease and/or bleaching outbreaks; (2) restore a reef that has been physically impacted by ship groundings, anchor damage, or storms; (3) increase a reef's species or genetic diversity to promote resilience to human-based and natural stressors; and (4) conduct research to assess the effectiveness of restoration methods, coral resilience to climate change, coral disease, or other perturbations and their effects on corals.

Transplantation involves stabilizing the substrate, reattaching fragments, and/or attaching nursery-raised corals to reef or other hard bottom substrate. As with transport to nurseries, colonies are either transported underwater to nearby outplanting sites or placed in bins with seawater on board a vessel or vehicle if they need to be transported a further distance (Figure 2-22). Before outplanting corals, the substrate may need to be cleaned of fouling organisms such as sponges and algae, which can hinder attachment and overgrow the newly outplanted corals. Larger coral pieces or substrate may be attached or secured using cement, rebar, nails, epoxy, and/or limestone. The placement, attachment, or stabilization of smaller coral fragments, individual coral colonies, or nursery-reared corals is typically done using epoxy, cement, concrete nails, other mechanical devices (e.g., plastic cable ties), or hemp rope, or corals may be attached directly to a rack or other stabilization structure that remains on site and becomes overgrown by the transplanted corals (e.g., bamboo rack). Generally, transplanted corals are attached either directly to the seafloor or to a base (e.g., a concrete disk or limestone), which is then affixed to the seafloor (Figure 2-23).

Figure 2-22. Transporting corals from nursery to outplanting site. Left: A diver transports coral underwater to the outplanting site; Right: Corals are transported out of water. *Source: Mote Marine Laboratory (left); David Gross (right)*

Figure 2-23. Left: Nursery reared corals outplanted on a reef using epoxy. Center: Outplanted coral micro fragments using epoxy. Right: Nursery reared corals using nails and cable tie*s. Source: Kelli O'Donnell*

New and innovative coral restoration techniques include ways to increase the outplanting efficiency, increase survivorship of outplanted corals, enhance natural coral recruitment, and/or increase use of biodegradable materials. Activities may include the use of novel structures (bamboo, hemp rope, and natural limestone) to grow corals in nurseries and directly outplant onto the reef on a pilot scale. For example, one of the newer outplanting techniques uses hemp ropes containing nursery grown corals that are nailed to the substrate. Corals are attached to the rope by looping around the bases of large coral colonies, zip tying, or putting smaller corals into the twist of the rope. When ready for outplanting, the rope is laid across the substrate and nailed into place. Once the corals begin to grow and attach to substrate, the hemp rope will eventually biodegrade. Additionally, an example to increase coral recruitment using "flypaper" techniques or settlement tents attract coral larvae to settle on suitable restored substrate, thereby enhancing recruitment to the restoration site. Another method involves the collection of coral gametes *in-situ* followed by *ex-situ* fertilization and settlement on plates or other structures that can be transplanted on the reef.

2.3.2.3 Other Interventions

Urchin Propagation and Outplanting

In order to increase herbivory on reefs and increase coral recruitment habitat (i.e., hard substrate free of high macroalgal cover), efforts are underway to collect, culture, and outplant sea urchins, such as *Diadema antillarum* and *Tripneustes gratilla*. There are two methods for collecting urchins to rear in captivity. The first method involves the collection of adult urchins and coaxing the urchins to spawn and release gametes into containers in the lab. The gametes are then mixed together to produce zygotes (larvae) and urchin larvae are kept suspended until their settlement stage. Urchins that settle are then reared in a lab nursery setting until they reach a suitable size for outplanting. The second method involves the collection of juvenile urchins on the seafloor or newly settled urchins using settlement plates. For settlement plates, mooring lines are attached to cement anchor blocks in a sand channel in a coral reef for up to 6 months. Settlement plates, which are artificial turf squares, are attached along the mooring lines. The plates are collected monthly and brought to the laboratory for analysis. Settled urchins are picked off the plates and moved to a nursery culture tank. Juvenile urchins can also be collected and moved to a nursery tank to be grown to a certain size.

Divers outplant urchins either by placing them directly on the reef or by placing them in temporary corrals or cages that consists of galvanized chicken wire, nylon, or plastic mesh that is typically one-inch diameter or less (Figure 2-24). The plastic chicken wire, nylon, or plastic mesh is attached to the bottom of the corral so that it can be molded to the reef and fully enclose the corrals. The cages/corrals are held in place using PVC or rebar and are placed around the reef or around isolated coral colonies for about one month for urchin acclimation and to help facilitate herbivory. Urchin outplanting may be done in conjunction with coral outplanting.

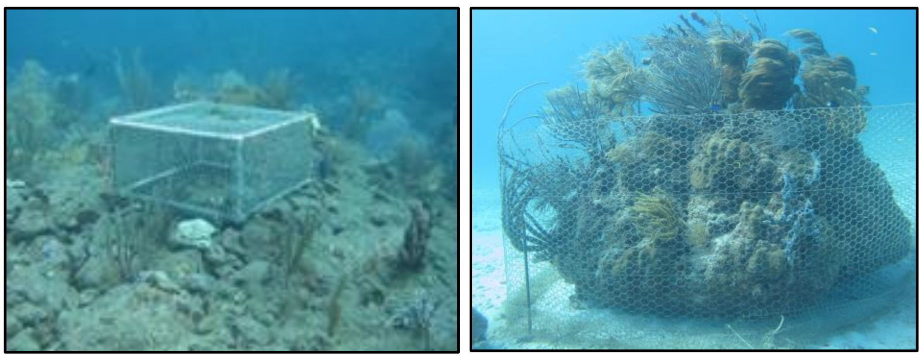

Figure 2-24. Left: Diadema outplanting cage; Right: Chicken wire mesh around coral to contain outplanted urchins.
Source: NOAA (left); Coastal Survey Solutions, LLC (right)

Invasive Species Removal

To help restore the condition of coral reefs and coral reef ecosystems, management efforts have been implemented to remove invasive species such algae, seagrass, and fish (e.g., lionfish in the Atlantic and Caribbean). Invasive algae and seagrass can be removed by hand or by using a suction pump that transports the invasive algae or seagrass to a boat for sorting and disposal on land. The removed algae can also be used as fertilizer on land. Biological controls can also be used to control invasive algae. The use of biological controls relies on predation, parasitism, herbivory, and other natural mechanisms through the release of native organisms (e.g., parrotfish and urchins) that control invasive organism or organisms in areas that have large invasive populations. Lionfish are removed by divers using hand nets, slurp guns, spears, or traps (Figure 2-25). Captured specimens are used in research, disposed of on-land, or if the appropriate licenses are held, sold to fish markets.

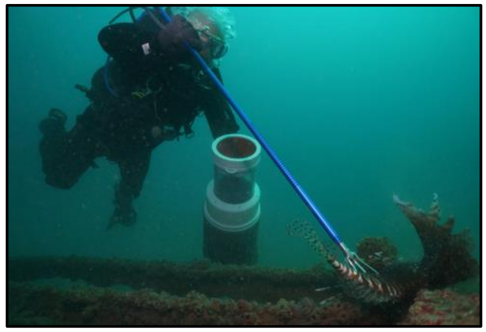

Figure 2-25. Diver removes an invasive lionfish using a spear. *Source: Alex Fogg*

Nuisance Species Control

Crown-of-thorns starfish (*Acanthaster planci*) infestation on coral reefs in the Pacific/Indo-Pacific are controlled by injecting ox bile and bile derivatives, acetic acid (vinegar), sodium bisulfite, or physical removal. Ox-bile is a natural substance that kills the creature but does no harm to the reef (Figure 2-26). For this method, divers inject the ox bile near the central disk of each starfish using an ox bile injector, a 46 cm (18-in) metal tube that houses a syringe with a needle and contains ox bile. Acetic acid is injected on the central disk of each starfish using a similar injector. The sodium bisulfite method requires multiple injections on the central disk of each starfish. After a crown-of-thorns is injected and dies, it is left on the reef. If injectors are not available, the starfish can be physically removed from the water and transferred to land for disposal.

Figure 2-26. Crown-of-thorns starfish injected with ox bile in American Samoa.
Source: National Marine Sanctuary of American Samoa

Divers can remove other corallivores, such as the gastropods, *Coralliophila abbreviata* and *Drupella* spp., fireworms, and butterflyfish by hand or with a bar, pick, tongs, or hand net. Those removed specimens are either brought back to a lab for analysis or disposed of on land. Additionally, other nuisance species such as octocorals, may be removed by hand to prepare sites for coral restoration activities.

Coral Disease Control/Management

Corals are affected by a variety of diseases caused by bacteria, fungi, viruses, or environmental stressors such as temperature, nutrients, ultraviolet radiation, or toxins. The physical manifestation of diseases on corals include discoloration in the form of bands or spots, lesions, tissue sloughing that exposes the skeleton, and growth anomalies. While the exact causes of many coral diseases are not entirely known, researchers have used management strategies to try to control coral disease. These strategies include the surgical removal of diseased tissue, removing diseased portions of coral colonies or entire diseased colonies (or sacrificing corals in place), removing the area between the diseased tissue and the healthy tissue (forming a break between the healthy/unhealthy tissue areas), application of clay or underwater epoxy putty directly over the diseased tissue or in the break line made between the healthy and unhealthy tissue, aspirating the diseased tissue with large syringes or pumps to remove cyanobacteria or other microorganisms (Figure 2-27), or a combination of these activities. In extreme situations, healthy corals may be removed from the water and cared for at ex situ facilities until the disease event has subsided or ended, to preserve genetic diversity and ensure that highly susceptible species are not locally extirpated by disease. Corals are cultured on land with the intention of returning them to their home reefs once conditions would support their survival.

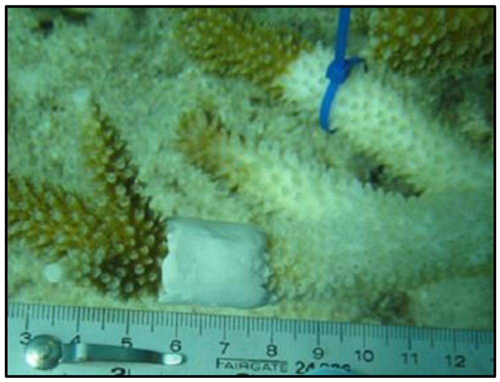

Figure 2-27. An example of an epoxy to form a break between healthy and diseased tissue to prevent further spread of the disease. *Source: NOAA*

Diseased coral may also be treated *in-situ* with antibiotics or powdered chlorine. In severe cases, diseased corals might be treated with a white petrolatum mixture or similar non-toxic compound (e.g., epoxy, clay) mixed with amoxicillin (60 mg/mL of petrolatum mixture; usually one application) or chlorine powder (calcium hypochlorite at ~15 mL/50 mL epoxy). The amount of the mixture applied to individual corals depends on coral size; larger infected colonies may require up to five grams of antibiotic to treat the disease. Future activities may include the administration of additional antibiotics or other drugs *in-situ* to address the causal agents of the coral disease once they have been tested in research laboratories. In addition, diseased and healthy coral specimens will continue to be used to support laboratory research on the causative agents of disease outbreaks. Healthy corals raised in *in-situ* or *ex-situ* coral nurseries may be used to repopulate reef areas that have been degraded by disease outbreaks, (see Section 2.3.6 and 2.3.7). However, effects of antibiotic application in the field on coral reef ecosystem species are unknown at this time (see Section 4.4.3.1). Site-specific NEPA analysis would be required before use of this technique in the field.

Coral Genomics, Stress Hardening and Survival Analysis

Coral samples can be analyzed in the laboratory for genotype sequencing that includes DNA isolations, genotype sequencing, and data preparation using standard and routine procedures to help understand the genetic makeup of resilient corals. This information can be used to support selective or managed breeding of corals by mixing gametes from different populations or individuals that have certain traits (e.g., heat or disease resistance) and by hybridizing species to select for certain traits expressed by corals that would then be grown in nurseries and outplanted if permits allow.

Studies can be conducted in the laboratory or *in-situ* to assess how corals respond to warmer waters, bleaching, pollution, and coral disease and understand why or how some corals appear to be more resistant or resilient to stressors than others. *In-situ* activities can involve temporarily transferring or transplanting corals from areas of high stress (pollution, high temperatures) to less stressed areas to determine how well they survive or maintain resistance to stressors, or transplanting healthy corals from less stressed areas to higher-stress areas to see if the corals acclimate and remain acclimated to the adverse conditions. Coral can also be taken into a laboratory setting and exposed to warmer temperatures or other stressors and placed back on the reefs. Generally, these types of studies are small-scale pilot studies may involve attaching corals using zip ties to gridded crates or structures that are temporarily placed in the sites using the mooring methods described in Section 2.3.1.2, Instruments Moored to the Seafloor. Resilient and resistant corals identified though these types of studies may be grown in nurseries and outplanted if permits allow.

The collection of coral gametes from wild corals or nursery-reared corals (see Section 2.3.1.5.2, Coral) can be cross fertilized with other coral gametes to create new genotypes, and rearing of those corals in *ex-situ*. These new genotype corals may be used for laboratory studies or outplanted if permits allow.

To help understand resistance to coral diseases, diseases can be transferred to healthy fragments by grafting (cable tying) a small piece of diseased tissue to the healthy tissues (Williams & Miller, 2005; Vollmer & Kline, 2008; Brant et. al, 2013). This can be done *in-situ* or *ex-situ*. In *ex-situ* situations, diseases can also be transferred using filtered homogenates (Vollmer & Kline, 2011), or via other means such as through water exchange or direct tissue contact.

Potential Future Coral Intervention Activities

Future work to assist with the restoration of coral reefs may include outplanting of corals with modified symbionts, movement of corals to non-native areas to enhance diversity (assisted migration), shading of corals/coral reefs, water cooling, and other methods to treat diseases, such as probiotics. At this point in time, there is not enough information to describe the methods that would be used to describe these activities, but CRCP may consider implementing pilot studies in the future. Site-specific NEPA analysis would be required before implementing these techniques in the field.

2.3.3 Watershed Management and Restoration

The CRCP's efforts to protect coral reef ecosystems from land-based sources of pollution focus on the implementation of watershed management through technical support for Watershed Management Plans (WMPs) and/or Conservation Action Plans (CAPs) and on-the-ground restoration activities to reduce rates of erosion and the quantities of transported sediment and other pollutants impacting coral reef ecosystems. The projects vary in size (acreage) and combination of management or restoration techniques implemented, but for an example of previous projects, see https://www.coris.noaa.gov/activities/projects/watershed/.

2.3.3.1 Technical Support for Watershed Management Plans

The CRCP provides technical assistance toward the development and implementation of WMPs and/or CAPs in watersheds that have been identified as priority areas by the jurisdictions. The primary purpose of a WMP or CAP is to outline a comprehensive set of actions and an overall management strategy for improving and protecting the watershed from nonpoint and point sources of pollution associated with changes in land use, and residential, commercial, and agricultural activities. A WMP/CAP identifies a set of key recommendations, specific partners, and next steps towards implementation of land-based pollution control strategies. WMP/CAP recommendations typically include BMPs and/or management activities that target the reduction and movement of sediment, nutrients, and contaminants within watersheds. Examples include re-vegetation and stabilization of land, stream-banks, and dirt-roads/trails; changes in stormwater and wastewater treatment practices; and improvements to site design practices. Implementation of BMPs and management activities are essential to maintaining hydrologic functions including streamflow and groundwater recharge to limit land-based sources of pollution inputs and impacts to nearshore marine environments, particularly coral reef ecosystems.

The CRCP supports data collection for WMP/CAP development. This includes *in situ* monitoring of the nearshore reefs, remote sensing data, and field assessments of the watershed. Nearshore reef *in situ* monitoring collects information on water quality, sedimentation rates and assessments of benthic habitats, fish, and invertebrates. Field assessments are conducted to identify areas of concern that contribute to land-based sources of pollution. Areas of concern can include places where there are stormwater drainage areas, septic systems, streams/ghuts (ephemeral streams), unpaved roads, impervious surfaces, conveyances, detention areas, point sources of pollution (including commercial, industrial, and municipal), and/or intermittent streams and wetlands. The types of activities involved in field assessments include the collection of sediment samples via plugs or grabs; the collection of water samples; and walking through wetlands and along streams and shorelines to look for potential problem areas and ground truth remote sensing data, identify ghuts, and release tracer dyes to locate point source pollution hotspots. Tracer dyes are released at a known point and monitored for discharge at another known point. Data generated from remote sensing are used to determine land use, land cover, benthic habitats, and turbidity.

2.3.3.2 Vegetative Plantings

Bare soil is stabilized through the establishment of vegetative cover (Figure 2-28). On highly erodible sites, grass seeds, mulch, fertilizer, and water can be combined and sprayed onto the hillside as hydroseed for quick and effective erosion control (Figure 2-30). While various plants can be used to revegetate bare soils, the CRCP uses native or non-weedy/non-invasive plants (e.g., vetiver grass) for this purpose (Figure 2-29). Plantings may also be used with existing or dormant crops as conservation cover (i.e., shade grown coffee). When plantings necessitate fertilizer, efforts are taken to minimize potential leaching of nutrients to water bodies including by adhering to minimum application rates, understanding near-term climate predictions to prevent storm conveyance of nutrients, and assuring a sufficient buffer between fertilizer application points and any nearby stream.

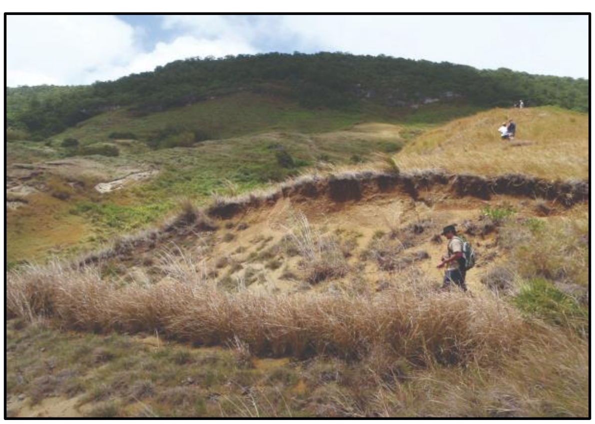

Figure 2-28. Volunteers plant vetiver grass to stabilize soil in the Talakahaya watershed in Rota, Commonwealth of the Northern Mariana Islands. *Source: NOAA*

Figure 2-29. West Maui erosion control in watershed using vetiver grass to catch sedimentation. Planting vetiver rows (left); finished vetiver rows (right). *Source: West Maui Ridge to Reef*

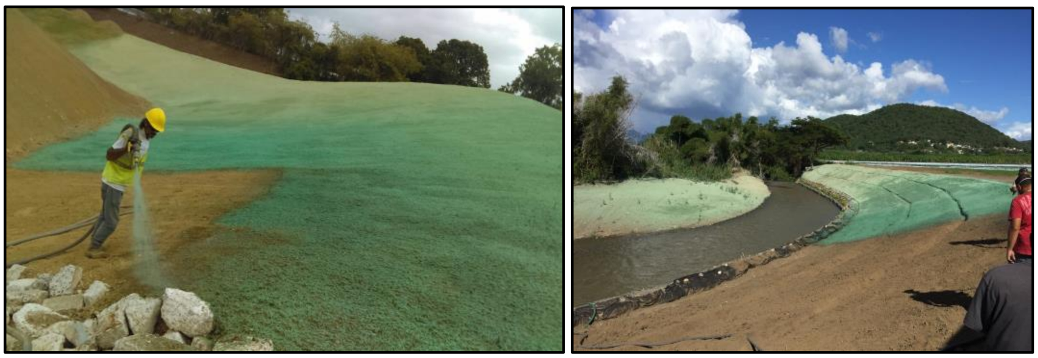

Figure 2-30. Hillside hydroseeding in Puerto Rico. *Source: Protectores de Cuencas*

2.3.3.3 Unpaved Road/Trail Stabilization

Unpaved roads and trails can be significant sources of erosion and sedimentation. Construction of broad-based dips, at the lowest point where the road grade curves, and water bars, which are small ditches constructed at low points, are two erosion control measures used to direct runoff from unpaved roads before it has a chance to erode the roadway through the formation of gullies and channels in the road. Designs incorporating these or similar elements allow runoff to be directed along various portions of the road to low points within the road that are then sloped to the downstream side of the road, where a stabilized outlet receives the flow and directs it downstream. Additionally, roads can be paved to prevent further erosion and sedimentation (Figure 2-31; Figure 2-32; Figure 2-33).

Figure 2-31. Gerda Marsh road stabilization on St. Johns, USVI. *Source: Coral Bay Community Council*

Figure 2-32. Freeman's Ground, St. Johns, USVI retaining wall for road stabilization. *Source: Coral Bay Community Council*

Figure 2-33. Dirt road stabilization in Puerto Rico. *Source: Protectores de Cuencas*

2.3.3.4 Stormwater Best Management Practices

Surface runoff from storm events or stormwater is a significant source of sporadic, erosive flows, erosion, and sedimentation. Stormwater BMPs are designed to reduce the velocity of stormwater flows and trap and remove sediments and other contaminants that may be transported in the stormwater. There are several types of BMPs designed for these purposes, including for treating various sizes of drainage areas. The implementation of these BMPs is site specific. BMPs include bioretention cells, baffle boxes, culvert repair or replacement, curb inlet grate filters, grass swales, stormwater or sediment basins, constructed wetlands, low impact development, stream bank or gut stabilization, and fencing.

***Bioretention Cell (Rain Gardens*)**

A bioretention cell, or a rain garden, is a low-impact development measure placed along the flow path of stormwater runoff to capture and treat stormwater containing pollutants in order to reduce runoff volume, peak flow, and pollutant loadings to natural water bodies. Bioretention cells help to break up extensive impervious areas (e.g., resorts, shopping plazas, industrial areas, and roadways). A bioretention cell is comprised of a shallow depression excavated and backfilled with media used to promote infiltration and supporting plants that both physically trap and bioremediate pollutants (i.e., heavy metals and nutrients). This system detains the volume of stormwater runoff known as the "first flush," which is the initial surface runoff generated on impervious or semi-impervious areas during a rain event. The "first flush" portion of rainfall typically contains the highest concentration of pollutants and is treated within the bioretention cell through natural chemical processes that include plant root uptake and soil retention. Bioretention cells have soft design features incorporating vegetative areas and can be installed alone or as part of a series of stormwater management measures (Figure 2-34; Figure 2-35).

Figure 2-34. Constructing (left) and finished (right) bioretention area in West Maui. *Source: West Maui Ridge to Reefs*

Figure 2-35. Constructing a rain garden in West Maui. *Source: West Maui Ridge to Reefs*

Baffle Box

A baffle box is a multi-chambered concrete box that contains a series of sediment settling chambers separated by baffles. The baffle box is tied into an existing stormwater drainage system, or at a drainage outfall, to decrease stormwater velocities to allow settling of sediment, suspended particles, and associated pollutants in the boxes. Baffle boxes can also be outfitted with trash screens to capture trash and debris or can be outfitted with absorbent membranes to trap floating pollutants (e.g., hydrocarbons) to further minimize transport of contaminants to water bodies.

Culvert Repair or Replacement

Undersized or collapsed culverts can impede natural flows and concentrate flows, which may increase the velocity of flows, flooding, and channel bank erosion. Standard culverts can be removed, repaired, or replaced with structures such as bottomless culverts to increase the area of flow and decrease the velocity of flow resulting in decreased channel bank erosion and sediment transport to downstream habitats.

Curb/Grate Inlet Basket (with filter)

Curb or grate inlet baskets are manufactured frames that can be fitted with filters or fabric and placed in a curb opening to remove trash, sediment, or debris. Baskets trap items larger than sediment and can remove large quantities of hydrocarbons, including oils and grease, when fitted with an optional absorbent polymer.

Swale

A grass swale is a shallow excavation, constructed on a gradually sloped grade, lined with grass along a waterway or roadway (Figure 2-36). The vegetated conveyance channel slows stormwater flows, temporarily impounds a portion of the flow, filters a portion of the pollutants contained in stormwater flow, settles out sediment, encourages infiltration into the underlying soils, and reduces the potential for bank erosion caused by runoff velocity within the channel. Grass swales can be installed when runoff needs to be conveyed to a natural drainage channel from another stormwater treatment structure or from a land use that has incorporated preventative treatment measures. Grass swales can be especially effective when constructed at grades approaching level because they slow water flow to the maximum extent possible while still maintaining a positive grade. Ponding may occur in swales, which will aid in additional settling and treatment of stormwater runoff.

Figure 2-36. An example of swale construction in Puerto Rico. *Source: Protectores de Cuencas*

Stormwater Ponds or Sediment Basins

Stormwater ponds or sediment basins are a stormwater drainage feature designed to retain stormwater, reduce flow velocities, and retain sediment (Figure 2-37). The ponds or basins can be designed to store a permanent or intermittent pool of water, based on the design of the outlet. The outlets can be designed as a pipe or an overflow structure, or they can link into another stormwater BMP like a constructed wetland. The design of the pond or basin is site specific and dependent on the intended purpose and the size of the drainage area.

Figure 2-37. Examples of constructed stormwater ponds in Puerto Rico. *Source: Protectores de Cuencas*

Check Dams

Erosion in small rills or gullies in the upper reaches of watersheds may be slowed with the use of check dams or fiber rolls. Check dams are small structures that slow the flow of water in small erosion features. They are often made of natural materials (e.g., wattles, dead branches, or fiber rolls) or stones. These are designed to slow the velocity of water and reduce runoff in the areas below.

Fiber Mats and Rolls or Filter Socks

Bare soils may be stabilized with fiber mats made of natural materials like woven jute or coconut (coir) fiber mats. These mats are a good option for soils affected by wildfire or construction and temporarily hold soil in place until vegetation can take root and hold the soil in place. They allow water to percolate and can provide a stable foundation for native plant growth or be sown with seed. These mats can also be rolled and secured with short wooden stakes to create a barrier to slow overland flow on bare soils. In some cases, a filter sock filled with mulch, compost, or other filter material, can be used in a similar fashion.

2.3.3.5 Constructed Wetland

A constructed wetland is an artificial wetland that may be a marsh, mangrove area, or swamp created for pollutant retention and removal (Figure 2-38; Figure 2-39). Constructed wetlands have characteristics similar to natural wetlands and use the same natural processes (e.g., microbial activity) to remove pollutants from stormwater, wastewater, or sewage effluent and also allow sediments to settle. The constructed wetland can also provide habitat for native and migratory wildlife.

Figure 2-38. Example of an under construction (left) and finished floating wetland (right). *Source: West Maui Ridge to Reef*

Figure 2-39. Building constructed wetland (left) and finished wetland (right). *Source: Protectores de Cuencas*

2.3.3.6 Low Impact Development

Low Impact Development (LID) strategies integrate the use of site planning and stormwater management to promote the infiltration and retention of stormwater and associated pollutants at their source. The overall goal of LID is to maintain a site's pre-development hydrologic condition to the greatest degree practicable. The stormwater BMPs associated with LID, subsequently referred to as LID practices, utilize natural processes (e.g., infiltration, temporary detention, and groundwater recharge) to disperse stormwater throughout the site and retain stormwater volume and associated pollutants on-site, rather than conveying stormwater and associated pollutants directly to receiving waters. In general, LID practices focus on reducing impervious cover (e.g., using pervious pavers, pervious concrete [Figure 2-40]), retaining stormwater (e.g., cisterns, rain barrels), and/or slowing the velocity of stormwater runoff to allow for stormwater infiltration and retention of pollutants on site (e.g., bioretention swales, vegetated buffers, green roofs, and infiltration wells/trenches).

Figure 2-40. Examples of low impact development practices and permeable parking areas that allow for filtration of rain/run off.
Source: Protectores de Cuencas

2.3.3.7 Stream Bank or Ghut Stabilization

Stream bank stabilization is defined as the stabilization of an eroding stream bank using practices that consist primarily of a mixture of "soft" or "hard" engineering practices. "Soft" engineering practices include, but are not limited to, regrading with natural materials like coconut (coir) fiber mats, grasses, and various shrubs and trees to reduce erosive slopes and stabilizing those slopes via vegetation and their root structure. "Hard" stabilization practices include, but are not limited to, installation of turf reinforcement matting, riprap or other rock, and gabions to reduce velocities of storm flows and stabilize erosive stream banks. The use of "hard" engineering techniques is not considered a restoration or enhancement strategy, but may be necessary in certain locations where erosion threatens adjacent properties and the probability of success using soft engineering practices is low. Other sections along the channel banks can be treated with bioengineering and soft engineering practices, which can be expected to reduce bank erosion, increase site aesthetics, enhance in-stream habitat, and be less costly compared to hardened structures.

Turf reinforcement mats are made of synthetic fabric and are used to line bare soil areas along channel banks to protect the channel bed and bank from erosion. These mats may also be used in landscaping in areas with bare soils. They provide a long-term solution for erosion control and maintain intimate contact with the subgrade, resulting in rapid seedling emergence and minimal soil loss. Turf mats allow water to infiltrate into the substrate and provide for hydraulic connectivity to groundwater. Turf mats are made of non-biodegradable fabric to ensure long-term stabilization of soils.

Riprap is angular rock used for stabilizing steep soil slopes on which a healthy stand of vegetation cannot be established or within concentrated channels that would otherwise be susceptible to erosion from rainfall and concentrated runoff. The size of the rock used is based on the expected shear stress induced by flowing water. Depending on the site conditions (e.g., waterflow, velocity), rocks may be reinforced or held together with rebar and mortar or placed in wire baskets (gabions). Non-reinforced riprap structures are usually anchored into the ground to increase their resistance to movement. A geotextile fabric is typically installed prior to riprap placement to prevent undermining of soils and different sizes of rock are installed under and within the larger boulders to further stabilize the riprap.

2.3.3.8 Fencing

A fence is installed to prevent livestock (e.g., cattle or horses) or feral animals from accessing a stream or other sensitive area. The goal is to reduce erosion caused by trampling as well as abate nutrient or bacteria input.

2.3.3.9 Elevated Boardwalks and Delimitation of Ecologically Sensitive Vegetative Areas

Measures to reduce impacts to sensitive vegetated areas include the installation of treated wooden posts or other markers to identify sensitive areas (Figure 2-41). Treated posts or boulders can also be used to prevent vehicular access to these areas. Posts are generally installed by digging holes about a foot and a half deep and securing the post with cement. To provide public access across sensitive areas, raised boardwalks may be built using treated wood anchored on piles.

Figure 2-41. Examples of elevated boardwalks and delimitation of sensitive vegetation areas while allowing public access to beaches. *Source: Protectores de Cuencas*

2.3.3.10 Removal of Terrestrial Invasive or Nuisance Species

In some situations, invasive or nuisance species, such as bamboo (*Bambusa vulgaris*) and feral goats and hogs, may impair watershed health and impair native habitat restoration. In such cases, invasive or nuisance species may be removed using appropriate methods (e.g., humane capture and relocation, trained herding animals, and culling of herd). All restoration sites should be restored using BMPs for stormwater control and appropriate native vegetation. For bamboo, this may include the cut stump method where bamboo stems are cut low to the ground and then spot treated with direct, limited application of an appropriate pesticide. Pesticide use should be limited to the minimum amount necessary to control the problem species.

2.3.4 Reduction of Physical Impacts to Coral Reef Ecosystem

The CRCP supports activities such as community-based involvement in coastal cleanup activities, the removal of derelict fishing gear and other marine debris from coral reef ecosystems, and the installation of mooring buoys and other buoys to mark access to protected areas or limited access zones to reduce physical impacts.

2.3.4.1 Buoy Installation

Recreational Boat/Day Moorings

Anchor damage is a common disturbance to coral reefs and seagrass beds (Davis, 1977; Jameson et al., 1999; Rogers et al., 1988) and permanent boat mooring systems are a widely accepted means to lessen the harmful effects of recreational boat anchoring and aid in coral ecosystem conservation (Halas, 1985; Halas, 1997; Rogers et al., 1988). All mooring buoy systems consist of the following three elements: an anchor on the sea bottom, a buoy floating on the water surface, and a line connecting the two (Figure 2-

42). CRCP only funds embedment anchors, which are embedded into either solid bedrock or soft substrate and held in place by the weight of the sand, rubble, or hard substrate.

Figure 2-42. A boater secures the buoy mooring line to anchor his vessel. *Source: NOAA*

A common mooring buoy system used in areas with flat, solid bedrock is the Halas system (Halas, 1985; Halas, 1997). The system consists of a stainless steel eye bolt cemented into a small hole 50 mm wide x 609 mm deep (2 in wide x 24 in deep) drilled into hard substrate. A floating line shackled to the eye bolt extends to the surface and through a polyethylene buoy to a pickup line, which attaches to a boat. The hole for the eye bolt is typically drilled in flat, solid, uncolonized bedrock using an underwater hydraulic drill. The hole is located away from branching coral formations that could catch or abrade the slack down line. Installation takes about 30 minutes to drill the hole and about another five minutes to set the steel rod with previously mixed hydraulic cement or epoxy. Installation does not produce significant amounts of sediments or destroy living coral colonies. The Halas system eliminates the need for the heavy chain used for conventional mooring systems, which can often damage the surrounding sea bottom (Project AWARE & PADI International Resort Association, 1996).

Embedment anchors suitable for soft bottom, such as sand, rubble, and seagrass beds, include systems such as the Manta Ray® and the Helix (Project AWARE & PADI International Resort Association, 1996). The Manta Ray® system consists of a utility anchor attached to an eight-foot anchor rod that is hammered under the soft bottom using a hydraulic underwater jackhammer and gad (Figure 2-43). The anchor is set using a load locker or by tying a line from the anchor to a workboat and driving the boat either forward or in reverse to apply pressure along the line and cause the anchor to open. A thimble eye at the upper end of the anchor rod is used for the attachment of the floating line, which extends to the surface through a buoy to a pick up line. Installation of a Manta Ray® System produces only minimal short-term impacts in the form of a small sediment plume during drilling. Installation time varies with sea bottom characteristics, but usually can be installed in less than 30 minutes.

Screwing mooring anchors, such as the Helix system, which uses circular shaft (disk dimensions: 10-25.4 cm [4-10 in], shaft 1.9-3.2 cm [0.75-1.25 in] x 114-168 cm [45-66 in]) are anchored by screwing the shaft into soil by hand using a steel rod to turn it. The termination end or exposed end of the shaft has an eye bolt to which a floating line is attached and extends to the surface through a polyethylene buoy to a pickup line.

For the installation of these systems, a vessel is necessary to access the area and serve as a work platform. Two diving teams usually perform buoy installation. Each diving team consists of a pair of divers. A support team in charge of boating safety, equipment, and material handling is also present on the vessel.

The installation of each mooring anchoring system may take between 35 and 45 minutes, depending on the depth and the type of substrate and system to be installed. If needed, hydraulic tools will be lowered to the sea bottom to divers. Air bags should be used to ease and control both the descent and ascent of the submerged tools to avoid dragging them on the seafloor. Dive teams assist in ensuring the vessel is anchored over the working site in an area and manner that does not impact marine habitat.

Figure 2-43. A diver installs a mooring buoy on the seafloor. *Source: NOAA*

Storm Moorings

Storm moorings in the form of designated mooring fields are used to secure watercraft during storms. Mooring fields for storm moorings consist of open link mooring chain laid out in parallel rows and secured to the seabed with hydraulically installed helical embedment anchors. Installation of embedment anchors is done using the same methods as described for the installation of recreational boat moorings. Individual mooring lines are attached to the ground chain between the installed helical embedment anchors, thereby spreading the load between the anchors. Marker buoys delineate where fore and aft secure shackle attachment points are connected to the ground chains in order for each boat to attach its individual down lines. Storm mooring fields are designed to allow sufficient room between boats and clear passageways for transiting boats.

Marker Buoys

Marker buoys are used to designate particular areas for use/nonuse by recreational boats and jet skis, swimmers, divers and snorkelers; to demarcate boundaries of preservation areas, zones in protected areas; and to identify shallow seagrass and reef areas, among other things. Buoys consist of a floating buoy or cylindrical floating pipe that can carry an informational message and are secured in a fashion similar to that used for mooring buoys based on the substrate (Figure 2-44). Where possible, marker buoys generally use round shaft anchors or weighted anchors and are placed in sand to avoid the expense and complication of drilling in bedrock.

Figure 2-44. Examples of marker buoys. Left: Yellow marker buoys are used denote zones with special regulations in the Florida Keys National Marine Sanctuary. Right: Spar buoys for Wildlife Management Areas and sites on the Shipwreck Trail in the Florida Keys National Marine Sanctuary. *Source: NOAA*

2.3.4.2 Debris Removal

Debris removal projects include coastal/beach clean-ups and in-water removal of debris (e.g., plastics, glass, metal and rubber, and derelict fishing gear). The purpose of debris removal is to eliminate immediate physical, biological, or chemical threats to the survival of living coastal and marine resources and their habitats. For in-water removal of debris caught/entangled on coral, SCUBA divers or snorkelers employ methods to reduce further negative impacts to coral (i.e., cutting nets and fishing line instead of pulling on the objects and breaking coral). SCUBA divers and snorkelers will also be trained how to safely remove debris to ensure it is not entangled and to avoid interactions with ESA-listed species.

For in-water marine debris removal efforts, a vessel may be necessary to access the area and serve as a work platform. A support team in charge of boating safety, equipment, and material handling should also present on the vessel. Air bags should be used to ease and control of ascent of any larger or heavy debris to avoid dragging items along the seafloor. Dive teams assist in ensuring the vessel is anchored over the working site in an area and manner that does not impact marine habitat.

For examples of previously funded marine removal projects, see https://data.nodc.noaa.gov/coris/library/NOAA/CRCP/other/grants/NFWF/NA10NOS4630103_Final_Reports/23649_forweb.pdf and https://data.nodc.noaa.gov/coris/library/NOAA/CRCP/other/other_crcp_publications/SEFCRI/FDOU_Project/FDOU_Project_29_30_32_Year3.pdf.

2.3.5 Outreach/Education and Program Operations

2.3.5.1 Education and Outreach

The CRCP also conducts several education and outreach activities including affixing signs within formation about conserving and protecting resources, involving the public and stakeholders in hands-on coral preservation and conservation activities, and outreach to members of the user community often using educational materials.

Signage

Informational and educational signs are placed in strategic locations to alert and educate the public about important conservation and preservation messages. Land-based educational signs are placed near streams, in coastal areas at sites determined to be highly visible by the public. Signboards are firmly fastened to a metal post or wood pole, which is secured in concrete in the ground or driven with a hammer into soft bottom substrate.

Educational signs may also be placed in the water as part of an underwater trail (Figure 2-45). Tail signs may either be signs posted on stone markers on the seafloor that may or may not include a floating buoy for easy identification or the marker is the floating buoy, which contains educational information on the buoy. The stone markers are placed on the seafloor and are held in place using stainless steel pins as described in 2.3.1.2, Instruments Moored to the Seafloor. Buoy markers are installed using the methods described in Section 2.3.4.1, Buoy Installation. Vessels and SCUBA divers will be necessary for the installation and maintenance of the markers. Air bags should be used to ease and control of ascent of any larger or heavy debris to avoid dragging items along the seafloor. If anchoring, the dive teams assist in ensuring the vessel is anchored over the working site in an area and in a way that does not impact marine habitat. The markers are maintained/cleaned by hand periodically by divers using plastic brushes.

Figure 2-45. A diver maintains an underwater stone marker trail sign at Buck Island National Monument, USVI.
Source: National Park Service

Hands-on Educational Activities

Some outreach activities involve bringing stakeholders into the field to experience and learn about coral reef resources first hand. These activities include training citizens to conduct biological assessments (e.g., fish and/or coral identification and measurements) or participate in on-the ground/in-water restoration. Trainings include not only the techniques needed to conduct the work and minimize impacts to corals and habitats, but also considerations regarding health and safety precautions need to conduct the various activities (Figure 2-46). In-water activities may involve diving/snorkeling from land or boat and kayaking along the coastline. Inexperienced snorkelers and swimmers are required to wear a floatation device. All divers participating must be certified for diving and have had proper training in diving and be capable of exhibiting responsible dive practices (e.g., proper buoyancy). Land-based activities may include walking in or near vegetative areas adjacent to the coastline and/or along beaches in order to conduct the restoration activities.

Figure 2-46. Left: An education event on coral reefs and snorkeling in the Manell-Geus watershed in Guam; Right: Snorkelers after orientation learn about Guam's coral reefs. *Source: NOAA, Valerie Brown*

Other Outreach Activities

The CRCP is engaged in national, international, and local outreach initiatives to build awareness of and support for coral reef conservation efforts. Associated activities include the development of posters, booklets, videos, and training materials for various audiences; and outreach to fishermen, local schools, and other user groups through community meetings. The CRCP also supports and maintains the Coral Reef Information System, which provides access to NOAA coral reef information and data products with emphasis on the U.S. states, territories, and remote island areas.

2.3.5.2 Data Analysis and Modeling

Computer-based analysis of data collected through mapping, monitoring, and research or that has been collected by other agencies or scientist. The data can be used to create a variety of models to help improve management and guide the implementation of projects.

2.3.5.3 Program and Interagency Coordination/Management

The CRCP oversees U.S. coordination efforts through the USCRTF by serving as its co-chair and steering committee secretariat. The CRCP reviews plans, policies, and regulations related to coral reef conservation and management; supports meetings; manages CRCP data; implements and manages external funding opportunities; and supports program staff and travel to implement the program activities and coordination**.** The CRCP also provides support for international conferences such as the International Coral Reef Symposium.

2.3.5.4 Operational Activities

To support its mapping, monitoring, research, and restoration activities, the CRCP uses NOAA ships, charter boats, and small vessels.

NOAA operates a wide assortment of hydrographic survey, oceanographic research, and fisheries survey vessels, which play a critical role in the collection of data to support CRCP's goals and objectives. All vessels are operated by NOAA's Office of Marine and Aviation Operations (OMAO), an office composed of civilians and officers of the NOAA Commissioned Corps. OMAO also manages the NOAA Diving Program and NOAA Small Boat Program.

Research and monitoring activities funded by the CRCP occurring in the Atlantic and Caribbean has typically been conducted on the NOAA research vessel *(R/V) Nancy Foster* and work in the Pacific Island used to use *R/V Hi'ialakai*. Future work in the Pacific will be conducted on other NOAA vessels due to the planned decommissioning of the *R/V Hi'ialakai*. The *R/V Nancy Foster* is one of the most operationally diverse platforms in the NOAA fleet. CRCP operations conducted on the *R/V Nancy Foster* include the characterization of habitats and fauna, bathymetric surveys, physical and chemical oceanography studies, and pollution assessments. This vessel employs state of the art navigation, propulsion, and mission systems resulting in high quality and efficient data collection with cutting edge technology including high-resolution multibeam echosounders, split-beam echosounders, and a vast array of oceanographic and atmospheric sensors. Additional capabilities include water and sediment sampling, net towing, sub-bottom profiling, diving with air and nitrox (Nitrogen/Oxygen mix that has more Oxygen than 21% and less Nitrogen than 79%), AUV and ROV support with dynamic positioning, small boat operations, and buoy servicing.

In some instances, it is not possible or appropriate to use NOAA vessels for CRCP funded activities; therefore, the principal investigators charter ships or small boats. All vessels chartered by NOAA shall meet applicable international, federal, state, and local pollution control laws and regulations. Vessels shall be outfitted and operated in accordance with applicable U.S. Coast Guard and International Maritime Organization regulations for the control of pollution by air emissions, sewage, oil, trash and garbage.

This document does not consider the following:

- Vessel operations that are not related to CRCP activities, such as transits to a new homeport or to a dry dock, to a non-CRCP funded activity, or from a non-CRCP funded activity to a port;
- Vessel construction and acquisition, repairs, maintenance, or upgrades, such as the installation or testing of new scientific equipment; and
- Any chartered vessel operations that are not undertaken as part of a CRCP-funded activity.

2.4 Alternatives

NEPA and the CEQ regulations require all EISs to include alternatives to the proposed action and require Federal agencies to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" 42 U.S.C. § 4332(C) & (E). CEQ considers the alternatives requirement so critical to informed decision-making that it refers to the alternatives analysis as the "heart of the [EIS]." 40 C.F.R. § 1502.14. Agencies must "rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated." 40 C.F.R. § 1502.14(a). The analysis must "[d]evote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits" 40 C.F.R. § 1502.14(b). It is well accepted that an agency must only consider "reasonable alternatives" bounded by the agency's purpose and need for acting and need not speculate or consider alternatives that are not viable.

2.4.1 Approach to Alternatives Analysis

Based on environmental issues identified through scoping and the objectives described above in the purpose and need statement, the CRCP developed and evaluated a reasonable range of alternatives for implementing the program in accordance with NEPA, CEQ's implementing regulations, and NOAA's internal implementing procedures set forth in the Companion Manual to NOAA Administrative Order 216-6A. Our approach to developing a reasonable range of alternatives follows:

- NOAA has set forth a basic statement of its purpose and need for taking action that will provide reasonable bounds for identifying viable courses of action;

- NOAA then developed screening criteria (2.4.1.1) based on objectives designed to achieve the stated purpose and need;
- Based on scoping to identify important issues of environmental concern and the criteria described below in Section 2.4.2.3, NOAA identified a range of alternatives potentially capable of meeting the agency's purpose and need;
- Each alternative was evaluated using the screening criteria described below in Section 2.4.1.1 to determine whether each alternative is viable. Viable alternatives were carried forward for full evaluation, and those determined not to meet the CRCP's purpose and need were not carried forward but NOAA provides an explanation supporting their exclusion;
- A No Action Alternative reflecting the "status quo" (i.e., current management of the CRCP), will be carried forward for detailed evaluation as it will establish an important baseline against which to compare and contrast one or more reasonable action alternatives.

2.4.1.1 Screening Criteria for Developing Reasonable Alternatives

Based on the purpose and need for action stated in Sections 1.4.1 and 1.4.2, an alternative for implementation of the CRCP must meet the following criteria to be considered a reasonable alternative carried forward for detailed consideration. The alternatives must:

A. Seeks to meet NOAA's duties and obligations and be consistent with the authorities specified by Congress in the CRCA;
B. Seeks to meet one or more goals established by the CRCP Strategic Plan Section 2.2;
C. Be implemented in a manner that ensures compliance with applicable statutory requirements protecting natural and cultural resources Section 1.10.3; and
D. Be implemented in a manner that is practicable from economic, technological, and policy standpoints.

2.4.2 Alternatives Carried Forward for Detailed Analysis

2.4.2.1 No Action Alternative

The No Action Alternative maintains the status quo of continued operation of the CRCP based on addressing the three primary threats (i.e., fishing impacts, land-based sources of pollution, and climate change), supporting research and possible application of coral restoration and intervention techniques to restore viable coral populations in response to to imminent threats, such as increased bleaching and disease, and addressing physical impacts to coral reefs. CRCP operations include the implementation of monitoring, mapping, research activities, watershed and coral reef restoration, reduction of physical impacts to coral reef ecosystems, outreach and education, and program operations as described above in Section 2.3. The CRCP would continue to be implemented using available appropriations, across four NOAA line offices, using a mix of internal and external funding, across existing geographic areas, and in collaboration with similar partners. The CRCP would continue to conduct program activities under the No Action Alternative in compliance with mandatory mitigation measures developed in compliance with applicable environmental laws such as the ESA as well as mitigation measures set forth in Appendix A. The CRCP does not currently require implementation of the Discretionary Conservation and Mitigation Measures (DCCMs) proposed in Appendix B. Some mitigation measures listed in Appendix B may be implemented on a project-by-project basis. For the purposes of this DPEIS, it is assumed that the activities would be conducted in the same manner as they currently are.

2.4.2.2 Alternative 1

Alternative 1 reflects the operation of the CRCP to address the three primary threats (i.e., fishing impacts, land-based sources of pollution, and climate change) but would not include the in-water activities that restore viable coral populations (i.e., in-water coral restoration and intervention techniques) and the activities that reduce physical impacts to coral reefs (i.e., marine debris removal and installation of buoys). This alternative would refocus CRCP's resources and efforts on and prioritize the three primary threats, which include monitoring and research to support coral reef fisheries and ecosystem management and conservation, on-the-ground watershed restoration to reduce land-based sedimentation and pollution, and outreach and education. The CRCP would continue to be implemented using available appropriations, across four NOAA line offices, using a mix of internal and external funding, across existing geographic areas, and using similar partners. The CRCP would continue to conduct program activities in compliance with mandatory mitigation measures listed in Appendix A and developed in compliance with applicable environmental laws such as the ESA.

2.4.2.3 Alternative 2

Alternative 2 is continued operation of CRCP including the in-water coral restoration and intervention activities and reduction of physical impacts to coral reef ecosystems that support restoring viable coral populations (i.e., the No Action Alternative) plus requiring the implementation of DCMMs (Appendix B).

2.4.2.4 Summary Comparison of Alternatives

The fundamental distinctions between the alternatives are listed in Table 2-2. The distinction between Alternative 1 and the No Action Alternative is that No Action Alternative includes restoration and intervention activities that support viable coral populations and activities that reduce physical impacts to coral reefs. Alternative 1 would therefore focus the CRCP's resources on addressing the three primary threats set forth in the CRCP Strategic Plan. The fundamental difference between Alternative 2 and the No Action Alternative is that Alternative 2 includes a suite of standard, DCMMs that would supplement the conservation and mitigation measures that are currently implemented. These mitigation measures would then be implemented across the program as mandatory. While some of the measures listed in Appendix B may be implemented on a project-by-project basis, there is no existing CRCP requirement mandating their implementation. All alternatives would require the CRCP to continue to be implemented in accordance with applicable law and mandatory mitigation and conservation measures developed through statutory compliance (e.g., terms and conditions set forth in the Incidental Take Statement of a Biological Opinion issued under Section 7 of the ESA). Discretionary measures developed through statutory compliance (e.g., conservation recommendations provided by NMFS Office of Habitat Conservation through an EFH consultation under the MSA) would be required to be implemented under Alternative 2, but would remain discretionary under the No Action Alternative. The lack of required discretionary mitigation measures is the primary distinction between the No Action Alternative and Alternative 2, and the impacts analysis in Chapter 4 therefore evaluates the distinction between the CRCP with (Alternative 2) and without (No Action Alternative) mandatory implementation of the measures listed in Appendix B. The summary of activities within each alternative is listed in Table 2-3.

Table 2-2. The implementation of the CRCP under each of the alternatives.

	No Action Alternative	Alternative 1	Alternative 2
Monitoring, mapping, and research	X	X	X
Coral restoration and interventions	X	--	X
Watershed management and restoration	X	X	X
Reduction of physical impacts to coral reef ecosystems	X	--	X
Outreach/education and program operations	X	X	X
Continued compliance with mandatory mitigation measures (Appendix A)	X	X	X
Requirement of discretionary conservation and mitigation measures(Appendix B)	--	--	X

Table 2-3. Summary of the on-the-ground and in-the-water activities anticipated under the proposed alternatives.

Activities	**No Action Alternative: Continued implementation of the CRCP Strategic Plan, which addresses land-based sources of pollution, improve fisheries sustainability, address climate impacts, and coral restoration.**	**Alternative 1: Implementation of activities to address the three primary threats - land-based sources of pollution, fishing impacts, and climate change.**	**Alternative 2: Implementation of the No Action Alternative supplemented with discretionary conservation and mitigation measures.**
Monitoring, Mapping, and Research Activities			
Biological Monitoring			
SCUBA and/or Snorkel Surveys	**X**	**X**	**X**
Stationary Cameras	**X**	**X**	**X**

SCUBA/Snorkel Mandatory Mitigation Measure	**X**	**X**	**X**
SCUBA/Snorkel Discretionary Mitigation Measure	**--**	**--**	**X**
Geological and Oceanographic Monitoring			
In-water Instruments (Moored and Moving)	**X**	**X**	**X**
Instruments Moored Discretionary Mitigation Measure	**--**	**--**	**X**
ROV Discretionary Mitigation Measures	**--**	**--**	**X**
Fish Monitoring and Detection Using Echosounder	**X**	**X**	**X**
Water Quality/Sediment Monitoring	**X**	**X**	**X**
Socioeconomic Monitoring	**X**	**X**	**X**
Mapping (in-water, aerial, and satellite)	**X**	**X**	**X**
Acoustic Mapping Discretionary Mitigation Measure	**--**	**--**	**X**
Research			
Tagging	**X**	**X**	**X**
Collection of Fish (Lethal/non-lethal and coral samples), Invertebrates, and Seagrass	**X**	**X**	**X**
Coral Fragments, Cores. Settlement Plates, Gamete collection, and measurements	**X**	**X**	**X**
Coral Collection Discretionary mitigation Measures	**--**	**--**	**X**

Invasive Species Discretionary Mitigation Measures	**--**	**--**	**X**
Coral restoration and interventions			
Coral Nursery			
***In-situ* Nursery Development/Enhancement**	**X**	**--**	**X**
Nursery Maintenance	**X**	**--**	**X**
Coral Transplantation	**X**	**--**	**X**
Coral Restoration Mitigation Measures	**--**	**--**	**X**
Other Interventions	**X**		**X**
Watershed Management and Restoration			
Technical Support for Watershed Management Plans	**X**	**X**	**X**
On-the-ground Watershed Restoration Activities	**X**	**X**	**X**
Watershed Restoration Discretionary Mitigation Measures	**--**	**--**	**X**
Projects that Might Temporarily Increase Sedimentation Mitigation Measures	**--**	**--**	**X**
Reducing physical impacts to coral reef ecosystems			
Buoy Installation	**X**		**X**
Marine Debris Removal	**X**		**X**
Buoy Installation Discretionary Mitigation Measures	**--**	**--**	**X**
Outreach/Education and Program Operations			

Outreach/Education	**X**	**X**	**X**
Data Analysis and Modeling	**X**	**X**	**X**
Program and Interagency Coordination/Administration	**X**	**X**	**X**
Operational Activities (Vessels)	**X**	**X**	**X**
Discretionary Mitigation Measures - Other	**--**	**--**	**X**

2.4.3 Alternatives Initially Considered but not Carried Forward

2.4.3.1 Functional Alternative

NOAA considered the functional alternative of shifting management and conservation of coral reefs to non-NOAA organizations. Under this alternative, coral management and conservation would shift primarily to other Federal agencies, states, territories, and local governments. NOAA did not carry this alternative forward as it did not meet screening criteria A and B (see Section 2.4.1.1). Shifting management in this manner would not meet NOAA's obligations under the CRCA. NOAA did not identify any other functional alternatives to consider.

2.4.3.2 Operational Alternatives

The primary operational alternatives considered altering the mechanism and distribution of funding and effort (e.g., assistance awards, internal implementation, etc.) and modifying program priorities. NOAA did not carry these operational alternatives forward as they did not meet screening criteria B and D. These operational alternatives were thoroughly considered and addressed in the planning process that culminated with the CRCP Strategic Plan. The CRCP Strategic Plan has been finalized and sets forth program objectives, priorities, and guidance. That plan was adopted after substantial outreach to and coordination with a wide array of stakeholders and affected parties and reflects their input. Reinitiating the planning process to consider these alternatives again would be inefficient, waste limited administrative resources, and disrupt program implementation. Other operational alternatives focused on achieving efficiencies in managing the program. Alternative means of implementing mitigation measures would meet all four screening criteria and thus meet the purpose and need for the proposed action. These operational alternatives have been carried forward for detailed analysis in this DPEIS. Public comments submitted in response to our publication of the NOI to prepare a PEIS suggested expanding the range of alternatives to include an expansive set of intervention techniques to respond to threats to coral reefs through spatial management, restoration, pollution control, and providing resources to repair reefs. Measures to combat the adverse effects of fishing and land-based pollution are already included in the CRCP and will continue to be refined and implemented over time. In addition, researching and implementing novel intervention techniques related to coral restoration, as suggested, is already included in the No Action Alternative and Alternative 2. Adding additional measures such as regulation of fisheries, establishment of marine protected areas, and development of an insurance program to repair reefs in the event of a disaster, while laudable objectives, are beyond the scope of the CRCP's authority and existing policy for the program and thus inconsistent with screening criterion D. The CRCP considers these suggestions to be alternatives for additional program elements rather than mitigation for program activities. The focus of mitigation efforts will be on avoiding or minimizing adverse impacts to marine resources as the CRCP is implemented through project-specific activities over time.

3. AFFECTED ENVIRONMENT

3.1 Introduction

The Affected Environment section of this DPEIS describes the existing areas and resources likely to be affected by the CRCP, in compliance with the CEQ regulations 40 C.F.R. § 1502.15 and 1980, the NOAA's 216-6A Companion Manual, which states:

> "The environmental impact statement shall succinctly describe the environment of the area(s) to be affected or created by the alternatives under consideration. The descriptions shall be no longer than is necessary to understand the effects of the alternatives. Data and analyses in a statement shall be commensurate with the importance of the impact, with less important material summarized, consolidated, or simply referenced. Agencies shall avoid useless bulk in statements and shall concentrate effort and attention on important issues. Verbose descriptions of the affected environment are themselves no measure of the adequacy of an environmental impact statement."

This chapter describes resources likely to be affected directly, indirectly, or cumulatively by the No Action Alternative and two Action Alternatives. If other resources present within the area of potential effect are unlikely to be affected, they will receive only brief evaluations in the following Environmental Consequences chapter. Chapter three is organized by resource categories that are common across all CRCP areas of influence, followed by details regarding applicable CRCP jurisdictions. Past and ongoing factors that influence the current condition of resources discussed is guided by internal and external scoping, including public comment in response to NOAA's publication of a Notice of Intent to prepare an EIS (Note- provide a hyperlink here for this NOI). Where appropriate, information from relevant existing documentation is incorporated by reference, in compliance with 40 C.F.R. § 1502.21.

The affected environment for the CRCP covers the areas with tropical coral reef ecosystems within the U.S., U.S. territories, and within the Coral Triangle (formed by the Philippines, Malaysia, and Solomon Islands) and Caribbean Sea. Affected resources include coral reef, mangrove, and seagrass habitats, the surrounding water column, as well as the living coastal and marine resources that use these habitats such as algae, plankton, and diverse invertebrate and vertebrate species. The U.S. has jurisdiction over an estimated 19,702 km^2 of shallow-water coral reefs. Thus, the extent of the potentially affected environment associated with the proposed action is substantial and includes all tropical coral reef habitats in state and territorial waters, plus offshore habitats and coastal areas that influence or affect coral reef ecosystems within the U.S. Exclusive Economic Zone (Figures 1-1 and 1-2).

Approach to use of Chapter 3:

- This is a programmatic document and description of the affected environment will only focus on primary environmental resources likely to be impacted by CRCP activities;

- The description of the affected environment is presented at two levels--first, a general description of common resources that occur in all geographic areas within the action area, and second, a more specific description focuses on resources within each jurisdiction;
- The vast majority of data and information necessary to describe the affected environment at a programmatic or planning level exists; and
- Historical natural and anthropogenic trends are directly related to the current condition of resources described in the affected environment and are discussed in Chapter 3 to provide an understanding of the conditions and causes leading to the "snapshot" of the current condition of resources and therefore discussed in this chapter and, where appropriate, cross referenced in Chapter 4's evaluation of cumulative impacts.

3.1.1 The context in which Action Occurs

Global coral health in the context of time is an important and overarching consideration for understanding the Affected Environment descriptions below. A snapshot of coral reef ecosystems does not effectively describe the conditions that CRCP activities are impacting. Global environmental trends discussed below are already having significant negative impacts on coral reef ecosystems.

Corals have already survived multiple major extinction events, which can be attributed to changes in global temperatures and ocean circulation patterns (Hallock, 1997; Kiessling, 2001; Pandolfi et al., 2011). In the Modern era, global mean greenhouse gases have increased since the advent of the Industrial Era, leading to an increase in atmospheric and ocean temperatures, sea level, and ocean acidification (Pachauri et al., 2014).

These increasing trends for temperature, sea level, and ocean acidification have only accelerated in recent years and with them so have the frequency and severity of coral bleaching events (Glynn, 1993; Gattuso et al., 2014; Hoegh-Guldberg et al., 2014; Hughes et al., 2018), resulting in significant mortality worldwide. Earth's current climate is comparable to the Paleocene/Eocene Thermal Maximum, which was also characterized by a rapid rise in atmospheric greenhouse gas concentrations, increased temperatures, sea level height, and ocean acidification, resulting in a global reduction of coral (Pandolfi et al., 2011). This impact of this acceleration is most visible for ocean temperatures, which triggered a three-year, global bleaching event from 2014-2017 that was without precedent in recorded history (Eakin et al., 2018). This 36-month event brought bleaching-level thermal stress to 75% and mortality-level stress to 30% of the world's shallow-water coral reefs, with much more severe levels locally (Eakin et al., 2018).

Ocean temperatures have a substantial impact on coral health. During periods of thermal stress, the corals expel their symbiotic zooxanthellae (known as "coral bleaching"), which removes a primary energy and oxygen source for the coral. Although coral can recover from a bleaching episode, bleaching leaves corals vulnerable to disease and other stressors and can also lead to mortality (Brandt & Mcmanus, 2009; Brandt et al., 2013). As outlined in Section 3.1.1, thermally-induced global bleaching events are occurring with greater frequency and intensity due to climate change.

Kennedy et al. (2002), Link et al. (2015), and Osgood (2008) suggest global climate change could affect temperature changes in coastal and marine ecosystems. These changes can influence organisms' metabolisms and alter ecological processes such as productivity and species' interactions; changes precipitation patterns and lead to a rise in sea level which could change the water balance of coastal ecosystems; alter patterns of wind and water circulation in the ocean environment; and influence the productivity of critical coastal ecosystems such as wetlands, estuaries, and coral reefs. The distribution of native and exotic species, the prevalence of disease in keystone animals such as corals and the occurrence and intensity of toxic algal blooms may also change with increased water temperature.

Ocean acidification, or the decline in ocean pH due to an increase in CO_2 molecules caused by rising atmospheric CO_2 (Sabine et al., 2004), is another hazard to coral reef health (Anthony et al., 2011; Pandolfi, 2011). This acidification makes it difficult for corals to build their skeletons and requires them to use more energy (Pandolfi, 2011). This additional stress makes corals more prone to disease and bleaching.

Global sea level changes are of particular concern for corals. Decreases in sea level may lead to increased exposure at low tides and potentially high rates of coral mortality. Because corals grow slowly, they may be able to survive and continue building reefs with very gradual rises in sea level. However, rapid sea-level rise that outpaces the growth rate of coral also poses a threat to corals if they become less exposed to the sunlight required for survival in deeper waters (Hoegh-Guldberg et al., 2007).

Coral threats are not limited to climate change-related stressors. Land-based sources of pollution and overfishing are also factors that have and continue to contribute to the decline of coral reef systems. Land-based sources of pollution include the human-produced plastics and chemicals that are harmful to corals and the excessive nutrient loading caused by changing land use upstream and shoreline erosion (Hall et al., 2015; Zaneveld et al., 2016). These factors increase coral susceptibility to disease and mortality and increase the vulnerability of other related ecosystem components, such as seagrasses and mangroves, to environmental effects.

3.2 Physical Environment

3.2.1 Action Area

While deepwater corals exist in many regions throughout the world, the primary focus of the CRCP has been on the shallow (<30 m [<90 ft] depth) and mesophotic (30-150 m [90-500 ft] depth) coral reefs and associated life forms found between 30ºN latitude and 30ºS latitude. The majority of the CRCP funding supports activities within U.S. waters nestled within the 200 nm exclusive economic zone (EEZ) in seven jurisdictions: USVI, Puerto Rico, Florida, Hawaii, American Samoa, the CNMI, and Guam. In addition, the CRCP also occasionally supports activities within Pacific Remote Islands Marine National Monument (PRIMNM) (i.e., Baker, Howland, Jarvis, Johnston, Kingman, Palmyra, and Wake); deeper reefs in the northern Gulf of Mexico (including the Flower Garden Banks); the western Atlantic and the Caribbean Basin (Figure 3-1). Although the CRCP supports coral reef conservation activities in some international areas, such activities are primarily administrative, such as workshops, in the Freely Associated States (i.e., Federated States of Micronesia, Palau, and the Republic of the Marshall Islands); Western Samoa; and the Coral Triangle Region (i.e., Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands and Timor-Leste). In addition, some small monitoring efforts occur in the Freely Associated States.

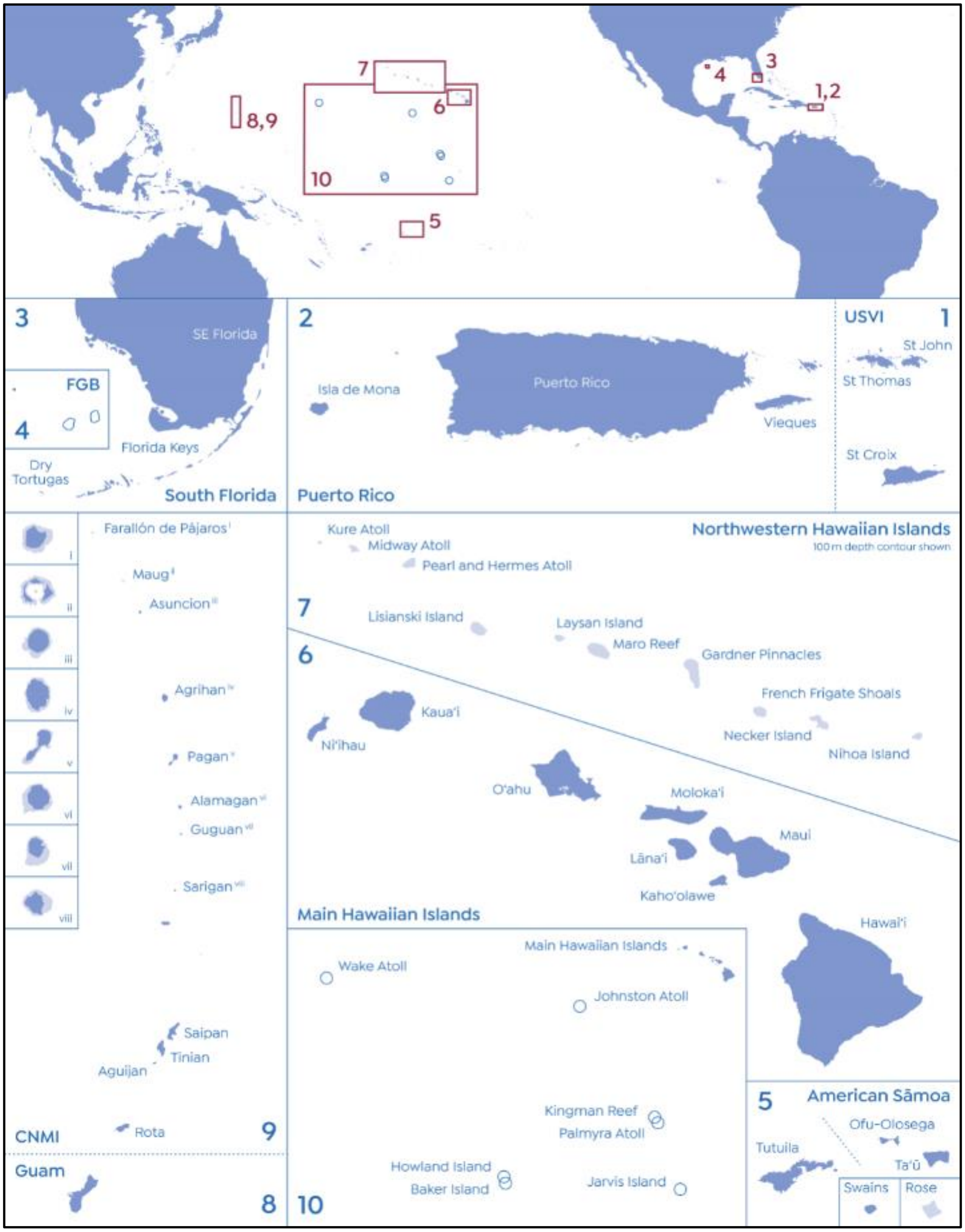

Figure 3-1. Map of U.S. areas with coral reefs. *Source: NOAA*

CRCP activities are not restricted to coral reefs. Coral reef health can be linked to conditions upstream, whereby land-based sources of pollution and land use practices that generate sediment and other pollutants across those watersheds drain into coral reef areas. CRCP research activities related to coral health, fisheries, and restoration also utilize terrestrial and marine spaces for indoor and outdoor laboratories and coral nurseries.

3.2.2 Existing Natural Hazards

The status and health of coral reef ecosystems are heavily influenced by their oceanographic setting and natural disasters. This includes ocean temperatures, ocean pH, relative sea level, coastal erosion, tropical storms, earthquakes, tsunamis, and volcanic activity. This section discusses how these natural hazards affect coral health.

3.2.2.1 Coastal erosion, transport, and deposition

Erosion and changes in sediment transport and deposition may be affected by coastal development, ocean energy, and strong weather events. Coastal development can reduce vegetation that retains sediments and increase coastline hardness via construction of seawalls or other similar structures. Energy from ocean currents and waves affect coral reefs and coastlines through erosion and breaking corals and other hard structures. Nearshore ocean currents transport and deposit eroded and other loose sediments. Sediment deposition on coral reefs can suffocate corals or reduce light available for photosynthesis of zooxanthellae, thus affecting coral health.

Common coastal habitats include maritime forests, scrub thickets, freshwater swamps, freshwater marshes, mangrove swamps, saltwater and brackish marshes and swamps, and grassy or forested dunes (Morton et al., 2004). Each type of coastal vegetation has unique features that can retard land loss. For example, dense stands of salt marsh and mangroves trap sediment or offer resistance to waves and currents so that land loss is prevented or mitigated. Dune grasses also help stabilize blowing sand and can assist in dune enlargement. However, the roots of grasses and trees are generally too shallow to reduce erosion from large storm waves that lower the back beach and undercut the dunes or uplands (Morton et al., 2004). The density and type of vegetative cover also influence land loss by dissipating the wave energy reaching sheltered shores, encouraging the accumulation of organic and inorganic sediment, and acting as a sediment binder that resists erosion.

3.2.2.2 Tropical Storms

In contrast to the chronic effects of routine ocean currents and wave energy, U.S. coral reefs are also subject to acute and extreme impacts of storms. Importantly, in coastal areas with healthy coral reefs, the reefs are valuable natural infrastructure that provide the ecosystem service of storm protection by attenuating waves, which reduces damage from storm surges and wave action. In the Atlantic, storms form off the West African coast and move toward the Caribbean. Most recently, Hurricanes Irma (2017) and Maria (2017) damaged coral reefs in the USVI, Puerto Rico, and Florida. More storms hit Florida than any other U.S. state, and since 1851 only eighteen hurricane seasons have passed without a known storm impacting the state, with a cumulative impact from the storms totaling over $191 billion in damage (2017 USD) (Pasch et al., 2019).

Coral jurisdictions in the Pacific are also subject to tropical storm system impacts. In American Samoa, these systems usually form when sea surface temperatures are at their highest, during the months of November through May. The CNMI is centrally located in the most prolific tropical cyclone basin. Coastal flooding, inundation, and inland flooding from tropical typhoons and monsoon surges pose the greatest acute threat to the CNMI’s communities, watersheds, and reef ecosystems. Similarly, Guam has been hit by four typhoons with sustained winds greater than 150 mph since 1994. Although Guam has been spared a direct hit by a typhoon-strength storm since Super Typhoon Pongsona in December 2002, storm systems regularly pass close to the island (U.S. Naval Oceanography Command Center, 1990).

The impacts of tropical storms on coral reefs vary. Storm surges can result in the grounding of vessels and loss of fishing gear, which physically damages coral reefs. High wave energy, coupled with storm surges, may cause coral to break or overturn. Although such physical damage can be bad for corals, fragmentation of certain types of corals, such as branching corals, facilitates asexual reproductive success. Furthermore, severe storms can also transport marine debris that could physically damage corals. Storms may also increase suspension of sediments, erosion, and transport of inland sediments and debris via rivers swollen from large precipitation events, all of which negatively affect coral directly, via smothering, and indirectly, through reduced water clarity and salinity. The heavy precipitation can be exacerbated by urban runoff, failing sewage systems, unpaved roads, farms, land clearing and development, increasing the consequences for culturally significant fishing activities, marine-related tourism, and overall reef resilience (World Bank Organization, 2017). However, during periods of high water temperature, heavy precipitation from storms can cool temperatures, thus reducing the extent of coral bleaching and enabling conditions that allow for recovery from bleaching.

3.2.2.3 Disease

Corals are affected by an array of diseases, which can cause mortality on an ocean-basin scale. In the Caribbean, coral diseases include white plague-II, yellow band disease, white band, black band, white pox, red band, Caribbean ciliate infection, dark spots disease, fungal aspergillosis, and tumors. These diseases are especially prevalent during times of stress (e.g., bleaching), as demonstrated in 2005 when a bleaching event coincided with a 2,530% increase in disease lesions, a 770% increase in denuded skeletons, and a loss of 51.5% live coral cover in the USVI (Miller et al., 2006) and intense outbreaks of white plague-II and yellow band disease mainly affecting *Montastraea*, *Diploria*, and *Colpophyllia* species in Puerto Rico (Garcia-Sais et al., 2008).

Numerous diseases have been documented with increasing frequency since the first reports of coral disease in the Florida Keys emerged in the 1970's (e.g., Porter et al., 2001). The Florida Reef Tract is currently experiencing one of the most widespread and virulent disease outbreaks on record: stony coral tissue loss disease (Sharp & Maxwell, 2018). This disease is one previously unknown and its outbreak has resulted in the mortality of thousands of colonies of at least 20 species of scleractinians, including primary reef builders and ESA-listed species (Sharp & Maxwell, 2018). The disease was first reported near Key Biscayne in 2014 (Precht et al., 2016) and progressed southward along the Florida Reef Tract, reaching Key West by December 2017 (Sharp & Maxwell, 2018). The disease has since spread to St. Thomas in USVI, Bahamas, Jamaica, Mexico, and likely other locations throughout the Caribbean. A limited understanding of the disease outbreak, due to limited diagnostic capacity, and its mode and rate of transmission, has greatly hindered management efforts to control or prevent the spread of the disease (Sharp & Maxwell, 2018).

In the Pacific, coral populations continue to be spared from epidemic disease outbreaks. However, a 2003 survey (N=73) of the Northwestern Hawaiian Islands found ten types of coral diseases (Aeby, 2006). The coral diseases were found at most of the survey sites (68.5%) but at low levels of occurrence with an average of 0.5 % colonies showing signs of infection (Aeby, 2006). Additional surveys in 2004 and 2005 identified 12 coral diseases across the Hawaiian Archipelago (Aeby, 2011). These diseases included *Porites* growth anomalies, *Porites* trematodiasis, *Porites* multi-focal tissue loss, *Porites* discolored tissue thinning syndrome, *Porites* brown necrotizing disease, *Porites* bleaching with tissue loss, *Montipora* multifoci tissue loss syndrome, *Montipora* white syndrome, *Montipora* patchy tissue loss, *Montipora* growth anomaly, *Acropora* white syndrome, and *Acropora* growth anomaly (Aeby, 2006; Aeby, 2011). Later, a 2004 disease outbreak around Kauai was determined to be black band disease (Aeby et al., 2015). *Montipor*a white syndrome, which causes acute tissue loss, has been documented throughout the main Hawaiian Islands; however, prevalence of this disease is approximately four times higher in Kaneohe Bay, Oahu (average prevalence=0.27 + 0.08% SE) than in the other main islands (Friedlander et al., 2008).

Coral diseases in American Samoa are widespread and present on regularly monitored coral reefs, though only a very small proportion (0.14%) are affected, with the most common disease being the white syndrome, similar to that found on the Great Barrier Reef (Fenner, 2019). Likewise, white syndrome appears to be the most prevalent disease in Guam (observed in nine out of 10 sites) and the source of greatest tissue mortality, though black band disease, brown band disease, ulcerative white spots, and multiple growth anomalies are also present on Guam reefs (Burdick et al., 2008; Cheney, 1977; Raymundo et al., 2003).

3.2.3 Ridge to Reef Habitats

CRCP-supported activities occur in some inland habitats affecting marine or estuarine waters. They may also affect adjacent or continuous habitats that support living coastal and marine resources. Habitats and their geological and soil resources that may be impacted vary among and within jurisdictions and include sandy beaches, cays/keys, rocky coastlines, mud bottoms, and many other types of substrates and source materials. Geologic features and soils depend on location, local physical geography, climate, geologic activity level, and a number of other attributes. A general description of the types of habitats in the affected areas follows.

3.2.3.1 Riparian and Upland Habitat

The riparian zone is defined by the area within the floodplain or a zone hydrologically influenced by a stream or river (Hunt, 1988). Riparian environments are maintained by high water tables and experience seasonal or periodic flooding. The characteristics of the riparian zone vary between regions, river and watershed size, and stream order. Riparian habitat may also contain or adjoin riverine wetlands and share with them functions including water storage, sediment retention, nutrient and contaminant removal, and maintenance of habitat for plants and animals. These ecosystems have distinctive vegetation and soils, and are characterized by the combination of species diversity, density, and productivity. There are continuous interactions between riparian, aquatic, and upland ecosystems via the transfer or exchange of energy, nutrients, and species (National Research Council, 1995).

3.2.3.2 Beaches and Dunes

Sandy beaches include sandy bluffs, embayments, barrier islands, and dunes consisting of fine to coarse (diameters from 0.5 mm to 2 mm) sediments and may contain substantial amounts of shell fragments. They are naturally unstable due to constant action of waves, currents, and winds, with sand seasonally moving offshore and onshore. These beaches exhibit low species diversity, but high densities of those tolerant species, like some invertebrates, that can withstand the high-energy conditions.

Sand dunes form when wind and waves push sand above the mean high water level where it is trapped by coarser sediments or vegetation. Dunes mature via plant succession, with small, salt-tolerant pioneer species overtaken by woodier species to form maritime forests, if given a stable environment. Dunes provide habitat for organisms including seabirds and sea turtles that rely on beaches for nesting habitat.

3.2.3.3 Mudflats

Mudflats are level and unvegetated areas adjacent to shorelines or islands, often backed by sandy beaches or marshes and occur in areas where general circulation results in sediment deposition (Thayer et al., 2003). Composed of fine-grained sediments and covered with shallow-water at low-water tidal areas where exposure to the air is temporary, they provide both burrowing habitat for invertebrates and feeding grounds for birds and fish (Mitsch & Gosselink, 2000). Mudflats provide key substrata for biofilms, or communities of microorganisms (collectively called microphytobenthos) embedded in a matrix of polymeric compounds, which are dominated by photosynthetic microalgae, mostly diatoms (De Brouwer & Stal, 2001). These biofilms provide food source for snails and other invertebrates, a few species of fish, and shorebirds. Disruptive events, can have a major impact on these microscopic communities and impact the mudflat ecosystem as a whole.

3.2.3.4 Subtidal Bottom

Subtidal bottoms below the low tide line can be either hard or soft substrates. They are composed of unconsolidated fine- to coarse-grained sediments. Located adjacent to beaches or other sediment sources (Thayer et al., 2003), they can support a diversity of fauna, depending on factors including the type of substrate (i.e., sand or mud), content of organic matter, and depth. Many subtidal bottoms are dominated by infaunal invertebrates, including polychaete worms, crustaceans, echinoderms, and mollusks.

Subtidal bottom ecology is sensitive to pollution, such as wastewater discharge, that alters levels of organic and small particulate material. The often vague physical distinction between sand and mud habitats creates overlap in species distributions. The species assemblages of the subtidal soft bottom are divided into offshore eelgrass bed, subtidal mud, and subtidal sand ecotypes (Ricketts et al., 1985).

3.2.3.5 Soft-Bottom Habitat

Soft-bottom habitat is formed by unconsolidated sediments that lack vascular plants (i.e., seagrasses). Although soft-bottom habitat lacks visible structural features, many microscopic plants occur at the sediment surface and burrowing invertebrates, such as polychaetes and crustaceans, commonly occur below the surface (Peterson, 1979; Alongi, 1990). Soft-bottom habitats provide ecological services to coastal ecosystems, such as biogeochemical processing and recycling of watershed-derived nutrients and toxic substances (Peterson & Lubchenco, 1997) in addition to foraging habitat for many fishery species and their prey. The high availability of food and refuge for predators make soft-bottom habitats, especially those in shallow-waters and close to mangroves, seagrass, live/hard bottom, or inlets, important nursery areas for many species of juvenile fish (Ross & Epperly, 1985). Flatfishes, rays, and small cryptic species, such as shrimp and crabs, can bury in the sediment, camouflaging themselves from predators whereas predators in shallow-water also bury themselves, relying upon ambush tactics for feeding. Consequently, many fishes, crabs, and shrimp in subtidal, soft bottom habitats forage nocturnally (Summerson & Peterson, 1984).

3.2.3.6 Hard-Bottom Habitat

Hard-bottom constitutes a group of communities characterized by a thin veneer of corals or other sessile, benthic organisms that secrete a skeleton or shell (alive or dead) and other biota overlying assorted sediment types. Hard bottom usually has low relief and is on the continental shelf (Bright et al., 1991) and many are associated with relic reefs where the coral veneer is supported by coquina, limestone, or relic coral, molluscan, and annelid reefs. Diverse biotic zonation patterns have evolved in many of these communities because of their geologic structure and geographic location. Species compositions may vary dependent upon water depth and associated parameters (light, temperature, etc.) (NOAA, 1998).

3.2.3.7 Coral Reefs

The U.S. has jurisdiction over an estimated 19,700 km^2 of coral reefs, not including the Freely Associated States (Turgeon et al., 2002). Twenty-two coral species from the Caribbean and Indo-Pacific regions are listed under the ESA (Appendix E). Coral reefs provide habitat for thousands of species of fish and shellfish and hundreds of species of corals, algae, sponges, echinoderms, mollusks, bryozoans, crustaceans, and many other groups of organisms (Reaka-Kudla, 1997). Therefore, the health of coral reefs has profound implications on these species and on the marine ecosystem as a whole. Some of the functional roles of coral reefs and associated habitats include:

- Complex, high-relief habitat that serves as refuge for motile fish and invertebrates and microhabitats for cryptic fauna and flora;
- Breeding, feeding, and nursery habitats for a variety of marine species;
- Hard substrate for settlement and growth of sessile organisms;
- Enhancement of global biogeochemical cycles including a storehouse of carbon dioxide;
- High productivity based on sunlight and coral/zooxanthellae symbiosis that supports a complex food web;
- Repository of marine biodiversity with potential medicinal use substances;
- Recreational opportunities, such as diving and snorkeling;
- Protection for coastal areas from strong wave action and full impacts of storms, of which they absorb 97% (Ferrario et al., 2014); and
- Natural recorders of past climate and environmental variation.

The CRCP focuses on shallow-water coral reefs, whose location makes them especially vulnerable to the constant oceanographic forcing of currents, waves, and tides whose energy is greatest in shallow depths. These corals require proximity to the ocean surface for exposure to sunlight, which drives photosynthesis within their dinoflagellate symbionts, providing nutrients essential for coral growth and reproductive processes (Muscatine et al., 1977). Generally, shallow-water corals require fully marine waters, stable and warm temperatures, low wave energy and turbidity, ample sunlight, and the presence of suitable substratum. Coral reef systems are often strongly linked to upstream freshwater and terrestrial systems and, therefore, cannot be treated as completely independent from separate from these watersheds and shorelines (Virginia Institute of Marine Science, 1975). These associated catchments' health is influential to that of coral reefs.

Shallow-water reef-building corals are tiny individual polyps that cluster together to form larger coral colonies. A typical coral reef is composed of complexes of coral colonies and other organisms that construct a calcium carbonate (limestone) structure. Living corals and other benthic organisms form a thin veneer that overlies this limestone framework that has been deposited over thousands of years by previous reef-building individuals. This structure is solidified by the combined processes of cementing crustose coralline algae, mechanical action of waves, bioerosion from boring sponges and other organisms, and the chemical action of rainwater. Reef-building stony corals are the predominant organisms responsible for most of the reef's framework growth, followed by crustose coralline algae on wave exposed reef slopes, and green algae (e.g., *Halimeda* spp.) in back reef and lagoonal depositional zones (Zundelevich et al., 2007).

Coral reefs can be broadly classified into four types (Darwin, 1889): fringing reefs, which grow close to shorelines and generally have a high degree of non-carbonate sediment; barrier reefs, which are offshore and have a high degree of consolidated limestone sediments; atolls, which are a wall of reefs that encloses a central lagoon; and those which do not fall into any of these classifications, such as platform, pinnacle, and patch reefs. Coral reefs may be further described by their geomorphology and predominant biotic communities. Eleven geoform types of shallow-water and mesophotic coral reefs include aggregate coral reef, shallow/mesophotic coral carbonate mound, coral head/bomme, coral pinnacle, fragile mesophotic coral reef, fringing coral reef, halo, linear coral reef, patch coral reef, and spur and groove coral reef (FGDC, 2012).

For most coral reef types, there are distinct zones, defined by differences in depth, wave energy, currents, light, temperature, and sediment (Figure 3-2). The zone closest to shore is broadly called the reef flat, comprised of the lagoon and back reef areas. Shallow-waters in the reef flat are protected from waves behind the reef crest and experience a large range in temperature and salinity and accumulate sediments. Coral growth in this zone is limited by these extreme conditions. Despite low coral cover and extreme swings in environmental conditions, this reef flat is a haven for marine species (NOAA, 2017a).

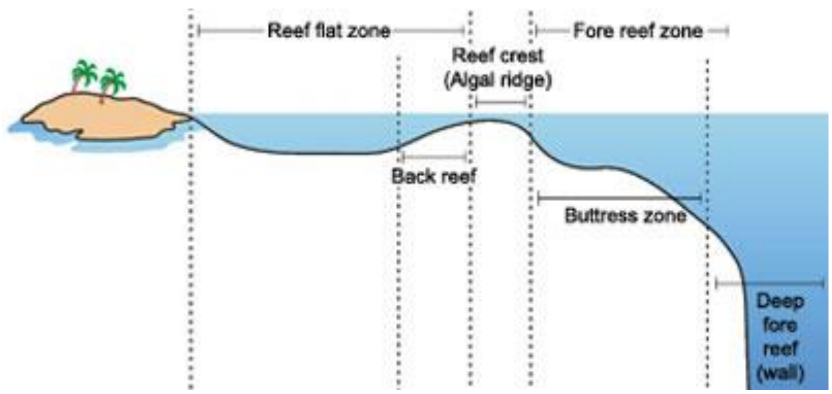

Figure 3-2. A diagram showing the different zones of a coral reef system.
Source: Cayman Islands Twilight Zone 2007 Exploration, Kyle Carothers, NOAA-OE

The reef crest protects the lagoon and is the highest point of the reef and absorbs the constant wave action from the open sea. Encrusting algae are prevalent, constantly repairing the wave damage to strong, closely-knit corals, which brace against the waves. This structure provides shelter to marine species seeking refuge.

Beyond the reef crest is the fore reef, comprised of the buttress zone and reef wall. Corals protrude seaward and create wave-reflecting vertical channels that help to drain sediments. As the buttress drops off to the reef wall, light and wave energy diminish and sediments increase with depth.

While most of the reef environment is depositional, the seaward growing portion of the reef is essential for the survival and maintenance of the rest of the reef system (Hoegh-Guldberg, 1999). Coral reefs predominate in many tropical benthic environments because of their ability to grow or maintain structures in the face of heavy or prevailing wave action. Coral may predominate a habitat (coral reefs), be a component of a habitat (hardbottom), or exist as individuals within a community characterized by other fauna (solitary corals) (GMFMC, 1998; NOAA, 2011).

Two of the main outputs of reefs are organic and inorganic carbon production. Reef organisms fix carbon for the production of their skeletons. The resulting skeletal structure provides a substrate for the settlement and attachment of other sessile organisms, as well as topographical relief that serves as habitat for motile fishes and invertebrates. Coral and algal skeletal materials are also broken down into sediments that form beaches and soft bottom habitats, are incorporated into the reef structure, and form an important part of the inorganic carbon pathway. Primary production of organic carbon by symbiotic zooxanthellae, turf algae, macroalgae, and coralline algae supports the diverse organisms and complex food webs found on coral reefs. Through herbivore grazing and dislodgement, turf algae and frondose algae are maintained in an early stage of growth and ecological succession where rates of photosynthesis and growth are highest. Secondary consumers (predators of herbivorous fishes and invertebrates) further enhance reef productivity by maintaining their prey in high growth phases and by supplying concentrated nutrients to their prey (McClanahan et al., 2002).

3.2.4 Environmental Quality

3.2.4.1 Water Resources and Quality

Water quality is a generic term that describes the relationship between concentrations of various chemical and physical contaminants or pollutants and the ability of water resources to support their ecosystems adequately. Water quality is a function of many factors, including nitrogen, phosphorus, chlorophyll a, dissolved oxygen content, and water clarity.

Water resources in the areas that could be affected by CRCP-supported projects include surface waters and groundwater. Surface waters include marine waters (oceanic), which support tidally influenced water bodies (such as estuaries), coastal wetlands, coral reefs, mangrove forests, and upwelling areas, among others. Nontidal freshwater resources include those inland rivers, streams, and their corresponding floodplains, in addition to lakes and ponds. Water resources also are affected by or associated stormwater runoff (point and nonpoint releases), which can directly and indirectly affect water quality.

The ocean waters (Pacific and Atlantic, including the Gulf of Mexico and Caribbean Sea) that border the U.S. coral jurisdictions are saline (marine) to varying degrees. These marine waters are the primary medium for living coastal and marine resources and comprise the bulk of essential fish habitat (Section 3.4.2 - Regulatory Environment). Marine water quality is altered by point and nonpoint source pollution from agricultural and stormwater runoff and wastewater discharge. Pollution, including eutrophication and sedimentation associated with land-based activities, has been associated with the degradation of water quality and coral reef health and diversity (LaPointe et al., 2010). Some of the sources of land-based pollution include: improper coastal development, road construction, dredging and beach renourishment, land clearing for agriculture, golf course irrigation, discharge of untreated sewage, industrial waste, agrochemicals, and pharmaceuticals, and chemical and oil spills. Pollution not only affects the physical environment and the numbers of species and individuals that live in these waters, but also impacts human welfare through the exposure to contaminants, through possible consumption of exposed fish/shellfish and swimming, and the loss of recreational and commercial opportunities (EPA, 2004).

While excess nutrients are generally a problem for coral reefs, a continuous supply of inorganic nutrients is essential for maintenance of metabolic processes, the proper functioning of reef ecosystems, and the persistence of coral- and coralline algae-predominated communities. Many coral reefs occur in regions subjected to seasonal upwelling or other natural events that contribute temporary pulses of nutrients.

Nutrient fluxes associated with upwelling events, currents, tides and other sources can play an important role in overall productivity of coral reefs. Furthermore, reefs can persist in areas affected by nutrient loading, provided that the herbivores are sufficiently abundant and diverse to control the proliferation of macroalgae and cyanobacteria (Holbrook et al., 2016).

Estuaries are generally enclosed in part by the coastline, marshes, and wetlands; the seaward border may be barrier islands, reefs, and sand flats or mud flats. These areas of transition between the land and the sea are tidally driven, but, like rivers, they are sheltered from the full force of ocean wind and waves. Estuaries are biologically productive and directly support many species of plants, animals, birds, and fish, while also sequestering and storing substantial amounts of carbon from the atmosphere, particularly in their vegetated coastal wetlands. Bodies of water that may be estuaries include bays, harbors, sounds, and inlets. Nontidal surface waters include any lakes, ponds, rivers and streams that support diadromous fish or are hydrologically connected to coastal, marine, estuarine resources, or wetlands.

Groundwater is water beneath the land surface. It interfaces with surface waters and supplies streamflow during periods between rain events. Groundwater discharge is a large source of input to many tidal and nontidal water resources (including rivers, streams, and estuaries) and influences the overall water quality in these areas. Groundwater quality can be compromised in many ways, including spills and seepage from buried disposal areas (e.g., landfills) and from failing septic systems.

Floodplains are adjacent to stream channels that may be inundated during periods of high water (Linsley et al., 1982) and are composed of sediments deposited by these streams. Floodplains include a floodway (the width of the river that must be reserved to discharge the 100-year flood without increasing the water surface by more than 1 ft) and a flood fringe (the area of the floodplain outside the floodway that is susceptible to flooding). A 100-year flood is the flood elevation with a one percent chance of being equaled or exceeded in any one year (FEMA, 2004). Development and agricultural activities within floodplains may alter the water flow and may increase flooding and runoff. Agricultural inputs to coastal waters reportedly affect approximately 25% of the total global reef area around the globe (Kroon et al., 2014). Floodwaters can transport sediment, pollution, nutrients, pathogens, and debris from the floodplain to coastal areas, which can decrease water quality, increase turbulence, block waterways, and may also put human life and property at risk.

Stormwater refers to water flows caused by heavy precipitation rates or volumes that exceed the ability of the ground to absorb it, with excess flowing downslope. In many locations across the U.S., stormwater has been diverted into marine, estuary, and freshwater bodies. The results could lead to an overall loss of ecological value due to declining water quality associated with constituents in the runoff. Chemical contamination (including metals and organic substances from urban, agricultural, and industrial sources) of water bodies and sediments has also resulted in declining water quality, affecting marine, estuarine, and freshwater resources (EPA, 2004).

Domestic and industrial wastewater discharges (sewage) are reportedly the largest component of coastal pollution due to poorly or untreated discharge or stormwater runoff (Wear & Thurber, 2015). Stressors from domestic and industrial wastewater and associated responses increased bleaching, reduction in coral growth rates, disease, reduced photosynthesis of coral symbionts, reduced coral species richness, lethal and sublethal impacts to corals (Wear & Thurber, 2015). Although the amount of domestic and industrial wastewater discharged into tropical oceans is difficult to quantify, 104 of 112 coral reef areas, including territories, states, and countries, have documented sewage contamination and most occur as direct ocean discharge (only three of the 112 geographies are uninhabited and therefore have no potential for direct sewage contamination) (Wear & Thurber, 2015). While other stressors can increase susceptibility to infection, sewage provides a mechanism for rapid delivery and disease progression (Wear & Thurber, 2015).

3.2.4.2 Air Quality

In the U.S., National Ambient Air Quality Standards have been developed to evaluate the acceptable levels of sulfur dioxide, carbon monoxide, ozone, nitrogen oxides, lead, and inhalable particulate matter. Local air quality can be assessed through carbon monoxide and inhalable particulate matter, while the remaining pollutants are associated with regional air quality stemming from widely dispersed sources of pollution. Air quality can be altered by anthropogenic and natural sources such as African dust, volcanic dust, wildfires, aerosols, and fossil fuels.

Also, hundreds of millions of tons of eroded mineral soils (dust) are carried in the atmosphere from the Sahara Desert and Sahel in Africa to the western Atlantic and Caribbean Sea (Rothenberger et al., 2008). Over the past 40 years, the quantity of dust has increased, and the composition of the dust cloud has been altered due to pesticide use, changes in land use, and burning of synthetic materials and biomass (fuel) in the dust source regions and in the areas over which they pass (Garrison et al., 2003; 2005). An international team of scientists led by the U.S. Geological Survey is examining the contaminants carried with African dust and the role they may play in the degradation of Caribbean coral reefs and other downwind ecosystems (Shinn et al., 2000; Garrison et al., 2003; 2005). Thus far, African dust has been found to carry viable microorganisms, including pathogens, nutrients such as iron, persistent organic pollutants and heavy metals (Rothenberger et al., 2008). A coral disease pathogen, the fungus *Aspergillus sydowii*, has been identified in dust (Weir-Brush et al., 2004). Pesticides, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls have been identified in African dust air masses in the Caribbean (USVI and Trinidad) and in Africa (Garrison et al., 2005). These contaminants are known to be toxic at very low concentrations, to persist in the environment, to bioaccumulate in organisms, and to interfere with reproduction and immune function. Some of these contaminants are known to shut down phytoplankton photosynthesis (Wurster, 1968).

Motorized vessels are also a source of air pollutants around coral reefs through the release of combustion products into the atmosphere. Anthropogenic sources of aerosols can reduce the growth rate of corals by enhancing reflective conditions through scattering sunlight and increasing clouds (Kwiatkowski et al., 2013).

3.2.4.3 Acoustic Environment

Healthy coral reef ecosystems are noisy environments. Many coral reef inhabitants produce an array of sounds for defense or territorial displays, feeding, schooling, courtship, or spawning, which can vary based on the time of day, lunar cycle, and seasonally (Lammers et al., 2008, Tricas & Boyle, 2014; Staaterman, 2014). Natural coral reef sounds, including wind, rain, and waves, may provide cues for larval settlement (Montgomery et al., 2006; Vermeij et al., 2010; Radford et al., 2011) and nocturnal movement (Montgomery et al., 2006; Simpson et al., 2008). Anthropogenic sounds, such as motor boats, hammer use, hydrographic surveys, and shipping, can interfere with the natural cues and the behavior reef inhabitants (Weilgart, 2018). Motor boats sounds have been shown to disrupt orientation behavior of settling fish larvae (Holles et al., 2013), increase metabolic rate (oxygen intake), and increase fish mortality by predation (Simpson et al., 2016). However, there is recent evidence that has shown that juvenile reef fish can become tolerant to repeated exposure to motor boat sound (Nedelec et al., 2016). More substantial acoustic stressors, such as seismic surveys, pile driving, and military testing and training, could lead to behavioral and injurious impacts of marine biota (U.S. Department of the Navy, 2018; 83 FR 36773).

3.3 Biological Environment

This section describes, generally, the organisms that may inhabit areas affected by CRCP activities. These areas stretch from the ridges of riparian habitat to the coral reefs and coral reef-associated ecosystems. Corals reefs ecosystems are known for their high species diversity. This section is organized by functional groups to provide the necessary context for how CRCP activities may impact them.

3.3.1 Primary Producers

Primary producers are those organisms that are able to fix carbon via chemosynthetic or, more commonly, photosynthetic processes. This group is dominated by phytoplankton, cyanobacteria, macroalgae (e.g., kelps and seaweeds), coralline algae (which are important for suitable habitat for coral recruitment), seagrasses, and mangroves. Corals, which leverage a symbiotic relationship with photosynthesizing dinoflagellates (unicellular algae) called zooxanthellae, can also be included within this group. Primary producers not only provide the food source necessary to sustain the ecosystem, but also contribute to habitat structure that provides shelter and favorably alters oceanographic processes to promote the settlement of many organisms on coral reefs. Left unchecked by herbivory, some primary producers may negatively affect the surrounding environment (Burkepile & Hay, 2010; McManus & Polsenberg, 2004). For example, certain algal species may outcompete corals, smothering them and causing a paradigm shift in the nature of the ecosystem (Done, 1992; Hughes, 1994; Hughes et al., 2007). Nutrient-enriched waters can lead to massive blooms of algae and cyanobacteria in the water column, which reduce light penetration and whose death and decay may create oxygen-depleted areas.

3.3.1.1 Phytoplankton and Algae

Microscopic marine plants (phytoplankton), bacteria (e.g., cyanobacteria), and other organisms form the base of the pelagic food web. Many species of phytoplankton inhabit coral reef systems, and marine life is highly dependent on their growth and productivity. Their numbers, biomass, and production vary greatly both spatially and temporally.

Algae in coral reef systems include zooxanthellae, microalgae, and macroalgae, which include coralline algae (both crustose and branching forms). The coral polyp provides habitat, carbon dioxide, and nutrients for zooxanthellae, while the algae provide the polyps with oxygen and carbohydrates, among other mutual benefits. Coralline algae are important in reef formation, cementing rubble together to form stable substrate (Skelton, 2003), and some species release chemicals prompting larval coral settlement (Tebben, 2015). These macroalgae are the primary spatial competitor to coral reefs.

3.3.1.2 Seagrasses

Submerged grasses or seagrasses differ from most other wetland plants in that they are evolved from terrestrial plants and adapted to living in almost exclusively subtidal areas, reside mainly in marine salinities, and use the water column for support although they may be exposed to the air during very low tides. Seagrasses occur across a wide depth range, from rocky intertidal habitats to depths of 40 meters, and across broad latitudinal ranges (Spalding et al., 2003; Orth et al., 2006). Distribution patterns are influenced by physical (waves, currents, tides), geological (sediment grain size), and geochemical factors (Koch, 2001). Waters with good light penetration facilitate seagrass colonization.

Seagrass roots and leaves dampen waves and slow currents, enhancing sediment stability and increases the accumulation of organic and inorganic material, and provide horizontal and vertical complexity to habitat, which, together with abundant and varied food sources, support densities of fauna generally exceeding those in un-vegetated habitats (Wood et al., 1969; Thayer et al., 1984).

Seagrass beds are nurseries for reef-associated fishes and invertebrates and harbor a wide range of benthic, demersal and pelagic organisms. This includes permanent residents, which spawn and spend most of their lives in seagrass beds, as well as transient species. Transient species either leave seagrass beds only to spawn or move between habitats on a daily basis, using seagrass beds for food or shelter. Additional transient species seek food and shelter in seagrass beds during their juvenile stage, and move to other habitats as sub-adults or adults (Parsons et al., 2015).

Seagrasses are very productive ecosystems that store and sequester substantial amounts of carbon belowground in soils at very high rates, commonly known as 'blue carbon' (Duarte et al., 2010; Donato et al., 2011; McLeod et al., 2011; Fourqurean et al., 2012). Such carbon sequestration makes these ecosystems approximately equivalent to terrestrial forests in their ability to serve as carbon sinks, despite having a much smaller geographic footprint (McLeod et al., 2011).

Since 1980, seagrass loss has been at a rate of 110 km^2 yr^{-1}, which is comparable to other important ecosystems, such as coral reefs and rainforests (Waycott et al., 2009). Factors contributing to the loss of seagrass include a broad spectrum of natural and anthropogenic causes, such as the direct effects of disease outbreaks, destructive fishing practices, boat propellers, coastal constructions, cyclones and other storms, and tsunamis; and the indirect effects from land-based sources of pollution, aquaculture, invasive species introductions, and trophic cascades caused by overfishing of predators (Waycott et al., 2009).

There are seven native species of seagrass in the Caribbean: turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), shoal grass (*Halodule wrightii*), widgeon grass (*Ruppia maritima*), *Halophila baillonii*, *H. engelmanni*, and paddle grass (*H. decipiens*) (Seagrass Watch, 2019). Turtle grass, manatee grass, shoal grass, widgeon grass, and paddle grass are all found throughout the Caribbean, with turtle grass being the most predominant. Manatee grass is often intermixed with turtle grass; shoal grass typically grows on sand and mud from the intertidal zone to five m (16 ft) deep; widgeon grass is in the brackish waters from 0-2.5 m (0-8.2 ft); and paddle grass is found 1-58 m (3-190 ft). *H. engelmanni* is found in the Bahamas, Florida, the Greater Antilles, and the western Caribbean down to 5 m (16 ft), and *H. baillonii* is only in the Lesser Antilles (Seagrass Watch, 2019). Johnson's seagrass (*Halophila johnsonii*), listed as threatened under the ESA, is found in lagoonal water along southeastern Florida from Sabastian Inlet to northern Biscayne Bay (NMFS, 2002). *H. stipulacea* is an invasive species found in the Caribbean but is native to the Red Sea and parts of the Indian Ocean (Willette & Ambrose, 2012). *H. stipulacea* forms monoculture beds in addition to interspersing with native populations of seagrasses and covers more than 100,000 m^2 of seafloor, ranging from the low tide line to 50 m (164 ft) depth (Willette & Ambrose, 2012).

Seagrass populations are more discrete in the U.S. Pacific jurisdictions. In American Samoa, surveys of the splash zone to 20 m (66 ft) depth, found two species of paddle weed (*Halophila ovalis* and *H. minor*), which differ only by the number of veins morphologically (Skelton, 2003). Guam and CNMI have three species of seagrasses: *H. uninervis*, *Enhalus acoroides*, and *H. minor* (Lobban & Tsuda, 2003). Hawaii has two native species of seagrasses *H. hawaiiana,* which is endemic to Hawaii*,* and *H. decipiens*.

3.3.1.3 Mangroves

Of tremendous importance to the function of coral reefs is their proximity to other associated communities, such as seagrass beds and mangroves (Mumby et al., 2004; Nagelkerken et al., 2000). Mangrove trees inhabit saltwater or brackish water in the coastal intertidal zone in the tropics and subtropics along protected coastlines, away from the direct action of waves (Kathiresan & Bingham, 2001). They have developed special adaptations to survive the variable flooding and salinity conditions imposed by the coastal environment and act as a buffer between the land and sea, trapping much of the soil and nutrients that runoff from land (Kathiresan & Bingham, 2001). In addition, mangroves store and sequester substantial amounts of "blue" carbon (Donato et al. 2011; McLeod et al. 2011), both in aboveground biomass and belowground in soils at high rates.

Mangrove ecosystems are often coupled to other systems, such as seagrass beds and coral reefs, and support fish, invertebrates, and birds. Mangroves provide important nursery habitat for reef fish, such as the rainbow parrotfish (*Scarus guacamaia*) and goliath grouper (*Epinephelus itajara*) (Koeing et al., 2007; Dorenbosch et al., 2006). Most of the production in mangroves is associated with the microbial community in the sediments, which breaks down the organic matter from land and leaves that fall off the trees, and is largely exported to reef communities where it is utilized as a nutrient source. Mangrove communities may also support large resident and migratory populations of mammals, reptiles, and other animals (Alongi, 2002).

A trend analysis indicated that mangrove losses across the U.S. have ranged between 14-57% from 1980-2005 compared to a worldwide reduction of 3.6 million ha, or 20% over the same 25 year period (FAO, 2007). Previous mangrove degradation and loss in the USVI was due to unsustainable development of tourism industries and related infrastructure; this trend has been reversed in favor of mangrove protection (FAO, 2007). Puerto Rico, with increased legal protection, colonization of new areas, and restoration of agricultural land back to mangroves, has actually experienced a net increase of 18% in mangrove area since 1980 (FAO, 2007). In Florida, mangrove ecosystems have been negated via drainage for agriculture, reclamation for urban development, and canalization, though large mangrove areas are protected in southern Florida, most notably within Everglades National Park, and laws have been enacted for the protection and sustainable utilization of mangroves (FAO, 2007). Mangroves in Guam been lost to dredging of wetlands; American Samoa has lost mangroves due to coastal development (filling, seawall construction, pollution, and dumping of waste and oil); and mangrove areas in the CNMI have been converted to agriculture (FAO, 2007). All three of these Pacific island jurisdictions have moved to conserve mangroves via reforestation and afforestation, led by the CNMI's creation of natural reserves and parks (FAO, 2007). Hawaiian mangroves stand in stark contrast with the other coral jurisdictions, as there are no native mangrove species, and introduced species have become invasive (Allen, 1998). There have been multiple efforts to control and remove these invasive mangroves from Hawaii to promote reclamation by native species (Allen, 1998).

3.3.2 Primary Consumers

Primary consumers are the species that eat primary producers. Some of these organisms, such as corals, sponges, and crinoids, feed on microalgae and plankton and contribute to coral reef habitat.

3.3.2.1 Corals

Corals as defined by the CRCA refers to the "species of the phylum Cnidaria, including:

1. All species of the orders Antipatharia (black corals), Scleractinia (stony corals), Gorgonacea (horny corals), Stolonifera (organpipe corals and others), Alcyanacea (soft corals), and Coenothecalia (blue coral), of the class Anthozoa; and
2. All species of the order Hydrocorallina (fire corals and hydrocorals) of the class Hydrozoa."

Coral taxonomy has changed slightly since CRCA was enacted. The current coral classifications are used throughout this DPEIS.

Stony coral organisms (i.e., scleractinians) are soft body polyps with a hard limestone (calcium carbonate) base (Barnes, 1987; Lalli & Parsons, 1995). For most species of stony corals, the polyps bud or divide and form connecting tissue between each polyp. These budding polyps form coral colonies. Coral colonies of various species can collectively form massive coral reefs (reefs or shoals composed primarily of corals). These reef-building corals are commonly referred to as hermatypic corals, which are the primary focus of CRCP. Globally, there are 794 reef-building corals, which are mainly distributed within the wider Caribbean and from East Africa and the Red Sea to Indo-Pacific (Spalding, 2001). Coral diversity is greater in the Indo-Pacific than in the Caribbean; for example, the Caribbean has 62 stony coral species and 719 stony coral species are found the Indo-Pacific (Spalding, 2001). Many stony corals have different growth forms, including branching, columnar, massive/lobate, plate-like, foliaceous (horizontal plates), encrusting, and free-living. These growth forms are influenced by environmental factors such as water motion, light, and biological factors such as genetics and coral symbionts. Coral growth rates range between 0.3-2 cm (0.1 - 0.77 in) per year for massive corals, and up to 10 (3.9 in) per year for branching corals; formation of a coral reef can take up to 10,000 years (Barnes, 1987).

Stony corals host symbiotic algae called zooxanthellae that provides the corals with energy, oxygen, and other photosynthetic byproducts, which corals use to make the calcium carbonate necessary to build their skeletons (Hoegh-Guldberg et al., 2007). Zooxanthellae are also the basis for the coral's color; a stressed coral can expel its zooxanthellae, which leaves the coral colorless and is considered bleached. In return, the zooxanthellae gain protection from predators and strong wave activity by residing within a coral polyp, and the algae use the carbon dioxide and water produced by the coral to photosynthesize. Their use of carbon dioxide and water also serves as waste removal, which contributes to efficient coral respiration. In addition to using energy from zooxanthellae, corals actively feed on plankton or benthos using nematocysts (Muscatine & Porter, 1977; Sebens, 1987), or stinging cells, and cilia with a mucus trap (Yonge, 1968; Goreau et al., 1971; Lewis & Price, 1975).

Shallow-water stony corals use asexual and sexual reproductive strategies to build large colonies that support coral reef ecosystems (Weiblen et al., 2000). Asexual reproduction takes place through budding, when a new polyp forms directly from parent polyps to expand the size of the colony or begins a new colony (Sumich, 1996). This occurs when the parent polyp reaches a certain size and divides. This process continues throughout the animal's life (Barnes & Hughes, 1999). Asexual reporduction also occurs when broken fragments (e.g., from hurricane damage) result in a new colony in a different location where the fragment landed. Regarding sexual reproduction, individual corals can be hermaphrodites, producing eggs and sperm within a single polyp or colony in one breeding cycle (Rinkevich & Loya, 1979); protandrous, performing male functions at small sizes before performing female functions at larger sizes to accommodate for the most energy-intensive egg production (Charnov, 1982); or gonochoric, where individual colonies are either male or female. Sexual reproduction in corals occurs via brooding or broadcast (or synchronous) spawning of gametes. Brooding coral species fertilize the egg within a polyp and releases planula larvae; this type of sexual reproduction allows quick settlement after the larvae are released into the water column. The other type of sexual reproduction, broadcast spawning, requires external fertilization, and the timing of reproduction is important to ensure that the gametes (eggs and sperm) can mix in the water column to produce zygotes (fertilized eggs). The spawning of coral gametes is generally driven by the lunar cycle, water temperature, and day length. The zygotes drift in the currents and divide to eventually form planula; the coral larvae then settle on suitable hard-bottom habitat. Both abiotic (e.g., light, hard substrate, and water quality) and biotic (e.g., the presence of crustose coralline algae and biofilm [i.e., bacteria and microorganisms], and the presence of competitors) factors may influence coral settlement (Ritson-Williams et al., 2009).

Coral health, reproduction, and recruitment can be altered by anthropogenic derived stressors. Sedimentation caused by runoff from land or dredging can affect corals by blocking light needed by the zooxanthellae, by suffocating polyps causing the tissue to die, by increasing suspended bacteria, and by covering settlement substrate (Erftemeijer et al., 2012; Fabricius, 2005). Sediment effects on corals can range from sublethal (changes in polyp activity, mucus production, respiration, photosynthesis, nutrient uptake and calcification) to mortality (Erftemeijer et al., 2012). The extent of impact varies by coral species and morphology, duration of the sedimentation event (days, weeks, or months), and the size of sediment grains (fine vs. course) (Erftemeijer et al., 2012). Increased nutrients, nitrogen and phosphorus, has also been shown to increase coral susceptibility to disease and bleaching (Vega Thurber et al., 2013; Wiedenmann et al., 2013; Voss & Richardson, 2006).

3.3.2.2 Other Primary Consumers

Zooplankton are microscopic animals that feed upon those primary producers suspended in the water column. Zooplankton include the larvae of numerous marine species, including the majority of coral reef invertebrates, which are dispersed into the pelagic environment to feed on the various types of plankton.

Some invertebrates are affixed to the seafloor and feed passively or actively on algae and plankton. Such sessile invertebrates are especially vulnerable to local threats and disturbances. These organisms also augment habitat area and complexity, further enhancing species diversity on coral reefs.

Other invertebrates, such as echinoderms, arthropods, and gastropods, are motile. Urchin species, which consume algae, have had profound effects upon coral reef ecosystems. The die-off of the Caribbean sea urchin (*Diadema antillarum*) from a disease epidemic in 1983-1984 was a critical event that contributed to phase shifts from coral-dominated ecosystems to fleshy macroalgae-dominated systems in many Caribbean locations, including Florida, Puerto Rico, and the USVI (Hughes et al., 2010).

Herbivorous fish feed by filtering plankton as they swim or actively grazing or scraping algae from the benthic substrate. Herbivorous families consist mostly of 75 species of surgeonfishes (*Acanthuridae*), all 27 species of rabbitfishes (*Siganidae*), all 79 species of parrotfishes (Subfamily *Scarinae* of the Family *Labridae*), majority of the 320 species of damselfishes (*Pomacentridae*), and smaller fishes, which include combtooth blennies (*Blenniidae*) and batfish (*Platax pinnatus*) (Hixon, 2015). These fish help control algal growth on coral reefs (Hughes et al., 2007; Paddack et al., 2006), and expose preferred substrate for the coral planular settlement. Other herbivores near coral reef ecosystems include manatees, dugongs, and sea turtles, which forage on the algae and seagrasses in or near coral reef ecosystems. Grazing behavior helps to sustain these systems (Lefebvre et al., 2017).

3.3.3 Secondary, Tertiary, and Apex Consumers

Secondary consumers feed upon primary consumers, tertiary consumers feed upon primary and secondary consumers, and apex consumers prey upon any consumer. Such functional roles keep the ecosystem in balance. This group of consumers includes predatory crustaceans, gastropods, cephalopods, sea snakes, fish (i.e., groupers, jacks, and sharks), seabirds, and marine mammals. Unsustainable fishing practices and other adverse effects on consumer species has caused a decline in these populations and affected coral reef ecosystems.

3.3.4 Invasive and Nuisance Species

Invasive species are those non-native species that are introduced to a system and colonize it using a competitive advantage. The most well-known example on coral reefs is the lionfish (*Pterois volitans* and *P. miles*) that were introduced to the Caribbean from the Indo-Pacific/Pacific via the aquarium trade (Hare & Whitfield, 2003). Venomous spines and a lack of natural predators enabled a population explosion of these fish. Lionfish mainly prey on small bodied and juvenile fishes and, therefore, are associated with a decline of native reef fish exemplified by reductions in species richness and community structure (Munoz et al., 2011; Green et al., 2012; Benkwitt, 2014). Invasive plant species that have altered the local ecosystems include the seagrass *Halophila stipulacea* in the Caribbean, marine algae, such as *Kappaphycus alvarezii* and *Gracilaria salicornia* in Hawaii, and red mangroves (*Rhizophora mangle*) in Hawaii (Christianen et al., 2018; Olinger et al., 2017; Allen, 1998). *Halophila stipulacea* has been reported throughout the Caribbean (Willette et al., 2014; Vera et al., 2014) and has been found to displace native seagrasses and alter juvenile fish assemblages (Willette & Ambrose, 2012; Olinger et al., 2017).

Native species that cause harm to ecosystems are considered nuisance species. A notable nuisance species in coral reef ecosystems in the Pacific is the crown-of-thorns starfish (*Acanthaster planci*), which prey upon certain coral species and kill colonies. Declines in Indo-Pacific coral cover caused by population explosions of the pandemic crown-of-thorns starfish have been widely documented for the past 40 years (Hughes et al., 2010; Kayal et al., 2012). Guam has experienced outbreaks of the *Chaetomorpha* macroalgae, which forms huge mats that can smother/shade corals, impede fishing, and tangle boat propellers (NOAA, 2015a).

3.3.5 Terrestrial and Freshwater Organisms

In addition to marine organisms, CRCP activities may affect terrestrial and freshwater organisms within streams, riparian zones, and coastal areas. Such areas provide habitat for invertebrates, freshwater fish, reptiles, birds, and mammals. Organisms of particular concern can be found in the Endangered Species (Section 3.4.2). In addition, a general description of terrestrial and freshwater habitats likely to be affected by CRCP activities is included in various sections above in Chapter 3, in the jurisdictional sections below in Section 3.6, and below in Chapter 4 preceding the impacts analysis. Those descriptions are not repeated here.

3.4 Regulatory Environment

This section describes some of the federal environmental regulations that are likely to apply to CRCP activities. Other federal regulations may apply, particularly on a project-specific basis, and NOAA and its partners consider and comply with all other applicable regulations for specific projects as well. This section includes, among other things, a table of ESA-listed species under NMFS's jurisdiction associated with coral reef ecosystems.

3.4.1 Essential Fish Habitat

Essential fish habitat (EFH) is defined in the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Essential fish habitat includes all types of aquatic habitat—wetlands, coral reefs, seagrasses, rivers—where fish and invertebrates spawn, breed, feed, or grow to maturity. The NMFS works with the regional fishery management councils to identify the EFH for every life stage of each federally managed species using the best available scientific information. The four regional fishery management councils that have authority within geographic range of the CRCP have designated EFH for their regions as follows. The CRCP is conducting a programmatic EFH consultation for the proposed action in coordination with NMFS (See Appendix C for full list of EFH).

EFH under the Western Pacific Regional Fishery Management Council (WPRFMC)

The CRCP implements activities in the Western Pacific off Hawaii, the Northwestern Hawaiian Islands, American Samoa, Guam, the CNMI, and the U.S. Pacific Island possessions that may be located within areas identified as EFH for species managed by the WPRFMC. The WPRFMC has classified shallow-water fish and invertebrates as ecosystem component species, and EFH is not designated for these species. The WPRFMC has EFH designations for bottomfish and seamount groundfish, crustaceans, pelagic and precious corals, which may overlap with shallow coral ecosystems. An example is the juvenile/adult habitat for Kona crab (*Ranina ranina*) that includes bottom habitat from the shoreline to a depth of 100 m (300 ft).

EFH under the Gulf of Mexico Fishery Management Council

The CRCP implements activities in the Gulf of Mexico that may be located within areas identified as EFH, including Habitat Areas of Particular Concern (HAPC) such as Madison-Swanson Marine Reserve, Tortugas North, Tortugas South, Florida Middle Grounds, Pulley Ridge, West Flower Garden Banks, and East Flower Garden Banks, (70 FR 76216). The HAPCs are closed to fishing entirely or closed during certain times of the year to specific gear types to provide protection for various managed species. The entire Gulf of Mexico is considered EFH for the following fishery management plans (FMPs): red drum (*Sciaenops ocellatus*) under the Red Drum FMP (GMFMC, 2019a); 11 species and life stages of reef fish, including grouper, snapper, and triggerfish, under the Reef Fish FMP (GMFMC, 2019b); coral and coral reefs under the Coral and Coral Reefs FMP (GMFMC, 2019c); spiny lobster (*Panulirus argus*) under the Spiny Lobster FMP (GMFMC, 2019d); king mackerel (*Scomberomorus cavalla*), Spanish (*S. maculatus*) mackerel, and cobia (*Rachycentron canadum*) under the Coastal Migratory Pelagic FMP (GMFMC, 2019e); and brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*F. duorarum*), white shrimp (*Litopenaeus setiferus*), rock shrimp (*Sicyonia brevirostris*), and royal red shrimp (*Pleoticus roustus*) under the Shrimp FMP (GMFMC, 2019f).

EFH under the South Atlantic Fishery Management Council

The CRCP implements activities off the coasts of east Florida and the Florida Keys that may be located within areas identified as EFH (GMFMC, 2005; SAFMC, 1998). The CRCP project areas may coincide with EFH for spiny lobster under the Spiny Lobster FMP (SAFMC, 2019a); with brown shrimp, pink shrimp, white shrimp, rock shrimp, and royal red shrimp under the Shrimp FMP (SAFMC, 2019b);

approximately 55 species in the snapper-grouper complex, including triggerfishes, grunts, snappers, sea basses, and groupers, under the Snapper-Grouper FMP (SAFMC, 2019c); king mackerel and Spanish mackerel, and cobia under the Coastal Migratory Pelagic FMP (SAFMC, 2019d); and coral and coral reefs under the Coral, Coral Reefs, and Live/Hard Bottom Habitat FMP (SAFMC, 2019e). This also includes supporting activities within designated EFH-HAPC such as coastal inlets for shrimp overwintering areas and red drum nursery habitat, documented sites of spawning aggregations, mangrove and seagrass habitat that provide nursery habitat for snappers and groupers, and spiny lobster habitat (Florida Bay, Biscayne Bay, Card Sound, and coral/hard bottom habitat from Jupiter Inlet, Florida through the Dry Tortugas, Florida.

EFH under Caribbean Fishery Management Council

The CRCP implements activities in Puerto Rico and the USVI that may be located within areas identified as EFH for species managed by the Caribbean FMC under a Generic Amendment to four FMPs (CFMC, 1998). The Reef Fish FMP (CFMC, 2019) identifies 13 species of reef fish, including grouper, snapper, grunt, triggerfish, and red hind (*Epinephelus guttatus*), and their life stages that may exist in CRCP project areas. Other species that may inhabit areas that coincide with CRCP project locations include over 100 species of coral and life stages, including stony corals, sea fans, and other gorgonians, and over 60 species of plants, including seagrasses, and invertebrates, under the Coral and Reef-Associated Plants and Invertebrates FMP (CFMC, 2019); spiny lobster under the Spiny Lobster FMP (CFMC, 2019); and queen conch (*Strombus gigas*) under the Queen Conch FMP (CFMC, 2019). EFH for these FMPs includes all water from either mean high tide or mean low tide to the outer boundary of the economic exclusive zone surrounding these territories. The CRCP may also support activities within designated HAPCs including areas such as Luís Peña Channel, Culebra; La Cordillera, Fajardo; Tourmaline Reefs, Mayagüez, Puerto Rico; Buck Island Reef National Park, St. Croix; Hind Bank Marine Conservation District, St. Thomas; and Alton Lagoon, St. Croix.

EFH under the Secretarial Atlantic Highly Migratory Species (HMS) Fishery Management Plan

The CRCP implements activities in the Atlantic/Caribbean and Gulf of Mexico that may be located within areas identified as EFH, including within HAPCs (82 FR 42329), for certain life stages of species managed by NOAA Fisheries HMS. The CRCP project areas may coincide with EFH for five species of tuna, six species of billfish, and 42 species of shark covered under this FMP.

3.4.2 Endangered Species Act

The ESA provides for the conservation of species that are in danger of extinction throughout all or a significant portion of their range or likely to become so within the foreseeable future and therefore are threatened with extinction. The ESA also provides authority to designate critical habitat for these species and protect the ecosystems on which they depend (16 U.S.C. § 1531). Table 3-1 lists the ESA-listed species and associated critical habitat within NMFS's jurisdiction; ESA-listed species and associated critical habitat within USFWS's jurisdiction can be found in Appendix E. The CRCP is conducting programmatic ESA Section 7 consultations for the proposed action in coordination with NMFS and USFWS. Consistent with existing CRCP practice, individual Section 7 consultations would be initiated during the planning process for site-specific projects if there is an ESA-listed species that may be affected by the proposed activity. Project proponents would adhere to any project modifications or other mandatory minimization and avoidance measures, such as terms and conditions for incidental take, resulting from formal consultations.

*Table 3-1. Endangered Species Act List of NMFS-listed Endangered or Threatened Species Associated with Coral Reef Ecosystems (E=endangered, T=threatened). *Some populations are considered threatened and others are considered endangered.*

Status	Species	Florida	Gulf of Mexico	Puerto Rico	Virgin Islands	American Samoa	CNMI	Guam	Hawaii	Foreign	Critical Habitat
Corals											
T	*Acropora Cervicornis,* Staghorn Coral	X	X	X	X	--	--	--	--	--	Coastal waters of Florida, Puerto Rico, and the USVI
T	*Acropora globiceps,* Coral	--	--	--	--	--	X	X	--	--	None designated
T	*Acropora jacquelineae,* Coral	--	--	--	--	X	--	--	--	X	None designated
T	*Acropora lokani,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Acropora palmata,* Elkhorn Coral	X	X	X	X	--	--	--	--	--	Coastal waters of Florida, Puerto Rico, and the USVI
T	*Acropora pharaonis,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Acropora retusa,* Coral	--	--	--	--	--	X	X	--	--	None designated
T	*Acropora rudis,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Acropora speciosa,* Coral	--	--	--	--	X	--	--	--		None designated
T	*Anacropora spinosa,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Acropora tenella,* Coral	--	--	--	--	--	--	--	--	X	None designated
E	*Cantharellus noumeae*, Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Dendrogyra cylindrus,* Pillar Coral	X	X	X	X	--	--	--	--	--	None designated
T	*Euphyllia paradivisa,* Coral	--	--	--	--	--	X	X	--	--	None designated
T	*Isopora crateriformis,* Coral	--	--	--	--	--	X	X	--	--	None designated

T	*Orbicella annularis,* Lobed Star Coral	X	X	X	X	--	--	--	--	--	None designated
T	*Orbicella faveolata,* Mountainous Star Coral	X	X	X	X	--	--	--	--	--	None designated
T	*Orbicella franksi,* Boulder Star Coral	X	X	X	X	--	--	--	--	--	None designated
T	*Montipora australiensis,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Mycetophyllia ferox,* Rough Cactus Coral	X	X	X	X	--	--	--	--	--	None designated
T	*Pavona diffluens,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Porites napopora,* Coral	--	--	--	--	--	--	--	--	X	None designated
T	*Seriatopora aculeata,* Coral	--	--	--	--	--	X	X	--	--	None designated
E	*Siderastrea glynni,* Coral	--	--	--	--	--	--	--	--	X	None designated
E	*Tubastraea floreana,* Coral	--	--	--	--	--	--	--	--	X	None designated
Other Invertebrates											
T	*Nautilus pompilius*, Chambered Nautilus	--	--	--	--	X	--	--	--	X	None designated
Marine Mammals											
E	*Balaenoptera borealis*, Sei Whale	X	X	X	X	X	X	X	X	X	None designated
E	*Balaenoptera edeni*, Gulf of Mexico Bryde's Whale	X	X	--	--	--	--	--	--	--	None designated
E	*Balaenoptera musculus*, Blue Whale	X	--	X	X	X	X	X	X	X	None designated
E	*Balaenoptera physalus*, Fin Whale	X	X	X	X	X	X	X	X	X	None designated
E	*Eubalaena glacialis,* North Atlantic Right Whale	X	--	--	--	--	--	--	--	--	Outside of CRCP's action area (Gulf of Maine and Georges Bank region and off the Southeast U.S. coast [Cape Fear, North Carolina, southward to approximately

											27 nm below Cape Canaveral, Florida])
E	*Monachus schauinslandi,* Hawaiian Monk Seal	--	--	--	--	--	--	--	X	--	Waters out 10-20 fathoms in Kure Atoll; Midway Islands (except Sand Island), Pearl and Hermes Reef, Lisianski Island, Laysan Island, Gardner Pinnacles, French Frigate Shoals, Mokumanamana, and Nihoa Island.
E	*Physeter Microcephalus,* Sperm Whale	X	X	X	X	X	X	X	X	X	None designated
E	*Psuedorca crassidens,* Hawaiian Insular False Killer Whale	--	--	--	--	--	--	--	X	--	Waters from 45-3,200 meters (49-3,500 yards) around the Main Hawaiian Islands
Sea Turtles											
E	*Caretta caretta,* Loggerhead Sea Turtle, North Pacific Distinct Population Segment*,* South Pacific Distinct Population Segment	--	--	--	--	X	X	X	X	--	None designated
T	*Caretta caretta,* Loggerhead Sea Turtle, Northwest Atlantic Distinct Population Segment	X	X	X	X	--	--	--	--	--	None designated
E	*Chelonia mydas,* Green Turtle, Central West Pacific Distinct Population Segment	--	--	--	--	X	X	X	X	--	None designated
T	*Chelonia mydas*, Green turtle, South Atlantic Distinct Population Segment	X	X	X	X	--	--	--	--	--	NMFS - Puerto Rico - Waters around Culebra Island

E	*Dermochelys coriacea,* Leatherback Sea Turtle	X	X	X	X	X	X	X	X	--	Outside of CRCP's action area (California coast from Point Arena to Point Arguello east of the 3,000 meter depth contour; and 64,760 km^2 stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter depth contour.)
E	*Eretmochelys imbricata,* Hawksbill Turtle	X	X	X	X	X	X	X	X	--	NMFS Coastal waters surrounding Mona and Monito Islands, Puerto Rico
E	*Lepidochelys kempii* Kemp's Ridley Turtle	X	X	--	--	--	--	--	--	--	None designated
T	*Lepidochelys oliveacea,* Olive Ridley Sea Turtle	--	--	--	--	X	X	X	X	--	None designated
Fish											
T	*Carcharhinus longimanus,* Oceanic Whitetip Shark	X	X	X	X	X	X	X	X	--	None designated
T	*Epinephelus striatus,* Nassau Grouper	X	X	X	X	--	--	--	--	--	None designated
T	*Manta birostri*s, Giant Manta Ray	--	--	--	--	X	X	X	X	--	None designated
E	*Pristis pectinata*, Smalltooth Sawfish	X	X	--	--	--	--	--	--	--	Charlotte Harbor and in the Ten Thousand Islands/Everglades, Florida
T	*Sphyrna lewini,* Scalloped Hammerhead Shark, Indo-West Pacific Distinct Population Segment and Central and Southwest Atlantic Distinct Population Segment	--	--	X	X	X	X	X	--	--	None designated
Plants											

T	*Halophila johnsonii,* Johnson's Seagrass	X	--	--	--	--	--	--	--	--	East Coast of FL from Sebastian Inlet to Central Biscayne Bay

Source: NMFS, 2019

3.4.3 Marine Mammal Protection Act

All marine mammals are protected under the MMPA regardless of whether they are also listed under the ESA. In the South Atlantic and Caribbean, including the Gulf of Mexico, there are 27 species of marine mammals, which include the West Indian manatee (*Trichechus manatus*) and 26 cetacean species (dolphins and whales). In the Pacific Ocean, there are 29 species of marine mammals, which include the Hawaiian monk seal, dugong (*Dugong dugong*), and 27 species of whales and dolphins. Dugongs and manatees primarily inhabit rivers, bays, canals, estuaries, mangroves, and coastal waters rich in seagrass and other vegetation. The Hawaiian monk seal is primarily found within the Hawaiian Islands and uses waters surrounding atolls, islands, and areas farther offshore on reefs and submerged banks. See Appendix F for full list of marine mammals in CRCP's action area. Most of the cetacean species reside in the oceanic habitat (depth ≥ 200 m [656 ft]), although some dolphins can be found in waters from oceanic to shallow coastal areas including bays and estuaries. The proposed action and alternatives incorporate avoidance and minimization measures that limit potential effects to marine mammals. CRCP determined that further coordination under MMPA was not required at this time. Future project-specific environmental analyses, if necessary, will assess any potential effects to marine mammal of each project or activity not fully addressed within this DPEIS to determine if permits or authorizations are needed to comply with MMPA. The CRCP activities include hydrographic surveys using active acoustic devices (e.g., side-scan echosounder, echosounders). Based on the analysis in Chapter 4, NOAA has determined that an incidental take authorization under the MMPA is not warranted for CRCP programmatic activities.

3.4.4 Clean Water Act

Surface water quality in states, territories, and authorized tribal lands are required to be reported to EPA every two years under the CWA Sections 305(b) and 303(d) for waters that have been assessed and indicate water quality that does not support healthy aquatic life. Section 404 of the U.S. CWA also provides a statutory definition of wetlands and assigns jurisdiction over protection of wetlands to the U.S. Army Corps of Engineers. Under Section 404 of the CWA, the U.S. Army Corps of Engineers requires that an interested party obtain a permit before filling, constructing on, or altering a jurisdictional wetland (33 U.S.C § 1344). Given the significant impacts that stormwater and land-based sources of pollution have had on coral reef ecosystems, the protections are critical to ensuring wetlands continue to provide mitigating ecosystem services.

3.4.5 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA, 16 U.S.C. § 1451) was enacted in 1972 to encourage coastal states, Great Lake states, and U.S. Territories and Commonwealths (collectively referred to as "coastal states" or "states") to preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone. The CZMA is a voluntary program, and all seven states and territories in the CRCP's action area have coastal management programs. The federal consistency provision, Section 307, requires federal actions (inside or outside a coastal zone) that affect any coastal zone resource, to be consistent with the enforceable policies of the state/territorial approved coastal management program. The CRCP is coordinating with each jurisdiction to develop an approach for consistency determinations with their enforceable policies for activities covered by DPEIS.

3.4.6 National Historic Preservation Act

Section 106 of the National Historic Preservation Act of 1966 (NHPA) (54 U.S.C. § 300101 et seq.) requires federal agencies to take into account the effects of their undertakings on historic properties in accordance with regulations issued by the Advisory Council on Historic Preservation at 36 C.F.R. Part 800. The regulations require that federal agencies consult with the Advisory Council on Historic Preservation, states, tribes, and other interested parties (consulting parties) when establishing an area of potential effects, identifying properties within the area of potential effects and determining their eligibility for inclusion in the National Register of Historic Properties (NRHP), making effects determinations to historic properties, and resolving adverse effects. The NRHP is an official Federal Government list of significant historical properties in architecture, engineering, archeology, history, and culture in general. Authorized by the NHPA, the NRHP is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect America's historic and archeological resources. The CRCP is coordinating with the Advisory Council on Historic Preservation to develop potential approaches for addressing programmatic activities. Furthermore, any CRCP activities that may affect historic properties would undergo individual consultations on a project-specific basis as appropriate. Any programmatic approach developed in coordination and consultation with the Advisory Council on Historic Preservation would guide project-specific compliance.

3.4.7 National Marine Sanctuaries Act

The National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.; NMSA) authorizes the Secretary of Commerce to designate and manage areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or esthetic qualities as national marine sanctuaries. Section 304(d) of the National Marine Sanctuaries Act requires interagency consultation between NOAA and federal agencies taking actions, including authorization of private activities, "likely to destroy, cause the loss of, or injure a sanctuary resource." In addition to consultation, a permit or other approval is required from the Office of National Marine Sanctuaries (ONMS) when any person wishes to conduct an activity within a sanctuary that is otherwise prohibited. Prohibitions are sanctuary specific, but commonly include disturbance of submerged lands, discharges, or injury to historic or cultural resources. The CRCP is coordinating with ONMS to explore the feasibility of conducting a programmatic NMSA 304(d) consultation. Any NMSA permits required for CRCP activities would be issued on a project-specific basis.

3.5 Socioeconomic Environment

This section outlines some of the human elements associated with U.S. coral reef jurisdictions. The CRCP recognizes that people and society are part of the coral reef ecosystem and incorporates related data into coral reef management strategies. The CRCP coordinates a variety of activities including the systematic collection of socioeconomic variables, including demographics in coral reef areas, human use of coral reef resources, as well as knowledge, attitudes, and perceptions of coral reefs and coral reef management. More details on some of the sections outlined below can be found in documents produced as part of the National Coral Reef Socioeconomic Monitoring Program (NOAA, 2018b).

3.5.1 Social Environment

3.5.1.1 Population

Human populations, both as total and density, and their ethnic compositions vary among the jurisdictions. For example, Atlantic jurisdictions have greater representation among white, black, and Hispanic communities, and Pacific jurisdictions tend to have more people of Asian and Pacific Islander descent. However, notions of race and ethnicity will vary based on the cultural and historical contexts of these places. For example, Hawaii is diverse, with 24% of the population identifying as two or more races, the highest reported level of multi-ethnicity of all U.S. states (U.S. Census Bureau, 2010). The Chamorro people of Guam and other indigenous persons of Micronesian heritage are broadly classified as Pacific Islander within census data.

3.5.1.2 Cultural Resources

Cultural resources include historic properties (buildings, sites, and structures including archeological sites) that are listed or eligible for listing under the National Historic Preservation Act (NHPA), archeological resources, and (sacred) tribal sites of traditional, cultural, and religious importance.

3.5.1.3 Public Health and Safety (Including Flood Risk Reduction and Shoreline Protection)

The main risks to public health and safety can be divided into slow-onset anthropogenic activities, such as pollution and improper land use practices, and hazardous natural events. The hazardous natural events include hurricanes, extreme rainfall events, volcanic activity, and earthquakes. Slow-onset events as a result of changing sea levels can lead to increased risk of flooding and, in some cases, saltwater intrusion into groundwater supplies. Human activities can release high levels of sediments into receiving water bodies. There are potential risks to the public from other non-point sources of contaminants.

Measures to reduce risk during extreme events include proper signage and public awareness activities to educate residents regarding evacuation routes and shelters. Engineering approaches to reduce risk include levees and spill prevention control mechanisms, as well as countermeasure planning during extreme events to ensure life and property are secured.

3.5.1.4 Environmental Justice

Under Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* federal agencies, such as NOAA, must assess whether its actions have a disproportionately high and adverse environmental and health impacts on minority and low-income populations. This mandate was expanded to include a similar analysis for children by Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks*.

All seven U.S. coral jurisdictions have minority and low-income populations. The coral reef ecosystem can be fundamental to the fabric of local communities, providing a food source, materials, and forming part of their cultural identity.

3.5.2 Economic Environment

Coral reef ecosystems, with vibrant colors and high biodiversity, are an economic driver for adjacent communities. Coral reefs and associated habitats provide economic and environmental services to millions of people through employment, recreation and tourism, shoreline protection, and sources of food, building materials, and pharmaceuticals. A recent global economic loss of coral reef ecosystem services due to increasing water temperatures is estimated to be $1 trillion (Hughes et al., 2017).

3.5.2.1 Coral Reef Ecosystem Value

The estimated total economic value (TEV) of coral reef services for across all U.S. jurisdictions is just over U.S. $3.4 billion per year (Brander & van Beukering, 2013; Table 3-2). This value is considered to be a partial estimate due to the limited geographical coverage and set of services for some state/territory TEV estimates (Brander & van Beukering, 2013). Furthermore, U.S. coral reefs are shown to provide a large reduction in flood risk that is quantified as saving more than 18,000 lives and with an annual value of $1.805 billion in 2010 U.S. dollars (Storlazzi et al., 2019).

Table 3-2. Total Economic Value of U.S. Reefs by Jurisdiction as conservative estimates.

	Area of coral reef valued (ha)	**Total Economic Value (millions 2007 USD)**
USVI	34,400	187
Puerto Rico	12,642	1,093
Florida	36,000	174
Hawaii	165,990	1,747
American Samoa	22,200	11
CNMI	6,494	65
Guam	7,159	139
Flower Garden Banks	N/A	N/A
Papahānaumokuākea	N/A	N/A
Pacific Island Remote Areas	N/A	N/A
Total	**284,885**	**3,416**

Source: Brander and van Beukering (2013)

3.5.2.3 Marine Transportation

Coral reefs and associated habitats reduce offshore wave energy and, due to their location and physical structure, reefs create calm back reef conditions that aid small craft navigation. Coral reefs also provide natural breakwater services in bays with harbors that support the docking of ships and other vessels. Marine transportation is an important component of coastal land use. Port development and operations, including expansion, have resulted in substantial alteration and damage to the natural environment. Port property often includes brownfields—abandoned industrial facilities where environmental contamination discourages development. Ongoing impacts include reductions in air and water quality and the importation of invasive aquatic species (Urban Harbors Institute, 2000).

Although ports are often located in environmentally compromised areas, Port Authorities are also involved in environmental remediation and clean-up efforts (Urban Harbors Institute, 2000). Maintaining or improving coastal and marine navigation systems often requires regular dredging of sediment from waterways. Dredged materials are removed from navigation channels, and 5-10% of those sediments may be contaminated (Urban Harbors Institute, 2000). If proper cautionary measures are not taken, coral mortality can occur during port dredging operations (Cunning et al., 2019).

Coral reef ecosystems support cruise ship tourism, sailing, fishery, and marina industries in coral jurisdictions. There is also a variety of jobs directly associated with small and large marine transportation interests, including in ports that serve as transportation hubs in many coral jurisdictions. Commerce associated with marina services such as boat repairs, food and beverage supplies, and other items relevant to the small craft sailing industry, as well as the shipping industry and mega-yachts in some jurisdictions, are important to local and regional economies.

3.5.2.4 Land Use and Cover

The majority of NOAA's efforts are located in or directly adjacent to coasts, estuaries, marshes, rivers, streams, and other aquatic features. As coastal areas are the most heavily developed areas in the U.S., a significant portion of project sites are in urban and suburban areas, where land uses range from residential (single- and multi-family) to recreational (e.g., beaches, estuaries, wetland preserves, rivers, and trails) to industrial (ports and aquaculture).

Impervious land cover, including military bases, industrial zones, and urban development, is a good indicator of human-developed land-use and is also associated with land-based pollution. Other sites are located in rural and agricultural areas, in addition to park lands. Tourism and recreational opportunities are an important use of coastal lands, and are dependent on a clean, healthy coastal environment. These activities include bird watching, hunting, fishing, beach-going, and boating.

Agriculture is an important land use in coastal and inland areas, affecting nearshore marine, estuarine, and freshwater resources. Since water is important for successful agricultural production, this land use is often located near freshwater bodies or in areas with freshwater aquifers. Agriculture often significantly alters the natural landscape and reduces the availability of high-quality fish habitat by building levees to drain wet areas or manage floodwaters, and reducing the quantity and quality of water in adjacent water bodies.

3.5.2.5 Fisheries

Reef-related commercial, recreational, and subsistence fisheries are economically important. Healthy coral reefs are important for sustainable fisheries production. Commercial fisheries are those that target wild stocks of species with the intent to sell their catch at market. Commercial fisheries landings in coral reef areas are not as large as those in temperate waters. Recreational and charter fisheries in coral reef areas are typically driven by tourism, with patrons hiring a local guide with knowledge of preferred fishing areas to maximize their success. For many coral reef-associated communities, subsistence harvest of coral reef fishes is a primary source of dietary protein. It is also regarded as less wasteful than commercial harvests due to its reef-to-table nature (Martin et al., 2017).

The harvest of fish and invertebrates for the aquarium industry is more prevalent outside of U.S. waters, but Hawaii and Puerto Rico have some active fisheries for the aquarium trade (LeGore et al., 2008; Miyasaka, 1997). However, the U.S. is the top importer of these organisms (Bruckner, 2005; Rhyne et al., 2017). Demand is driven by aquaria hobbyists, ornamental shell and coral skeleton collectors, as well as a live reef food fish trade, which targets the larger reef fish for consumption abroad.

3.6 Overview of Coral Reefs in U.S. States and Territories

This section serves to give relevant details and additional context at the state and territory jurisdictional level. Table 3-3 below generally describes the coral environment for the state and territory jurisdictions.

Table 3-3. Broad descriptions of the coral environment for the state and territory jurisdictions.

Jurisdiction	Ocean Basin	Coral Reef Type(s)	Ocean Temperature Range (°C)	Mean tidal range (cm)
USVI	Atlantic Caribbean	Patch, bank-barrier, fringing	26-29	22
Puerto Rico	Atlantic Caribbean	Patch, bank-barrier, fringing	25-28	20
Florida	Atlantic Caribbean	Patch, bank-barrier	23-30	75
Hawaii	Pacific	Barrier, fringing	22-28	39
American Samoa	Pacific	Fringing	27-29	79
CNMI	Pacific	Barrier, fringing	26-30	61
Guam	Pacific	Fringing	27-29	72
Flower Garden Banks	Gulf of Mexico	Patch	20-29	10
Papahānaumokuākea	Pacific	Patch, fringing	18-28	10
Pacific Island Remote Areas	Pacific	Patch, barrier, fringing	N/A	N/A

Source for ocean temperature data: www.nodc.noaa.gov; Source for tidal data: tidesandcurrents.noaa.gov (NOAA, 2019a)

3.6.1 U.S. Virgin Islands

3.6.1.1 Physical Environment

The USVI are located in the Caribbean in the northwestern most section of the Lesser Antilles. The total area of the USVI is 346 km^2 (215 mi^2). The USVI include three large main islands, St. Thomas (83 km2 [52 mi2]), St. John (52 km^2 [32 mi^2]), and St. Croix (218 km^2 [136 mi^2]), and more than 60 recognized cays or rocks (Gould et al., 2013). St. Thomas and St. John, located in the north, are geologically connected as part of the Puerto Rican bank (Rogers et al., 2008). St. Croix is located on a different shelf approximately 64 km (40 mi) to the south (Gould et al., 2013) (Figure 3-3).

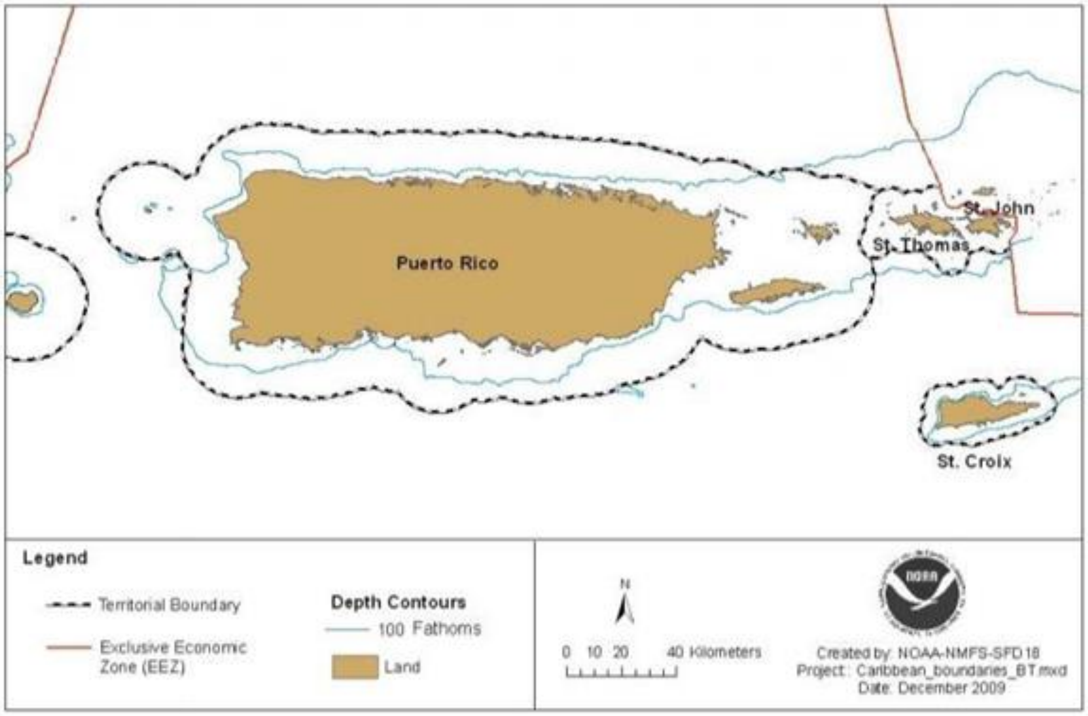

Figure 3-3. Map of U.S. Caribbean: Puerto Rico and the USVI. *Source: NOAA, 2009*

St. Thomas and St. John are volcanic in origin, with typically steep terrain and irregular coastlines. St. Croix is of sedimentary origin and generally consists of more rolling hills with a straighter coastline (Gould et al., 2013; Nemeth & Platenberg, 2007).

Coastal currents within the USVI are driven by winds and tides and range from 0-40 cm/s (0-15.8 in/s), but are typically less than 10 cm/s (0-4 in/s) (Rogers et al., 2008). These weak currents are dominated by tidal action and entrainment within the semi-enclosed bays of the islands (Rogers et al., 2008). Offshore surface currents (0-5 m [0-16 ft] depth) are stronger on average (23 cm/s [0-9 in/s]; ranging from 12-65 cm/s [5-26 in/s]), while bottom currents (up to 30 m [98 ft] depth) remain weak (average 16 cm/s [6 in/s]; range from 10-27 cm/s [4-11 in/s]) (Rogers et al., 2008).

Climate and Weather

The climate of the USVI is subtropical. The islands experience warm and humid conditions with minimal temperature variations between seasons (Runkle et al., 2018). There is less than 6ºC (42.8ºF) difference between the mean temperatures of the coolest and warmest months. The highest temperatures occur in August or September, and the lowest occur in January or February (Gould et al., 2013). The North Atlantic subtropical high, which brings persistent northeast trade winds to the islands, is the primary influence on the climate of the region (Runkle et al., 2018).

Precipitation across the USVI varies seasonally, with rainfall generally the heaviest from May to December along the northern and central portions of the islands (Gould et al., 2013). Though the islands are not high in elevation, topographic effects on precipitation still occur as the west or upwind sides tend to be wetter than the east or downwind sides. The average rainfall ranges from 75 cm (29.5 in) in the coastal areas to 140 cm (55.1 in) at higher elevations. St. Thomas and St. John typically receive slightly more annual rainfall than St. Croix (Gould et al., 2013).

Water Resources

Short, deeply incised, intermittent watercourses, or ghuts, drain the islands as there are no permanent rivers or streams in the USVI (Gardner et al., 2008; Olcott, 1999). Drainage tends to occur radially from central highpoints to the coast (Olcott, 1999). The flows through ghuts tend to be flashy due to the topography of the islands and rainfall patterns (Gardner et al., 2008).

Urban areas of the USVI rely on desalinated seawater for drinking water, while rural areas depend on rainwater collection systems and, to a lesser extent, groundwater supplies (Carr, 1990). Most groundwater exists at relatively shallow (2-20 m [7-66 ft]) depths in unconsolidated alluvial sediments or in shallow limestone deposits (EPA, 2004). The main aquifer in the USVI is the Kingshill aquifer of central St. Croix. This aquifer consists of limestone, marl, thin sandy interbeds, and conglomerates, and has a maximum thickness of about 60 meters (Olcott 1999). Minor aquifers on the other major islands are generally either alluvial valley aquifers, coastal embayment aquifers, or volcaniclastic-, igneous-, and sedimentary rock aquifers (Carr, 1990; Olcott, 1999).

While water quality is generally good, increased point and nonpoint source discharges have resulted in a declining trend (EPA, 2016). Direct discharges, run-off, and vessel wastes all contribute to this trend (EPA, 2016). Sources of pollutants in USVI ghuts are most often discharge from wastewater systems and urban runoff from storm sewers. Other frequent sources of pollution are confined animal feeding operations, minor industrial sources, and collection system failure by municipal sewage systems. Typical sources of groundwater contamination in the USVI include: bacterial contamination from failing septic systems; leaking municipal sewer lines; migration of contamination from previous injections and disposal practices; frequent sewage bypasses (generally described as discharges directly to the sea, but with some percolation into sub-soils); intrusion of saltwater caused by the over-pumping of the aquifers; invasion of volatile organic compounds; contamination from leaking underground storage tanks; and the indiscriminate/illegal discharges of waste (EPA, 2016).

3.6.1.2 Biological Environment

St. Thomas, St. John, and St. Croix and a number of small cays have a wide range of natural resources, including rare and endangered plants and animals; endemic species; and forests, mangroves, beaches, coves, cays, seagrass beds, and reefs (Gould et al., 2013). Coral reef ecosystems in the USVI face similar pressures as reefs elsewhere in the Caribbean (Jeffrey et al., 2005). Stressors impacting the structure and function of reefs include climate change, diseases, storms, coastal development and runoff, historical removal of wetlands and mangroves, coastal pollution, tourism and recreation, overfishing and destructive fishing practices, and ship and boat groundings (NOAA CoRIS, 2019a). Other, more specific stressors, have included the mass die-off of the long-spined sea urchin (*Diadema antillarum*) in the early 1980s and mass mortality of *Acropora* species and other reef-building corals due to disease and several coral bleaching events (Friedlander et al., 2013).

Marine

Marine habitats in the USVI include coral reefs, mangroves, seagrass beds, and sargassum mats. The variation and connectivity within these marine habitats support a rich variety of marine organisms, including corals, fish, molluscs, echinoderms, and others.

The USVI currently has *in situ* coral nurseries on St. Thomas (2) and St. Croix (3), managed by The Nature Conservancy (TNC) and University of the Virgin Islands, respectively. These are relatively small nurseries (established in 2009); outplanting began in 2011, and approximately 25,000 outplants have been added to the chosen reefs (79 FR 53851).

Coral reef habitats are found around the three main islands and most of cays of the USVI (Smith et al., 2018). Fringing, barrier, patch, shelf, submerged shelf-edge, spur and groove, and mesophotic reefs are all present in the USVI, with mesophotic reefs in waters 30-100 m (98-328 ft) in depth being the dominant reef structures around much of the territory (Smith et al., 2018). Reefs in St. Thomas and St. John tend to be comprised of fringing, patch, or spur and groove formations that are distributed variously around the islands. A well-developed barrier reef system with near-emergent reef crests that separate lagoons from offshore bank areas is found off the eastern and southern shores of St. Croix. Bank reefs and patch reefs are located on geological features at greater depths offshore (Jeffrey et al., 2005). Coral communities, not true coral reefs, are found growing on boulders and mangrove prop roots in shallow-water around most of the islands' shorelines (Rogers et al., 2008).

In general, the most developed reefs in the USVI are found off the eastern, windward ends of the islands (Rogers et al., 2008). Higher coral reef cover tends to be found on the lower forereefs of the fringing reefs around the islands compared to habitats at depths less than 20 m (66 ft) (Rogers et al., 2008). High cover is found on deeper offshore reefs like those that are part of the reef complexes off the south of St. Thomas and St. John (Rogers et al., 2008). Well-developed reefs dominated by *Orbicella annularis* complex (*O. annularis, O. franksi*, and *O. faveolata*) occur at depths of 33-47 m (108-154 ft) south of St. Thomas (Rogers et al., 2008). *Agaricia* species become relatively more abundant with depth (Rogers et al., 2008). Many shallow reefs have extensive stands of dead *Acropora palmata* (elkhorn coral); high density stands of living elkhorn still occur in some areas (Rogers et al., 2008).

Generally, based on NOAA's mapping of 485 km^2 (301 mi^2) of benthic habitats in the USVI to a nominal depth of 30 m (98 ft), coral reef and hard-bottom habitats comprise 61%, submerged aquatic vegetation and covers 33%, unconsolidated sediments comprise 4% of shallow-water areas (Jeffrey et al., 2005). The percent cover of living coral has been found to vary from 10% to 35% in the USVI (Jeffrey et al., 2005).

The coverage of living coral on various reef structures varies between the main islands. In St. Croix, for example, percent living coral varied from 4.4% to 39.1% among sites examined in one study (Jeffrey et al., 2005). Turf algae covering dead coral made up 50% or more of the benthic cover and was dominant at most sites (Jeffrey et al., 2005). Macroalgae coverage ranged from 3.2% to 34.9%. Sponges and gorgonians each comprised less than 10% of the substrata at all sites (Jeffrey et al., 2005). The composition of the coral community was similar among sites, with 10 species representing 95% of the coral community. *Montastraea* spp. and *Orbicella* spp. tended to be the most dominant corals (Jeffrey et al., 2005).

At St. Thomas, the percent cover of living coral ranged from 8.3% to 42% (Jeffrey et al., 2005). The coverage of dead coral covered with turf algae ranged from 15% to 45.6%. The percent cover of macroalgae ranged from 13.8% to 42.7% (Jeffrey et al., 2005). Sponges and gorgonians each comprised less than 10% of the benthic cover at all sites, and no gorgonians were found on shelf-edge sites (Jeffrey et al., 2005). Nearshore sites tended to have a lower percent cover of living coral and higher percent cover of dead coral covered with turf algae than did mid-shelf and shelf-edge sites (Jeffrey et al., 2005). Species within the *O. annularis* complex were generally less common at nearshore sites; these sites tended to have a higher percent composition of the stress-tolerant corals *Porites astreoides* and *Siderastrea siderea* than mid-shelf and shelf-edge sites (Jeffrey et al., 2005). Overall, the reefs of St. Thomas were generally dominated by species in the genera *Montastraea* and *Orbicella* (Jeffrey et al., 2005).

In a mutli-year study, Friedlander et al. (2013) observed some general spatial patterns in occurrence and cover of benthic organisms for St. John (Friedlander et al., 2013). Most coral reefs and hardbottom substrates in St. John appeared to be dominated by some form of algae, though occasional patches of hard corals, gorgonians, sponges, and other encrusting invertebrates were present. Another general pattern was the low average cover of live scleractinian coral (~5%) on coral reef and hardbottom areas (Friedlander et al., 2013). Friedlander et al. (2013) did, however, find a few hotspots of relatively high coral cover in southeastern St. John, particularly in Coral Bay (Friedlander et al., 2013). The five most dominant taxa in terms of coral cover around St. John were *O. annularis* complex, *M. cavernosa*, *P. astreoides*, *P. porites*, and *S. sidereal* (Friedlander et al., 2013). On average, total seagrass cover on seagrass beds was fairly low (32%) around St. John. *Thalassia testudinum* and *Syringodium filiforme* were the most frequently observed species. Many seagrass beds had diverse assemblages, containing macro algae, sponges, gorgonians, as well as living corals and other benthic invertebrates (Friedlander et al., 2013).

Invertebrates are a highly diverse component in the marine ecosystem and predominate coral reefs. Important invertebrates in the USVI include the scleractinians, commercially harvested Caribbean lobster (*Panulirus* spp), and queen conch (*Lobatus gigas*) (Johansen et al., 2018). Several species of the order Scleractinia in the USVI receive protected status from the ESA including elkhorn coral (*Acropora palmata*), the staghorn coral (*A. cervicornis*), the star corals (*Orbicella annularis*, *O. faveolata*, and *O. franksi*), the pillar coral (*Dendrogyra cylindrus*), and the rough cactus coral (*Mycetophyllia ferox*) (Johansen et al., 2018). USVI coral habitats are made up of at least 57 species of living corals, with over 40 species of scleractinian corals and three species of *Millepora* (Rogers et al., 2008; Smith et al., 2018). Other species of importance include sponges, algae-grazing urchins, and crabs.

Hundreds of fish species are known from USVI. For example, two studies have listed 400 species of fish from 93 families and 236 species, respectively (Rogers et al., 2008; Pittman et al., 2008). Friedlander et al. (2013) observed that fish species diversity was also highest where coral was most diverse and most abundant (Friedlander et al., 2013).

Four species of sea turtles (i.e., leatherback, green, hawksbill, and loggerhead) forage and nest within the territory, all of which are federally protected (Platenberg & Valiulus, 2018). The Caribbean provides feeding and calving grounds for approximately 30 species of marine mammals. Some species of marine mammals, including many dolphins and sperm whales, are resident year-round; others, such as the humpback whale, migrate long distances each year (Platenberg & Valiulus, 2018). ESA-listed species in the USVI include three baleen whales (blue, fin, and sei), one toothed whale (sperm), and one sirenian (West Indian manatee).

Freshwater and Terrestrial

Freshwater stream and pond systems are rare habitats in the USVI, and ghuts form the most extensive network of freshwater habitats in the USVI. The habitat value of these systems are high as they form some of the most diverse habitats in the USVI and are important for several aquatic species that spend part of their life cycle in freshwater and part in the marine environment (Gardner et al., 2008). These systems contain an array of species, including decapods (shrimp and crabs) and catadromous fish (Platenberg & Valiulus, 2018). Five species of shrimp from the families Palaemonidae and Atyidae are known from freshwater streams in the USVI (Platenberg & Valiulus, 2018). Observations of crabs are relatively rare though various crab species are associated with freshwater in the USVI (Platenberg & Valiulus, 2018). Freshwater fish include the Sirajo goby (*Sicydium plumieri*), mountain mullet (*Agonostoma monticola*), and small-scaled spinycheek sleeper (*Eleotris perniger*). Catadromous American eels (*Anguilla rostrata*) can also occasionally be found in freshwater systems in the USVI (Platenberg & Valiulus, 2018).

Terrestrial habitats in the USVI include forests, shrublands, beaches, and cays. Forests, both dry subtropical and subtropical moist, are the principal habitat across the larger islands in the USVI (Platenberg & Valiulus, 2018). Where extreme conditions, such as strong winds and salt spray or disturbance from agriculture and land use change, limit growth to low, scrubby vegetation, shrublands and grasslands predominate (Platenberg & Valiulus, 2018). Beaches and shorelines covering the coast of the USVI may vary widely from rocky cliffs to cobbly beaches to sand, and make up a large percentage of total area of the islands. Cays are present around the larger islands, particularly the northern USVI (Platenberg & Valiulus, 2018).

Thousands of terrestrial invertebrate species are found in the USVI, including insects, spiders, scorpions, millipedes, centipedes, snails, and slugs, among others. Gould et al. (2013) found the USVI terrestrial vertebrate biodiversity to be composed of over 294 species, including breeding and non-breeding residents, non-breeding and breeding migratory, vagrant or accidental species, and established exotics (Gould et al., 2013). Four native amphibians, belonging to two families, the rain frogs and the ditch frogs, are present in the USVI. All four species occur on St. Thomas and St. John (*Eleutherdactylus antillensis*, *E. cochranae*, *E. lentus*, and *Leptodactylus albilabris*), and three occur on St. Croix (*E. antillensis*, *E. lentus*, and *L. albilabris*) (Platenberg & Valiulus, 2018). An additional endemic, *Eleutherodactylus schwartzi*, is believed to be extirpated. Three non-native amphibians are also found in the USVI: cane toad (*Rhinella marinaI*), Cuban tree frog (*Osteopilus septentrionalis*), and common coqui (*Eleutherodactylus coqui*) (Platenberg & Valiulus, 2018). Twenty-three species of terrestrial reptiles exist in the USVI: 13 lizards (three non-native and four endemic to the Virgin Islands), seven snakes (three non-native and two endemic), two terrapins (both presumably non-native), and one tortoise (presumed introduced) (Platenberg & Valiulus, 2018).

Landbirds present in the USVI are primarily songbirds, doves and pigeons, cuckoos, and raptors (Platenberg & Valiulus, 2018). A wide variety of waterbirds are found in marshes, open water habitats, and along shorelines. A majority of these birds are migratory, breeding in North America and flying south to the Caribbean, Central America, or South America for the winter (Platenberg & Valiulus, 2018). The USVI are also an important habitat for resident and migratory seabirds. Of 39 species of seabirds recorded, 15 breed in the USVI (Platenberg & Valiulus, 2018). Boobies (Sulidae), pelicans (Pelecanidae), and frigatebirds (Fregatidae) are resident year-round. Most petrels and shearwaters (Procellariidae), storm-petrels (Hydrobatidae), tropicbirds (Phaethontidae), and jaegers, gulls, and terns (Laridae) are migratory (Platenberg & Valiulus, 2018).

The only mammals endemic to the USVI are the six bat species that feed on insects and/or fruit and serve as both pollinators and seed dispersers (NPS, 2017; Platenberg & Valiulus, 2018). Ten species of mammals have established feral or free-ranging populations, including the domestic cat (*Felis domesticus*), the small Indian mongoose (*Herpestes javanicus*), and the Norway rat (*Rattus norvegicus*).

Five plant species and five animal species in the USVI are listed as threatened or endangered (Appendix E).

3.6.1.3 Cultural Resources

The USVI, associated with the U.S. since 1917, have a rich cultural history connected to European explorers and colonizers, and the Taino and Carib Americans Indians, who inhabited the region before the arrival of the Europeans. Known human settlement in the Caribbean Islands reaches back at least 4,000 years (NPS, 2004). Signs of this long history have been preserved in architecture and artifacts. There are currently 90 sites listed on the National Register of Historic Places (NRHP), spread across 16 of the 20 subdistricts within the three islands/districts of the USVI (NPS, 2019a). Five sites are additionally designated National Historic Landmarks. Some properties of interest in the USVI include Fort Christian, a U.S. National Landmark and the oldest standing structure in the USVI, and Synagogue of Beracha Veshalom Vegmiluth Hasidim, the oldest synagogue in continuous use in the U.S. (NPS, 2013).

3.6.1.4 Socioeconomic Environment

Land Use and Cover

The landscape of the USVI is made up of a variety of ecosystems including forests, woodlands, shrublands, grasslands, wetlands, rocky shores, sandy beaches, and urban environments (Gould et al., 2013). Gould et al. (2013) identified 67.2% of the USVI as predominantly woody vegetation; 6.9% as grassland or herbaceous agriculture; 21.5% as developed land; about 1% as water; and 1.9% as natural barrens. Gould et al. (2013) also broke down these broad classifications further; woody vegetation, for example, was made up of 4.6% upper elevation and gallery moist forests, shrublands and woodlands; 60.7% dry forests, shrubland and woodland cover; and 1% flooded mangrove forests (Gould et al., 2013).

Historically, dramatic land cover changes on the USVI first came with the development of agricultural plantations during the 17th and 18th centuries (Gould et al., 2013). Wood-cutting and other economic activities became more important during the early 19th century (Gould et al., 2013). Pastures and livestock grazing also grew in importance but eventually gave way to industrialization and urbanization (Gould et al., 2013). Land use varies from island to island; St Thomas, for example, faces more pressure from urban development and the tourism industry while St. Croix has seen greater impacts from agricultural activities such as cattle grazing (Gould et al., 2013).

Table 3-4. Land area coverage of various land cover types in the USVI.

Land Cover Type	Area (km^2)	Area (%)
Forest, woodland and shrubland	236.2	67.2
Grasslands	25.2	7.2
Natural barrens	6.7	1.9
Agriculture	2.2	0.6
Artificial barrens	2.0	0.6
Developed areas	75.7	21.5
Water	3.6	1.0

Source: Gould et al., 2013

The USVI also has preservation areas, such as a national park and national monuments, created to conserve coral reef resources to varying degrees (Table 3-5).

Table 3-5. USVI designated marine areas, the year they were initially established and their current size. Asterisk indicates marine portion of the area only.

	Year Established	Area (km^2)
Buck Island Reef National Monument	1961	3.56
Virgin Islands National Park*	1962	22.86
Marine Conservation District	1999	41.00
Virgin Islands Coral Reef National Monument	2001	76.95

Source: Costa et al., 2012; NOAA, 2014; Jaap, 2015

Natural Resource Economy

Coral reef ecosystems in the USVI provide valuable ecological services, supporting a significant recreation and tourist industry and commercial and subsistence fisheries, as well as protecting shorelines from storms and wave action to prevent erosion, property damage, and loss of life (Jeffrey et al., 2005).

Gorstein et al. (2019) found human participation in recreational coral reef-related activities to be significant, with most USVI residents who were surveyed participating most frequently in swimming (79%) and beach recreation (78%) (Gorstein et al., 2019). Survey results also indicated that 17% of residents dive and 45% of residents snorkel. The same study found that just over 40% of residents indicated that they participate in fishing or gathering of marine resources.

The USVI's economy was historically dependent on agriculture and trade. In the last several decades, however, the economy has shifted to one that is mostly tourism-based. In 2016, tourism directly produced a GDP of $590.5 million and directly supported approximately 5,500 jobs (Gorstein et al., 2019).

The USVI commercial fishing industry is relatively small and artisanal (Jeffrey et al. 2005). Compared to much of the U.S. mainland, there is no dealer network, and most commercial fishermen harvest their catch one day and sell it by the roadside the next, although a few fishermen sell directly to restaurants and resorts (Fleming et al., 2017). The fleets are largely based in St. Thomas and St. Croix, with a few fishermen still working from the much less populated St. John. The USVI charter fleet likewise works mostly from St. Thomas and St. Croix, predominantly the former, due to its larger share of tourism traffic.

A variety of gear types are used across the main islands of the USVI. While traps and fish pots appear most popular on St. Thomas and St. John, hook and line and spearfishing are the most common on St. Croix (USVI DPNR, 2017).

Two long-term fisheries independent datasets, collected by the USVI Territorial Coral Reef Regional Monitoring Program and the NOAA Center for Coastal Monitoring and Assessment, emphasize the significant differences between the northern USVI and St. Croix in both the occurrence and size of several species of large and commercially important reef fishes (Kadison et al., 2017). Snappers (family Lutjanidae) and groupers (family Epinephelinae) are important USVI fisheries, with snapper biomass much lower on St. Croix sites than St. Thomas or St. John sites, while grouper biomass is low overall, but relatively higher in St. Thomas and St. John sites. There is a high variability between years for snappers in St. Thomas and St. John because some sites host spawning aggregations of cubera (*Lutjanus cyanopterus*) and schoolmaster snapper (*L. apodus*) (Smith et al., 2015).

Other major coral reef-associated fisheries in the USVI include Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Lobatus gigas*). Spiny lobster were the top species landed in 2016 on St. Thomas and St. John; landings of lobster were much lower on St. Croix (USVI DPNR, 2017). Queen conch is more frequently landed on St. Croix than on the other main islands (USVI DPNR, 2017).

Species that are currently designated as overfished, meaning that stock biomass is below a determined threshold for sustainability, include goliath grouper (*Epinephelus itajara*), Nassau grouper (*Epinephelus striatus*), and queen conch.

3.6.2 Puerto Rico

The Commonwealth of Puerto Rico is the easternmost archipelago of the Greater Antilles and is comprised of the main island; the oceanic islands of Mona, Monito, and Desecheo in the Mona Passage; Caja de Muertos Island on the south coast; Vieques Island; Culebra Island; and a series of smaller islets or cays known as the "Cordillera de Fajardo" (Garcia-Sais et al., 2005).

3.6.2.1 Physical Environment

The main island is approximately 180 km (112 mi) long and 50 km (31 mi) wide and has 620 km (385 mi) of coastline (Gould et al., 2008) (Figure 3-3). The dominant physiographic features of the island of Puerto Rico are the Central Mountain Range, or Cordillera Central, that runs east-west, a region of karst hills in the northwest, and the Luquillo Mountains of the northeast (Gould et al., 2008).

Puerto Rican coasts are composed mainly of rocky shores, sandy beaches and dunes, and wetlands. Wetlands can be found island-wide while rocky shores, as well as the sand beach and dune systems, are often found in the north coast. The geological, climatological, and oceanographic features that affect growth and development of coral reefs vary markedly along the coasts (García-Sais et al., 2005).

The north and northwest coasts have a relatively narrow shelf, and ecological communities are subject to strong wave action during winter from large swells coming from the north Atlantic (García-Sais et al., 2005). The largest rivers of Puerto Rico also discharge in this area, carrying substantial amounts of sediments and nutrients to the ocean. Sand dunes are abundant along the north coast, as are rocky beaches with rich intertidal communities and small seagrass patches (García-Sais et al., 2005). The northeast coast has a wider shelf, partially protected from wave action by the Cordillera de Fajardo. The east coast between Fajardo and Vieques is characterized by expansive sand deposits that do not support extensive coral growth (García-Sais et al., 2005). The south coast shelf is generally wider than that of the north coast and is subject to relatively low wave energy. Embayments and submarine canyons are found along the south coast. Small mangrove islets also exist on this coast, many providing hard substrate for coral development (García-Sais et al., 2005). On the south coast, the shelf-edge drops off at about 20 m with an abrupt, steep slope. A submerged coral reef lies at the edge of the shelf and gives protection to other reefs, seagrass and mangrove systems of the inner shelf (García-Sais et al., 2005). The southwest coast is relatively wide and dry, with many emergent and submerged coral reefs that provide for development of seagrass beds and fringing mangroves (García-Sais et al., 2005).

Tides in Puerto Rico are generally mixed, with semi-diurnal tides along the Atlantic-facing coast (mean range: 0.33 m [1.08 ft]) and diurnal tides on the Caribbean side (mean range: 0.20 m [0.65 ft]) (NOAA, 2019a). Currents in the Mona Passage and in the Vieques and Virgin Passages are strongly semidiurnal, with current velocities up to 2 kt (2.3 mps) (NOAA, 2019a). Large-scale circulation features such as the Caribbean Current and mesoscale eddies can affect coastal currents.

There are four marine protected areas that the Puerto Rico government jointly manages with NOAA: Jobos Bay National Estuarine Research Reserve and three seasonal closure areas for spawning aggregations of red hind grouper (*Epinephelus guttatus*)--Tourmaline Bank, Bajo de Cico, and Abrir La Sierra (DOE, 2017a).

Climate and Weather

The climate of Puerto Rico is tropical marine with moderate temperatures year round (Runkle et al., 2018). Temperatures average around 27°C (80°F) in lower elevations and 21°C (70°F) in the mountains and higher elevations. Temperatures are generally cooler in January, with an average minimum temperature of 22.2°C (72.0°F) and an average maximum temperature of 28.4°C (83.2°F), and warmer in August, with an average minimum temperature of 25.7°C (78.2°F) and an average maximum temperature of 31.8°C (89.2°F) (Runkle et al., 2018). The dominant influence on the island's climate is the North Atlantic subtropical high, which creates persistent prevailing trade winds from the east and northeast (Runkle et al., 2018).

The topography of the island also plays a significant role in the climate of the island. The mountains of the Cordillera Central are the primary factor in the rainfall and temperature variations that occur over very short distances on the island and serve as a natural divide that separates Puerto Rico into two climatologically discrete regions. The wetter, more humid regions of the island are found on the windward, northern side of the mountains, and drier, semi-arid climate is found in the leeward rain shadow (Gould et al., 2008; Runkle et al., 2018).

Mean annual rainfall on Puerto Rico ranges from below 90 cm (295 in) in the subtropical dry habitats to over 400 cm (1312 in) in the subtropical wet rain forest (Gould et al., 2008). Puerto Rico has a defined rainy season that lasts from April to November (Runkle et al., 2018). The rainfall in the wet season is largely a result of hurricanes and tropical storms. High sea surface temperatures during this season can also trigger local thunderstorm activity. In the dry season, rainfall is caused by cold fronts moving from west to east (Runkle et al., 2018).

Due to their position in the Caribbean hurricane belt, the islands of Puerto Rico are significantly affected by tropical cyclone events (hurricanes, tropical storms, and tropical depressions). These events typically occur near the islands once every two years, and they can have devastating impacts (Runkle et al., 2018). Tropical cyclones that have affected Puerto Rico in the 21st century include, but are not limited to, Tropical Storm Jeanne in 2004, Hurricane Irene (Category 1) in 2011, and Hurricane Irma (Category 5) in 2017 (Runkle et al., 2018). Hurricane Maria (Category 5) made landfall in Puerto Rico in September 2017 as a Category 4 hurricane, but locally winds reached Category 5 intensity. Maria led to overwhelming destruction across the islands. Extremely heavy rainfall and intense wave action and storm surge caused extensive damage. Severe flooding and mudslides also devastated much of Puerto Rico, and most residents lost power for months during the largest power outage in American history (Runkle et al., 2018).

Water Resources

Puerto Rican watersheds are small with steep channel gradients and narrow stream valleys that transport 57% of the mean annual precipitation (911 mm [36 in] of the 1,600 mm/yr [63 in/yr] on average from 1990-2000) to the coast (Warne et al., 2005). Major storms are generally intense and brief, rapidly producing floods from maximum daily discharge rates that can be more than three orders of magnitude above base discharge rates before quickly receding on the order of hours to a few days (Warne et al., 2005). With this runoff comes a substantial amount of transported sediment from upland watersheds to the coast, with mean annual suspended-sediment discharge from Puerto Rico into surrounding coastal waters estimated to have ranged from 2.7-9.0 million metric tons for the water years 1990-2000 (Warne et al., 2005).

Nonpoint source pollution of Puerto Rican rivers and streams via septic tanks, animal feeding operations, and urban runoff are the major sources of surface water contamination. This pollution causes the impairment of lakes, reservoirs, and ponds through depletion of dissolved oxygen, increases in fecal coliform, and pH, among other causes. The causes of impairment for coastal shorelines, bays, and estuaries are similar and include fecal coliform, low dissolved oxygen, non-mercury metals, turbidity, and pH.

Puerto Rico has two major aquifers (the karst North Coast Limestone and alluvial South Coastal Plain aquifers), and dissolved solids in both aquifers are dominated by calcium and bicarbonate ions (Olcott, 1999). In the northern aquifer, the chemical composition of the groundwater changes with proximity to the Atlantic Ocean; concentrations of magnesium, sulfate, and pH increase closer to the ocean (Olcott, 1999). Groundwater provides 16 percent of the water used in Puerto Rico (Rafael et al., 2016).

3.6.2.2 Biological Environment

Puerto Rico has a variety of unique marine and terrestrial ecosystems, including coastal mangrove forests, seagrass beds, tropical rain forests, tropical dry forests, and coastal plains. Puerto Rico is surrounded by over 5,000 km^2 (3,106 ft^2) of shallow-water coral reef ecosystems (NOAA CoRIS, 2019b). The present status of Puerto Rican coral reefs may be one of the most critical in the Caribbean (Garcia et al., 2003), with approximately 93% of Puerto Rico's coral reefs identified as vulnerable and 84% as high risk (Gorstein et al., 2017). Extensive urban and industrial development and a history of ineffective management policies to conserve these ecosystems played a role in the degradation of the reefs (Garcia et al., 2003). Other historical anthropogenic stressors include deforestation of mangrove forests in the north, dredging of bays, runoff from large-scale agricultural activities in the coastal plain, deforestation of riparian areas in large river watersheds, raw sewage disposal into rivers, and establishment of thermoelectric power plants on the north and south coasts (Garcia et al., 2003). Today, sedimentation, eutrophication, pollution, algal growth, and overfishing also negatively affect reefs. Other impacts such as coral bleaching, diseases, invasive species, and physical damage have also contributed to the declining health of the reefs (Gorstein et al., 2017). Hurricanes are natural catastrophic events that have also caused massive mortalities to coral reef and other coastal marine communities in Puerto Rico (Garcia-Sais et al., 2005).

Marine

At least three significant types of reefs—rock reefs, hard ground reefs, and coral reefs—are found within the Puerto Rican shelf (García-Sais et al., 2005; Garcia et al., 2003). Rock reefs are submerged hard substrate features of moderate to high topographic relief with low to very low coral cover. They are mostly colonized by turf algae and other encrusting biota. Coral colonies can be abundant in some cases (e.g., *Diploria* spp., *Siderastrea* spp., *Montastrea cavernosa*, *Porites astreoides*) but grow mostly as encrusting forms that provide minimal topographic relief (García-Sais et al., 2005; Garcia et al., 2003). Rock reefs fringe the west and northwest coasts and are likely the main components of deep reef systems beyond the shelf edge (García-Sais et al., 2005). These coasts are subjected to high wave energy, abrasion, and sedimentation stress (Garcia et al., 2003). Rock reefs are important habitats for fish and macroinvertebrates as the reefs are generally the only structure providing underwater topographic relief in these areas. Some rock reefs are characterized by the development of coralline communities adapted for growth under severe wave action and strong currents (García-Sais et al., 2005; Garcia et al., 2003).

Hard ground reefs are mostly flat platforms ranging in depth from 5-30 m. These reefs are typically covered by turf algae, encrusting sponges, and scattered patches of stony corals (García-Sais et al., 2005; Garcia et al., 2003). Coral colonies on hard ground reefs are generally encrusting forms, which may result from the high wave action that prevails in the winter months on the north coast (García-Sais et al., 2005; Garcia et al., 2003). One of the main contributors to topographic relief of hard ground reefs is the barrel sponge (*Xestospongia muta*) (García-Sais et al., 2005; Garcia et al., 2003). In many areas, low-relief, coarse-substrate sand channels cut through the hard ground reefs and are devoid of biota (García-Sais et al., 2005; Garcia et al., 2003). These systems are found off the central north and northeast coastlines (García-Sais et al., 2005; Garcia et al., 2003).

The coral reef ecosystems in Puerto Rico are mosaics of interrelated habitats, including mangrove forests, macroalgal beds, seagrass beds, and coral reefs, as well as other coral communities (García-Sais, 2008). Distribution of these ecosystems varies as the result of geomorphology and different exposure to wave and wind action, resulting in different types of reef formations that include fringing, patch, spur and groove, shelf-edge, and cays (Ballantine et al., 2008).

Fringing coral reefs are the most common coral reef formation in Puerto Rico and are found along most of the northeast, east, and south coastlines (Garcia et al., 2003). Coral is not the main component of the basic reef structure, but its development has significantly contributed to the topographic relief of the reef, providing habitat for a diverse biological assemblage consistent with a coral reef community (Garcia et al., 2003). Fringing reefs are also found off the northeast coast at Rio Grande, Luquillo, Fajardo, Culebra and Vieques. Fringing reefs on the north coast are characterized by the presence of shallow (0.5-3.0 m depth) back-reef communities dominated by *Porites porites* habitats and scattered colonies of different species (Garcia et al., 2003). On the south coast, coral reefs fringe many small islands or cays. These reefs may be found as fairly extensive coral formations at the mouths of coastal embayments (Garcia et al., 2003). In some cases, coral growth has led to the formation of emergent island reefs, such as the reefs off La Parguera where well-developed coral assemblages fringe the forereef section of the islet. A reef flat with *Porites porites* habitat is generally found with intermixed turtle seagrass (*Thalassia testudinum*) and scattered small, low-relief coral colonies. Development of the reef flat can lead to the growth of red mangroves (*Rhizophora mangle*) whose aquatic root system provides habitat for a diverse assemblage of juvenile reef fishes and invertebrates. As wave action brakes up coral colonies and fragments and deposits them on the emergent section of the reef, the reef will continue to grow (Garcia et al., 2003).

Shelf-edge reefs are the best developed coral reef ecosystems in Puerto Rico (Garcia et al., 2003). An extensive reef formation is found at the shelf-edge off the south coast. Another well-developed formation is the shelf-edge reef at the northern Tourmaline Reef off Bahía Mayaguez. The best developed reef within Puerto Rican waters is likely the shelf-edge reef found off the southwestern section of Isla de Mona where extensive sections surpass 60% of live coral cover (Garcia et al., 2003).

On the north coast, where large oceanic swells are present, reefs are generally dominated by macroalgae and have low abundance of scleractinian corals (1-5% cover) (Ballantine et al., 2008). Alcyonarians and the hydrocoral *Millepora squarrosa* are common along this coast but essentially absent on other coasts (Ballantine et al., 2008). The development of reefs on the north coast off Luquillo and other areas on the northeast coast may be associated with a wider shelf and corresponding reduction in ocean swells (Ballantine et al., 2008). Garcia et al. (2003) found that of 52 reefs examined, reefs with live coral cover below 10% were all on the northeast coast, including the island of Vieques. Mainland reefs from the north and northeast coastlines (Mameyal, Bajíos, Boca Vieja, Morrillos, Siete Mares, Pta. Candelero) all had low coral cover with Las Cabezas Reef in Fajardo being the only mainland reef from the northeast coastline with live coral cover above 10% (Garcia et al., 2003).

Coral reefs along the east coast of Puerto Rico tend to be well-developed, and fringing reefs along the mainland are the most common reef type in this region (Ballantine et al., 2008). Shallow areas tend be dominated by zoanthids and scleractinian coral taxa that are relatively rapid colonizers like *Porites astreoides* and *Siderastrea radians* (Ballantine et al., 2008). Nonetheless, scleractinian coral cover rarely exceeds 5% with the exception of extensive stands of *Acropora palmata,* which occur occasionally (Ballantine et al., 2008). On offshore islands, fringing reefs have variable scleractinian cover (Ballantine et al., 2008). The shallow windward zone (0.3-1.0 m) tends to have low scleractinian and hydrocoral cover (<10%) while the deeper windward zone (3-5 m) has structures resembling spur and groove formations with live scleractinian cover between 5% and 20% (Ballantine et al., 2008). At greater depths, live cover varies between 30% and 80% (Ballantine et al., 2008). Leeward areas typically have high scleractinian diversity and cover (Ballantine et al., 2008). On the east coast, coral assemblages also occur on shallow basalt outcrops (Ballantine et al., 2008). Here, scleractinian cover is patchy (1-35%), but non-reef building taxa like alcyonarians and zoanthids are abundant (Ballantine et al., 2008). Invertebrate cover in shallow areas of basaltic outcrop formations is typically low and dominated by hydrocorals. Deeper areas (10-20 m) of basaltic outcrops have low coral cover (<5%) (Ballantine et al., 2008). Shelf-edge reefs at even greater depths (20-40 m) are common on the east coast and have high scleractinian richness and cover (85-100%) (Ballantine et al., 2008).

The south and west coasts of Puerto Rico support extensive seagrass, coral reef, and algal communities. Mangrove forests and coralline keys dot the coast in areas protected from development (Ballantine et al., 2008). The territory's best-developed reefs occur in the La Parguera area of southwest Puerto Rico (Ballantine et al., 2008). In this area, an inner reef and a mid-shelf reef generally parallel the coastline (Ballantine et al., 2008). Depending on the environmental factors present, these reefs are dominated by algal, alcyonarian, or scleractinian-sponge communities (Ballantine et al., 2008). Fringing reefs bordering the shoreline are the dominant inshore coral reef habitat in La Parguera (Ballantine et al., 2008). According to Garcia et al. (2003), shallow reefs with live coral cover of 20% or higher were from the southeast coast (Garcia et al., 2003). Live coral cover at the deeper reefs studied (15-25 m) was highest at 44% at the shelf-edge reef off La Parguera (Garcia et al., 2003). Other reefs surveyed at depths between 15 and 25 m (49 and 82 ft) from the southwest coast (Penuelas, Turrumote) had live coral cover ranging from 16 to 27%. *Orbicella annularis*, *Montastrea cavernosa*, *Porites atreoides*, and *Agaricia* spp. were the most common coral taxa at the deeper reefs studied (Garcia et al., 2003).

At greater than 30 m (98 ft), deep reefs occur along the insular slope of Puerto Rico and associated islands (Ballantine et al., 2008). Scleractinian cover typically decreases with depth in deep reefs, with the maximum depth of hermatypic scleractinians between 70 m (21 ft) and 100 m (34 ft) (Ballantine et al., 2008). Alcyonarian abundances also decrease with depths over 65 m, but antipatharian abundance has been found to peak at 54 m (177 ft) (Ballantine et al., 2008). Up to depths of 100 m, sponges appear to be the major structural component of the deep reef fauna while algae account for much of the benthic cover (Ballantine et al., 2008).

The coral reefs of Puerto Rico have the greatest species richness in the Caribbean, with 125 hard corals, 112 soft corals and gorgonians, and over 200 species of fish (Kelty et al., 2004). At least 69 species of scleractinian corals, 46 alcyonarian species, 42 octocorals, four species of black coral (anthipatharians), and four hydrocorals have been identified in Puerto Rico (Ballantine et al., 2008; Garcia et al., 2003). Fish communities in Puerto Rican waters are represented by 260 species (Dennis et al., 2004), and some of the habitats described above are considered EFH for different species. The number of fish species has been found to positively correlate ($p<0.01$) with live coral cover on reefs surveyed around Puerto Rico (Garcia-Sais et al., 2005). Reefs with low live coral cover and high benthic algal cover exhibit less diverse fish communities (Garcia-Sais et al., 2005). The benthic marine algae in Puerto Rico is the best known in the Caribbean and consists of approximately 500 species (Ballantine et al., 2008).

Five species of sea turtle forage and nest within Puerto Rico; all five species are listed as federally endangered or threatened (Caribherp, 2019). More than 30 species of marine mammal have been documented in the Caribbean Sea (UNEP CEP, 2015). These species include sperm whale (*Physeter* *macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*), short-finned pilot whale (*Globicephala macrorhynchus*), rough-toothed dolphin (*Steno bredanensis*), bottlenose dolphin (*Tursiops truncatus*), Atlantic spotted dolphin (*Stenella frontalis*), Pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), and striped dolphin (*Stenella coeruleoalba*). ESA-listed species include the West Indian manatee Puerto Rico stock (Antillean subspecies, *Trichechus manatus manatus*) and five whale species: sperm, blue (*Balaenoptera musculus*), finback (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), and sei (*Balaenoptera borealis*).

During the last decades, losses to the system due to diseases, unsustainable fishing, and other human impacts have shaped the current state of the reefs. Important coral reef ecosystem species are sea turtles (all), sharks (all), butterfly fish (*Chaetodon capistratus*), black urchin (*Diadema antillarum*), and parrotfishes (all). Culturally important reef fish/marine species include spiny lobster (*Panulirus argus*); queen conch (*Strombus gigas*); snappers: silk (*Lutjanus vivanus*), lane (*Lutjanus synagris*), and yellowtail (*Lutjanus chrysurus*); hogfish (*Lachnolaimus maximus*); trunkfish (*Lactophrys spp.*); cowfish (Tetradontidae); grunts (Haemulidae); red hind (*Epinephelus guttatus*); queen trigger (*Balistes vetula*); and octopus (*Octopus* spp.).

Terrestrial and Freshwater

Freshwater habitats in Puerto Rico include rivers, reservoirs, lagoons, streams, and ponds. The central mountain chain is oriented east to west, and most of the major rivers in Puerto Rico flow toward the north shore. Rivers with smaller drainage basins discharge on the southeast coast and only small creeks discharge on the southwest coast. The island has no natural lakes.

Freshwater marshes have diverse vegetation consisting of grasses, sedges, rushes, and broadleaved aquatic plants while aquatic freshwater environments are dominated by vegetation such as water lily (*Nymphaea* spp.), alligator weed (*Alternanthera philoxeroides*), naiad (*Najas* spp.), fanwort (*Cabomba caroliniana*), and water hyacinth (*Eichhornia crassipes*).

Native freshwater fish assemblages of the Caribbean islands are dominated by species that migrate between freshwater and marine ecosystems and depend on the connectivity between riverine, estuarine and marine environments to complete their life cycles (USFWS, 2018a). Native species of Puerto Rico include the mountain mullet (*Agnosotomus monticola*), little anchovy (*Anchoa parva*), American eel (*Anguilla rostrata*), fat sleeper (*Dormitator maculatus*), and Sirajo goby (*Sicydium plumieri*) (Fishbase, 2017).

The landscape of Puerto Rico is made up of a variety of ecosystems including subtropical dry to moist forest, karst, woodlands, shrublands, grasslands, wetlands, rocky shores, sandy beaches, and urban environments (Gould et al., 2008). Puerto Rico possesses a varied range of habitats due to the differential rainfall around the island, a result of the Cordillera Central's influence over precipitation patterns. Puerto Rico has a diverse native flora with more than 180 higher vascular plant families and 3,100 species (Miller & Lugo, 2009).

These habitats also harbor many species of terrestrial invertebrates, amphibians, reptiles, birds, and mammals. Gould et al. (2008) indicated 436 vertebrate species have been recorded in Puerto Rico, including 328 birds, 57 reptiles, 27 mammals, and 24 amphibians (Gould et al.,2008). Sixty-nine of these species are endemic (Gould et al., 2008). Mammals in Puerto Rico include 13 living, native species, all of which are bats. Some important charismatic species for the region are the Puerto Rican parrot (*Amazona vittata*) and the Coquí tree frog (*Eleutherodactylus coqui*) (Miller & Lugo, 2009).

Non-native terrestrial mammals of Puerto Rico include introduced domestic animals and pest species such as the Indian mongoose (*Herpestes edwardsii*). Other introduced pest species include the black rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), and the house mouse (*Mus musculus*). Four species of non-native monkeys escaped from rearing colonies, including the Rhesus monkey (*Macaca mulatta*), and have occupied the southwest coast (Miller & Lugo, 2009).

Puerto Rico has 21 animals and 50 plants listed as federally endangered or threatened (Appendix E).

3.6.2.3 Cultural Resources

Like the USVI, Puerto Rico has a rich cultural history associated with the Taino and Carib peoples, as well as European and American influences. Associated with the U.S. since 1898, Puerto Rico has 351 properties listed on the NRHP, with one or more NRHP listings in each of Puerto Rico's 78 municipalities (NPS, 2019a). For example, during the 16th century, recognizing the need to protect the Spanish treasure fleets on their voyages to and from the New World, the Spanish erected extensive fortifications throughout their territories in the Caribbean Islands and the Gulf of Mexico. Designated a UNESCO World Heritage Site and National Historic Site, the Spanish system of fortifications in San Juan, Puerto Rico is the oldest European construction in the U.S. and one of the oldest in the New World (NPS, 2011).

3.6.2.4 Socioeconomic Environment

Land Use and Cover

Land cover in Puerto Rico was classified by Gould et al. (2008) as 53% predominantly woody vegetation, 32% grassland, 3% herbaceous agriculture, 11% developed and artificially barren land, <1% naturally barren land, and 1% fresh water (Table 3-6). The woody areas were further broken down into 26% low and mid-elevation moist forests, 18% upper elevation wet forests, 7% dry forests, and 1% flooded mangrove and Pterocarpus forests. The most abundant forest types are the montane wet evergreen secondary forest, which includes active and abandoned coffee plantations, and young secondary lowland moist forest on noncalcareous substrates (Gould et al., 2008). Nearly all of the moist and dry grasslands were found to be maintained by disturbance such as continuous or intermittent cattle grazing and or frequent burns (Gould et al., 2008). Natural barrens make up less than 1% of the area, but they are an important component of the landscape, both for human use and as wildlife habitat. Natural barrens include stony and sandy beaches, rocky cliffs and shelves, active riparian flood plains, and salt and mudflats (Gould et al., 2008). Development does not occur equally around the island and is concentrated in the coastal plain and lower hills. Sixty percent of the development occurs in the plains, where the most productive lands for agriculture are located, while developed areas cover less than 7% of the total area in the hills and mountains (Gould et al., 2008b).

Table 3-6. Land use/cover area size of Puerto Rico.

Land Use/Cover	Area (km^2)	Area (%)
Water	85.4	1.0
Developed areas	895.7	10.0
Forest, woodland, and shrubland	4718.7	52.7
Grasslands	2864.1	32.0
Agriculture	262.6	2.9
Natural barrens	35.8	0.4
Artificial barrens	86.9	1.0

Source: Gould et al., 2008

Within the land uses presented in Table 3-6, roughly 8% of Puerto Rico's land is designated for conservation. This includes public and private properties classified as state forests, national federal forests, wildlife refuges, natural reserves, natural protected areas, conservation easements, recently acquired lands for conservation, and other lands managed for conservation (Gould et al., 2011).

Natural Resource Economy

Communities in Puerto Rico benefit from coral reef resources through tourism, commercial fishing, and a range of recreational activities (Gorstein et al., 2017). Leeworthy et al. (2018) found that reef-using visitors to Puerto Rico spend over $1.9 billion annually within Puerto Rico. These expenditures support over 3% of jobs, account for nearly 4% of total income to the region, and generate nearly $2 billion in economic output to Puerto Rico (Leeworthy et al., 2018). Coral reefs also protect coastal infrastructure and beaches from erosion due to storm events and wave action, as well as provide material to replenish beaches (Gorstein et al., 2017).

Gorstein et al. (2017) found that participation in non-extractive recreational reef activities varies in Puerto Rico, with the two activities that residents participate in most frequently being beach recreation (83% participate) and swimming (51% participate). Participation in extractive activities such as spearfishing (5% participate), fishing (14% participate), and gathering of marine resources (6% participate) is less common (Gorstein et al., 2017).

Puerto Rico's commercial fishery is a multispecies, multi-gear, small-scale, artisanal fishery where harvest is used mostly for local consumption and is an important source of income and sustenance to many coastal communities (Matos-Caraballo & Agar, 2008).

In a 2008 study, Matos-Caraballo and Agar found that reef fishes were targeted by 77% of commercial fishermen—of those fishermen, 56% targeted deep-water snapper, 49% lobster, 42% pelagic fishes, 33% conch, and 31% bait (Matos-Caraballo & Agar, 2008). Tonioli and Agar (2011) found the lobster fishery to be the most valuable commercial fishery in Puerto Rico, yielding 265,518 lbs (120 metric tons) valued at $1,617,250 in 2008. SCUBA was the leading gear in this fishery, followed by fish and lobster traps (Tonioli & Agar, 2011). Queen conch (*Strombus gigas*) was found to be the second most important commercial fishery in Puerto Rico, yielding 208,676 lbs (94 metric tons) and $836,347 in 2008 (Tonioli & Agar, 2011). The primary gear type was SCUBA (Tonioli & Agar, 2011). The Caribbean Fishery Management Council has designated queen conch as overfished (NOAA, 2017b).

Gear usage and species targeted vary around the island. For example, the northern coast of Puerto Rico has a narrow insular shelf and an exposed coast that encourages the use of hook and line and, to a lesser extent, net gears, and discourages the use of traps and SCUBA (Tonioli & Agar, 2011). Fishermen in this region favor reef fish species such as yellowtail snapper (*Ocyurus chrysurus*), triggerfish (Balistidae), and parrotfish (Labridae and Scaridae); deep-water snappers such as silk (*Lutjanus vivanus*) and queen snappers (*Etelis oculatus*); and pelagic species such as dolphin-fish (*Coryphaena hippurus*), king mackerel (*Scomberomorus cavalla*), and little tunny (*Euthynnus alletteratus*) (Tonioli & Agar, 2011). By comparison, the southwest coast has a relatively shallow and extended shelf, where fishermen favor the use of bottom lines, SCUBA, and, to a lesser extent, troll lines and fish pots. This larger shelf allows fishermen to target a greater mix of species, including queen conch; spiny lobster; reef fish like yellowtail, lane (*Lutjanus synagris*), and mutton snappers (*Lutjanus analis*); deep-water snapper like silk and queen snappers; and pelagic species like dolphinfish, skipjack (*Katsuwonus pelamis*), blackfin (*Thunnus atlanticus*), and yellowfin tunas (*Thunnus albacares*); and king mackerel (Tonioli & Agar, 2011).

3.6.3 Florida

3.6.3.1 Physical Environment

Florida (170,304 km^2 [105,822 mi^2]) is the southernmost peninsula of the U.S., dividing the Gulf of Mexico and the Atlantic Ocean via the Straits of Florida. The Florida Current (up to 180 cm/s [71 in/s]), flowing east through the Straits of Florida, is adjacent to the Florida Reef Tract, which includes the Florida Keys National Marine Sanctuary, Biscayne National Park, Dry Tortugas National Park, and multiple other state and federal protected areas. The Florida Reef Tract, which spans about 370 km (200 nm) from Palm Beach County, Florida to the Dry Tortugas, is the third largest barrier reef in the world and contains patch reefs and bank reefs (Figure 3-4).

Figure 3-4. Location of the Florida Reef Tract (red). *Source: NOAA CoRIS, 2019c*

In addition to the Florida Reef Tract, habitats of the Atlantic Ocean and Gulf of Mexico contain both coral reef communities, patch reefs, and solitary coral colonies. Corals may dominate a habitat (coral reefs, patch reefs), be a significant component (hard bottom), or be individuals within the shelf region between central and southern Florida on the Atlantic coast. Immediately north of the Florida reef tract in southeastern Florida, the hard-bottom habitat is predominated by gorgonians and has several scleractinians as well (Wheaton & Jaap, 1976). The west Florida shelf in the Gulf of Mexico provides habitat for corals, particularly at the Florida Middle Grounds (FMG), which has reef-building species.

Climate and Weather

Florida's climate ranges from temperate in the north to subtropical in the south as the state lies at the convergence of these two climate zones (Andrews et al., 2005). Southeast Florida's climate ranges from subtropical to tropical maritime in Key West (Jaap et al., 2008). The Gulf of Mexico, Caribbean Sea, and Atlantic Ocean significantly influence Florida's generally warm, humid climate. The Gulfstream majorly influences water temperature and the transport of flora and fauna to the region. The Gulfstream enters into the Gulf of Mexico as the Loop Current and reverses flow to return to the Straits of Florida. There, it joins the main body of the Florida Current before flowing in a northeasterly direction towards Europe (Andrews et al., 2005).

South Florida experiences dramatic seasonal shifts in weather patterns, with heavy rains occurring primarily in the summer. North Florida's rainfall occurs mainly in winter because of the influence from continental frontal systems. Freezes occur yearly in North Florida but are rare in South Florida. Freeze events influence the range of tropical species up the Florida peninsula as tropical species range farther north along the coasts, which are better buffered from freeze events than interior areas (Florida FWCC, 2012).

Florida's climate is overlaid on the El Niño Southern Oscillation system cycles. El Niño brings warmer and wetter winters, fewer hurricanes, and doldrums in late summer that frequently lead to coral bleaching events, while La Niña results in drier and cooler winters, and more frequent hurricanes. Hurricanes, most common in August and September, force radical changes in the coral reef, seagrass, and mangrove communities (Jaap et al., 2008).

Ocean temperatures from data collected over 125 years range from 15.6-32.2°C (60.1-89.9°C) (Jaap et al., 2008). The lowest temperatures occurred at Fowey Rock near Cape Florida in February and the highest in August at Sand Key, Key West (Jaap et al., 2008).

Water Resources

Florida's freshwater supply comes from the systems of rivers, streams, wetlands, lakes, springs, aquifers, and estuaries across the state. Freshwater is used for public water supply, agricultural irrigation, commercial/industrial/institutional uses, domestic and small public supply, recreational irrigation, and power generation (FDEP, 2018a).

Like the Everglades, the natural landscape of much of the rest of south Florida has been altered with huge public works projects (Purdum, 2002). Canals, pumping stations, dikes, and weirs have all altered the watershed, and historic swamps, marshes, and associated sheetflow are commonly replaced by urban development and agriculture and drained by canals (Purdum, 2002).

Surface waters Florida-wide are impacted by impaired dissolved oxygen, fecal coliform, and eutrophication, among other things. Land-based pollution to the reef ecosystem occurs by discharges through inlets and bays, through sheet water flows and discharges coming from the Everglades into Florida Bay, or through outfalls in the northernmost section of the reef tract. For example, Enochs et al. (2019) demonstrated the important role that surface water plays on southeast Florida waters and highlighted the degree to which engineered freshwater systems can contribute to coastal acidification on localized scales (Enochs et al., 2019).

Supplying approximately 90% of the state's drinking water, Florida's underground aquifers are among the most productive in the world (South Florida Water Management District, 2010). The largest, oldest, and deepest aquifer in the southeastern U.S. is the Floridan aquifer. The Floridan aquifer is found beneath all of Florida and portions of Alabama, Georgia and South Carolina, and extends into the Gulf of Mexico and the Atlantic Ocean (St. Johns River Water Management District, 2019). This aquifer system is comprised of a sequence of limestone and dolomite, which thickens from about 250 ft (76 m) in Georgia to about 3,000 ft (914 m) in south Florida. The upper Floridan aquifer is the principal source of water supply in most of north and central Florida. In the far western panhandle and in southern Florida, the Floridan aquifer system is deep and produces salty and mineralized water. In these areas, the shallower Sand-and-Gravel Aquifer (in the west) and the Biscayne Aquifer (in the south) are used for water supply (FDEP, 2015).

Covering more than 4,000 mi^2 (6437 km^2) in southeastern Florida, the Biscayne Aquifer is a surficial aquifer. It is the most intensely used water source in Florida and supplies water to Miami-Dade, Broward, and southern Palm Beach Counties. Water from the Biscayne aquifer is also transported by pipeline to the Florida Keys (South Florida Water Management District, 2010).

In southwestern Florida, aquifers that lie between the Surficial Aquifer System and the Floridan Aquifer System are collectively referred to as the Intermediate Aquifer System. This aquifer system starts in Hillsborough and Polk Counties and extends south through Lee and Collier Counties. The Intermediate Aquifer System is the main source of water supply for Sarasota, Charlotte, and Lee Counties (South Florida Water Management District, 2010).

Several threats to Florida’s groundwater supply exist. Saltwater intrusion into the Biscayne Aquifer is driven by overuse and lack of replenishment of the aquifer from groundwater sources. Other threats include competing domestic, agricultural, and commercial interests, the latter including Florida Power and Light's Turkey Point Nuclear Power Plant.

3.6.3.2 Biological Environment

Florida has diverse and unique species and landscapes. Its ecological communities are shaped by the many different climates across which Florida spans. The proximity of the Florida reef tract to a highly urbanized coastal zone and growing population contributes to a number of human-related stressors to the reef communities. Water pollution, overfishing, coastal construction activities, vessel anchoring and grounding, and ballast water discharge threaten the region’s reefs (Banks et al., 2008). Other stressors include increasing water temperatures and bleaching, and disease (Collier et al., 2008).

Marine

Undeveloped areas along the coast of Florida contain extensive mangrove forests and a mosaic of exposed rock and sediments. The rock formations support coral reef development and the sediments support the most extensive seagrass beds in the world (Andrews et al., 2005).

Florida has wide-ranging shallow coral reef formations near its coasts. Conditions for extensive coral reef development around Florida exist largely due to the influence of the Gulfstream together with the presence of a broad-shallow continental shelf around the peninsula and the absence of any major rivers (Andrews et al., 2005).

These reefs extend over 300 miles around the peninsula from Stuart near the St. Lucie Inlet in Martin County on the east coast to the Dry Tortugas in the Gulf of Mexico (NOAA CoRIS, 2019c; Jaap et al., 2008). The Florida Reef Tract extends from south of Soldier Key (25°31.4′ N, 80°10.5′ W) to Dry Tortugas (24°38.4′ N, 82°51.8′ W) and has coral reef characteristics similar to many areas in the Bahamas and Caribbean Basin (Jaap et al., 2008; Andrews et al., 2005). The Florida Reef Tract does not include the reefs and hard-bottom habitats in Miami-Dade (north of Fowey Rock), Broward, Palm Beach, and Martin Counties that continue north to the St. Lucie Inlet (27°10′ N, 80°09′ W) (Jaap et al., 2008). All but the northernmost extent of the reef tract lies within the boundaries of the FKNMS. This 2,900 nmi^2 (5371 km^2) sanctuary was designated in 1990 and surrounds the entire archipelago of the Florida Keys (NOAA, 2007a). The northernmost portion of the reef tract lies within Biscayne National Park (BNP).

Extending north from the reef tract, still rich and diverse reefs and hard-bottom areas span from the northern border of BNP in Miami-Dade County to the St. Lucie Inlet (Andrews et al., 2005). These reefs are characterized by three parallel reef lines. The classic reef distribution pattern for central and southeastern waters of the Florida Atlantic coast consists of an inner reef in approximately 5-8 m (1.5-2.4 km) of water, a middle patch reef zone in about 9-15 m (2.7-4.6 km) of water, and an outer reef in approximately 18-30 m (2.4-9.1 km) of water (SAFMC, 2019). Nearshore reef habitats in southeast Florida include hard-bottom areas, patch reefs and worm reefs (*Phrag-matopoma* spp.) (Collier et al., 2008). The communities in these reefs includes over 30 species of stony corals and a diverse assemblage of gorgonians and sponges (SAFMC, 2018). Common stony coral species include: *Montastrea cavernosa*, *Siderastrea siderea*, *Porites astreoides*, *Solenastrea bournoni*, *Meandrina meandrites*, and *Dichocoenia stokesii*. Octocorals and sponges tend to have greater density than stony corals; some of the common octocoral genera include *Eunicea*, *Antillogorgia*, *Muricea*, *Plexaurella*, *Pterogorgia*, and *IcilogorgiaI* (SAFMC, 2018).

Middle reefs between the inner and offshore assemblages have more relief and dissecting channels than nearshore reefs (Jaap et al., 2008). Octocorals visually dominate, but stony corals are abundant and include great star coral (*Montastraea cavernosa*), massive starlet coral (*Siderastrea siderea*), and mustard hill coral (*Porites astreoides)* (Jaap, et al. 2008).

The offshore reef system often has stronger vertical relief and the highest diversity and abundance of sessile reef organisms (Jaap et al., 2008). Octocorals and large barrel sponges (*Xestospongia muta*) are most conspicuous, and moderate-sized colonies of star corals are common. Stony corals are somewhat larger than those located on the middle reef (Jaap et al., 2008).

The reef topography from Palm Beach County to Martin County is characterized by Anastasia Formation limestone ridges and terraces colonized by reef biota (Collier et al., 2005). Typical organisms are lesser starlet coral (*Siderastrea radians*) and colonial zoanthids (*Palythoa mammilosa* and *P. caribaeorum*)

(Andrews et al., 2005). *Pseudodiploria clivosa* forms large pancake-like colonies and provides the majority of the cover, and *Montastraea cavernosa* also attains large sizes (Jaap et al., 2008). Some extensive aggregations of staghorn coral (*Acropora cervicornis*) are present generally inshore of inner reefs in Broward County (Andrews et al., 2005).

The most productive reef development occurs seaward of the Florida Keys, and the most extensive living coral reef in the United States is adjacent to the island chain of the Florida Keys (NOAA, 2019). The densest and most well-developed reefs are found seaward of Key Largo and Elliott Key. Here, the two keys help protect the reefs from the effects of water exchange with Florida Bay, Biscayne Bay, Card Sound, Little Card Sound, and Barnes Sound, which are all situated between the Florida Keys and the peninsula (Jaap et al., 2008). The bays and sounds are shallow bodies of water and tend to be more rapidly changed by environmental events compared to the open ocean, resulting in wide swings in salinity, turbidity, and water temperature (Jaap et al., 2008). Channels between the Keys and the open ocean allow water from the bays to flow onto the reefs, especially in the middle Keys, which limits growth and results in poor reef development (Jaap et al., 2008).

Three types of coral reef habitats found in the Florida Keys are hard-bottom, patch reefs, and bank reefs (Andrews et al., 2005). Hard-bottom is an abundant and conspicuous habitat in this region (Jaap et al., 2008). It is found at a wide range of water depths and is characterized by rock colonized with calcifying algae (e.g., *Halimeda spp*.), sponges, octocorals, and several species of stony coral, including smooth starlet coral (*Siderastrea radians*) and common brain coral (*Diploria strigosa*) (Andrews et al., 2005).

Patch reefs are the most common type of reef in the Florida Keys (Jaap et al., 2008). They vary in size and morphology but massive stony corals dominate patch reefs, with boulder star coral (*Orbicella annularis*) being most prevalent (Andrews et al., 2005; Jaap et al. 2008). Other common framework species include *Colpophyllia natans* and *Siderastrea sidereal* (Andrews et al., 2005). Species diversity of stony corals is highest in patch reef habitats (Jaap et al., 2003). In the Keys, patch reefs are concentrated in north Key Largo, Hawk Channel between Marathon Key and Key West, and the area off of Elliott Key (Andrews et al., 2005). Generally, patch reefs found in the lagoon between the outer reefs and the Florida Keys may include star corals (*Montastraea* and *Orbicella* spp.), fire corals (*Millepora* spp.), regular finger coral (*Porites porites)*, mustard hill coral, starlet corals (*Siderastrea* spp.), brain coral (*Pseudodiploria clivosa)*, and staghorn coral (*Acropora cervicornis*). Elkhorn coral is usually absent. These habitats in the inshore waters in the immediate vicinity of the Keys are dominated by hardy corals (including *P. clivosa*, *Favia fragum*, *Porites porites, P. astreoides, Siderastrea radians, S. siderea, Manicina areolata*, and *Cladocora arbuscula*), which appear to have a greater tolerance to silt, thermohaline changes, and unconsolidated bottom (Vaughan, 1919; Kissling, 1965).

Bank reefs are the most seaward reef habitats in the Florida Keys (Andrews et al., 2005; Jaap et al., 2008). These reefs have unique spur-and-groove systems occurring in depths ranging from a few centimeters to 10 m (32 ft). The spur-and-groove systems are a series of ridges and channels built primarily by elkhorn coral (*Acropora palmata*) (Andrews et al., 2005).

Discontinuous and less biologically diverse coral reef assemblages continue northward along western Florida shores to the FMG (NOAA CoRIS, 2019c). This region is characterized by extensive hard-bottom ranging from low or moderate-relief rock outcrops and pavement to high-relief pinnacles and ridges, which are colonized by sessile macro-fauna such as Scleractinian corals, octo-corals, black corals and sponges (Collier et al., 2008). Some of these areas have been designated Habitat Areas of Particular

Con-cern (HAPC) such as the FMG and Pulley Ridge which are both dominated by shallow-water coral reef communities (Collier et al., 2008). The FMG are located 137 km off the west coast of Florida and are comprised of a series of carbonate ledges and represent the northernmost coral reefs in the continental U.S. (Collier et al., 2008). The FMG is known to have 19 zooxanthellate species (Jaap et al., 2008). Pulley Ridge is a rocky feature between the FMG and the southern margin of the Florida shelf that provides substrate for reef communities. The southernmost 30 km of this feature supports the deepest hermatypic coral reef in the U.S. (Collier et al., 2008). The Pulley Ridge coral reef ecosystem has up to 60% coral cover over broad areas, with the dominant zooxan-thellate Scleractinia are *Leptoseris cucullata*, *Agaricia lamarcki,* and *Agaricia fragilis* (Collier et al., 2008).

Florida's reef ecosystems are rich with species, supporting thousands of invertebrates and fish. There are 47 zooxanthellate species at Dry Tortugas, 38 at Looe Key, 28 in Biscayne National Park, 24 in the area north of the Miami harbor channel in Miami-Dade County, 36 off Broward County, 24 off Palm Beach County, and eight in Martin County on the reefs south of the St. Lucie Inlet. In addition to corals, sponges, shrimps, crabs, and lobsters are prevalent. The Florida Keys alone support more than 500 fish species, including 389 that are reef-associated (Jaap et al., 2008).

Five species of listed sea turtles (loggerhead, hawksbill, green, leatherback, and Kemp's ridley) frequent the water of Florida. Marine mammals include numerous whales, dolphins, and one species of coastal sirenian, the Florida manatee (*Trichechus manatus latirostris*).

Terrestrial and Freshwater

Northern Florida contains broad alluvial riparian habitats, and upland flats and ridges once dominated by longleaf pine communities. The central peninsula is generally broad flatlands once dominated by longleaf pine (*Pinus palustris*) and slash pine (*P. elliotti*), dry and wet prairies, and sandy ridges with scrub and sandhill communities. The southern tip of the peninsula has been heavily modified by development but tropically influenced hammocks, swamps, rocklands, and the freshwater marshes of the Big Cypress Swamp, Everglades, and the Florida Keys can still be found. In North Florida, rivers that originate in the southern Appalachians and Piedmont are home to increasingly rare mollusk and fish species. There are thousands of lakes throughout the Florida peninsula with Lake Okeechobee in South Florida being the eighth largest lake in the U.S. The limestone regions of North and Central Florida harbor numerous springs which, along with limestone caves and sinks, support many rare aquatic invertebrates (Florida FWCC, 2012).

Florida supports the fourth highest biodiversity in the U.S. and ranks third in the number of species listed as threatened or endangered by the USFWS. Florida has at least 3,500 native plant species (235 of which are endemic), 126 inland fish species (7 endemic), 57 species of amphibians (6 endemic species/subspecies), 127 reptiles (37 endemic species/subspecies), 283 bird species (7 endemic subspecies), 75 mammal species (58 endemic species/subspecies) and thousands of invertebrates (with at least 410 known to be endemic) (TNC, 2004; Florida FWCC, 2012).

Sixty-seven plants and 67 animals are listed as threatened or endangered in Florida (USFWS, 2019a; Appendix E).

3.6.3.3 Cultural Resources

Florida reflects a rich diversity of cultural influences from the long and varied history of settlement in the state. Historic resources include 12,000 year-old Native American sites, the remains of early European settlements, and more recently, Mediterranean Revival homes, and Art Deco buildings (FDEP, 2019). Florida has two federally recognized tribes: the Miccosukee Tribe of Indians of Florida and the Seminole Tribe of Florida (Dania, Big Cypress, Brighton, Hollywood and Tampa Reservations) (NCSL, 2018).

Among the notable examples are the Paleoindian Page/Ladson Site in Jefferson County, dating from 10,000-7,500 B.C.; the Archaic Windover Site near Titusville, which dates from 5,500 B.C.; Crystal River Indian Mounds (500 B.C.-A.D. 200); Castillo de San Marcos in St. Augustine, constructed between 1672 and 1696 and the oldest masonry fort in the United States; the Town of Eatonville, established in 1887 as the first all-black incorporated town in Florida; Florida's Historic Capitol, restored to its 1902 configuration; Miami Beach Art Deco Architectural District, a world renowned tourist destination; and Kennedy Space Center, site of U.S.-manned space flights and the launches that put Americans on the moon (Florida Department of State, 2012).

Florida contains vast underwater historical resources, notably in the Florida Keys where hundreds of shipwreck sites and artifacts, cultural remains of indigenous peoples' activities, Overseas Railroad remnants, and historic offshore structures have been documented. An estimated 2,000 shipwrecks are thought to have occurred in the Florida Keys, with archival research identifying more than 1,000 reported shipwrecks to date. Underwater historical sites and objects include paleoenvironmental deposits, isolated cannons, anchors, shipwrecks, and historical aids to navigation. Currently, 14 shipwrecks and five lighthouses within the Florida Keys National Marine Sanctuary are listed in the NRHP (NOAA ONMS, 2019). Florida has a total of 1,797 properties listed on the NRHP (NPS, 2019a).

3.6.3.4 Socioeconomic Environment

Land Use and Cover

Florida has a diverse history of land use and human settlement, in addition to a wide range of natural communities, high biodiversity, and abundant natural resources. Florida has a substantial percentage of its lands and waters in some kind of conservation designation (Table 3-6). Combined local, state, and federal conservation holdings comprise 29.4% of the state (Volk et al., 2017).

Table 3-7. Major land cover classes based on Florida Cooperative Land Cover data (2015).

Land Cover Type	Area (km^2)	Area (%)
Urban	22,921.5	15.76
Freshwater Herbaceous Wetlands	18,768.1	12.91
Freshwater Forested Wetlands	18,466.4	12.70
Tree Plantations	18,278.1	12.57
Pasturelands	16,570.9	11.40
Crops, Groves, Nurseries	11,489.4	7.90
Flatwoods	8,982.4	6.17
Shrubs and Other Rural	7,784.7	5.35
Mixed Hardwood-Coniferous	5,380.9	3.70
Freshwater	5,302.8	3.64
Sandhill and Upland Pine	3,816.4	2.62
Scrub	3,175.8	2.18
Mangroves	2,485.2	1.71
Upland Hardwood Forest	2,090.8	1.43
Salt Marsh	1,532.5	1.05
Extractive	1,040.0	0.71
Dry Prairie	716.4	0.49
Coastal Uplands	347.4	0.23
Exotic Plants	267.5	0.18
Rockland Forests	146.4	0.10

Source: Volk et al., 2017; USDA, 2015

The majority of Florida is still rural, with much of that land in agriculture or other disturbed cover types. Other than freshwater herbaceous and forested wetlands, the top land cover categories combined from the land cover source data are dominated by urban (high to low intensity) and agriculture (Volk et al., 2017; USDA, 2015).

Impervious land cover is a good indicator of development and is also associated with land-based pollution that can damage coral reefs. Miami-Dade County has the most impervious land cover out of the five south Florida counties in absolute terms, while Broward County has the most impervious cover by percentage.

Most of the development in Martin, Palm Beach, Broward, and Miami-Dade Counties lies within 32 km of the Atlantic coast. The large areas of the non-coastal, western parts of these counties consist mostly of rural towns, farmland, swamps, and preserves (such as Everglades National Park and Biscayne National Park). Moving inland, development becomes progressively less dense. Monroe County consists of a large area of mostly undeveloped land at the very southwestern tip of the Florida peninsula as well as a series of islands south of the peninsula (the Florida Keys), with Key West being the mostly densely developed and populous key (Gorstein et al., 2016).

Numerous state (e.g., state parks, aquatic preserves) and federal (e.g., national wildlife refuges, two former national marine sanctuaries) protected areas also exist in the Florida Keys and contribute to the overall protection of coral reef species and habitats of this region. BNP, Dry Tortugas National Park (DTNP), and the FKNMS are within the Florida reef tract. BNP is immediately north of FKNMS in the Atlantic Ocean, with a small FKNMS area extending along the BNP eastern border. The DTNP, which is about 70 miles west of Key West, is entirely surrounded by FKNMS. All three protected areas have high recreational use and several other uses as well.

Natural Resource Economy

Coral reefs have important ecosystem functions and provide crucial goods and services. They are also a tourist attraction, contributing to local income and foreign exchange. In addition, they form a unique natural ecosystem and a natural protection against wave erosion.

The economic value of Florida's coral reefs is significant. Coral reef activities in Martin, Palm Beach, Broward and Miami-Dade Counties are estimated to generate $3.4 billion in sales in general and income and support 36,000 jobs in the region each year (NOAA CoRIS, 2019c).

In a survey study by Gorstein et al. (2016), residents of South Florida reported participating in non-extractive recreational reef activity (Gorstein et al., 2016). Swimming (58%) and beach recreation (60%) were the two activities residents participated in most frequently. Participation in extractive activities like fishing and gathering was less common, with under a quarter responding that they fished and 14% indicating that they gathered marine resources (Gorstein et al., 2016).

In addition to local residents, millions of tourists visit to Florida to enjoy SCUBA diving, snorkeling, and fishing on South Florida's coral reefs. Tourism and recreation are two of Florida's most important and highest grossing industries, including reef-based tourism and recreation (Collier et al., 2008). Two studies of natu-ral and artificial reefs in southeast Florida found that a total of $2.3 bil-lion in sales and $1.1 billion in income were generated annually from natural reef-related expenditures, and more than 36,000 jobs were supported in the region (Johns et al., 2003; Collier et al., 2008). More recently, a National Marine Sanctuary Foundation study found that economic activity generated in FKNMS is responsible for contributing $4.4 billion and 43,000 jobs across the state of Florida (NMSF, 2019).

Recreational saltwater fisheries in Florida supported 2.3 million licenses that generated $37.1 million in revenue during FY17/18. The economic impact totaled $11.5 billion and supported 106,000 jobs. Commercial fishing generated $3.2 billion in income and supported 76,700. The top four species, in terms of dockside value, harvested in Florida in 2018 were shrimp ($48.9M), spiny lobster ($45M), stone crab (*Menippe mercenaria*) ($32.5M), and blue crab (*Callinectes sapidus*) ($12M) (Florida FWCC, 2019).

Inshore, sport fisheries pursue game fishes like spotted sea trout (*Cynosscion nebulosus*), sheepshead (*Archosargus probatocephalus*), black and red drum (*Sciaenops* spp.*)*, snook (*Centropomus undecimalis*), tarpon (*Megalops atlanticus*), bonefish (*Albula vulpes*), and permit (*Trachinotus falcatus*). Commercial fisheries in this area primarily target sponges and crabs (blue and stone) (Jaap et al., 2008). Offshore of the deep margin of the bank reefs, commercial and sport fisheries capture an array of species like amberjack (*Seriola dumerili*), king (*Scomberomorus cavalla*) and Spanish (*S. maculatus*) mackerel, barracuda (*Sphyraena barracuda*), sharks (Class Chondrichthyes), and small bait fishes (e.g., Exocoetidae, Mullidae, Carangidae, Clupeidae, and Engraulidae) (Jaap et al., 2008). Further offshore, commercial and sport fisheries catch dolphinfish (*Corypaena hippurus*), tunas (*Thunnus* spp.), and swordfish (*Xiphias gladius*), and sport fishers target sailfish (*Istiophorus* spp.), wahoo (*Acanthocybuim solandri*), and white (*Tetrapterus albidus*) and blue (*Makaira nigricans*) marlins. Reef fisheries target the "snapper-grouper complex," which consists of 73 species of mostly groupers and snappers, as well as grunts (Pomadasyidae), jacks (Carangidae), porgies (Sparidae), and hogfish (Labridae) (Jaap et al., 2008).

3.6.4 Hawaii

3.6.4.1 Physical Environment

Hawaii is the most isolated island chain in the world and can be divided into two areas: the Main Hawaiian Islands (MHI), consisting of populated, high volcanic islands; and, the Northwestern Hawaiian Islands (NWHI), consisting of mostly uninhabited atolls, islands, and banks (NOAA & UMCES, 2018; Friedlander et al., 2005) (Figure 3-5). The MHI form the southern part of the Hawaiian Archipelago, which trends northwest by southeast in between latitudes 19° N and 29° N (Jokiel, 2008). The MHI are located in the middle of the North Pacific Subtropical Gyre, centered at about 28°N (Friedlander et al., 2008). The main islands consist of eight emergent volcanic islands: Niihau, Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii (the Big Island). The islands range in age from seven-million-year-old Kauai to the geologically young Hawaii Island with active lava flows on its east side (Friedlander et al., 2008). This section only covers the populated southern portion of the archipelago, the islands of the MHI. These MHI also represent where most of the NOAA CRCP projects are implemented.

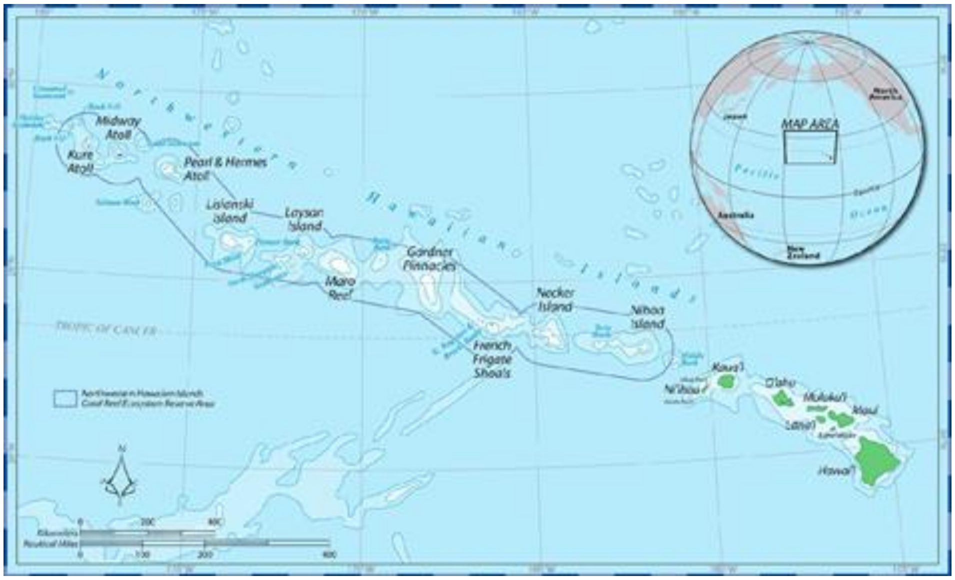

Figure 3-5. Map of the Hawaiian Island chain. *Source: Friedlander et al., 2009*

Due to Hawaii's location in the middle of the Pacific Ocean, its coral reefs are exposed to large open ocean swells, strong trade winds, and severe weather phenomena. These natural processes have a major impact on the structure of the coral reefs and result in distinctive communities. Mean tidal range for various stations in the MHI vary from 0.3-0.5 m (0.98-1.64 km) with maximum diurnal change varying between 0.3-0.8 m (0.98-2.62 km). The small tidal range and steep nature of Hawaiian shorelines results in a very narrow intertidal zone and poorly developed intertidal fauna (Jokiel, 2008). The total potential coral reef area in Hawaii (MHI and NWHI) is estimated to be 2,826 km^2 (1,756 mi^2) within the 10-fathom curve, and 53,000 km^2 (32,933 mi^2) within the 100-fathom curve, respectively (NOAA, 2009b).

There are many protected areas around Hawaii, including marine managed areas (MMA), marine life conservation districts, wildlife sanctuaries, natural area reserves, marine refuges, a national monument, as well as several fishery management areas. The two largest protected sites are the Papahanaumokuakea Marine National Monument and the Hawaiian Islands Humpback Whale National Marine Sanctuary. Hawaii has a mixture of MMAs (e.g., Kahekili Herbivore Fisheries Management Area, Hawaiian Islands Humpback Whale National Marine Sanctuary, and the Kikaua Point - Mākoleā Netting Restricted Area), which are specific geographic areas designated by statute or administrative rule for the purpose of managing a variety of marine, estuarine, or anchialine resources and their use. The resources may include any type of marine life (e.g., mammals, fish, invertebrates, algae, etc.) and their habitats. The goal of MMAs may also include preservation of cultural or historical resources (Hawaii Division of Aquatic Resources, 2019).

Climate and Weather

The Hawaiian climate is characterized by fairly uniform temperature conditions everywhere except at high elevations, a two-season year, marked geographic differences in rainfall, and generally humid conditions.

The archipelago experiences a mild, subtropical climate due to northeasterly trade winds. Daily temperatures remain relatively constant throughout the year, with the difference in average daytime temperature at sea level throughout the year being less than 10°C (50°F) (Fletcher et al., 2008). The seasonal range of sea surface temperatures near Hawaii is only about 3°C (6°F); the average surface water temperature around Oahu is 24°C (75°F) in winter and 27°C (81°F) in summer (Friedlander et al., 2008).

The trade winds that dominate the Hawaiian climate originate with the North Pacific high pressure center usually located to the northeast of the islands (Fletcher et al., 2008). These persistent trade winds approach Hawaii with greatest consistency in the summer. During the winter, from October through April, the variable and southerly Kona winds interrupt the northeasterly trade winds and bring abundant rain and cool, cloudy conditions (Fletcher et al., 2008).

Hawaii's warmest months are August and September, and the coolest months are February and March. Hawaii's heaviest rains occur during winter storms between October and April. (Jokiel, 2008). Ancient Hawaiians first defined the two seasons that govern Hawaii's climate: "kau wela" (hot season) and "ho'oilo" (to cause growth, referring to the rains of winter) (Fletcher et al., 2008).

Another major feature of Hawaii's climate is the significant differences in rainfall within short distances due to the effects of the steep volcanic topography on the high islands (Jokiel, 2008). The mountains block, deflect, and accelerate the flow of air, giving Hawaii a more varied climate than that of the surrounding ocean. For example, over the ocean near Hawaii, rainfall averages between 25 and 30 inches a year; however, the islands receive as much as 15 times that amount in some places and less than one third in others (NWS, undated). These variations also impact local conditions on the reefs around the islands.

The surface-water resources of Hawaii are of significant economic, ecological, cultural, and aesthetic importance. Hawaii contains approximately 3,326 mi (5,353 km) of rivers and streams and 5 mi^2 (8 km^2) of lakes and reservoirs in 580 watersheds (DOE, 2017c).

Streams supply more than 50% of the irrigation water in Hawaii. Most Hawaiian streams originate in the mountainous interiors of the islands and terminate at the coast. Streams in Hawaii are flashy in nature as rainfall is intense, drainage basins are small, basins and streams are steep, and channel storage is limited (Oki, 2003).

The main issues related to surface water in Hawaii include streamflow availability; the reduction of streamflow by surface diversions and, in some areas, groundwater withdrawals; floods; water-quality changes caused by human activities; and erosion and sediment transport. The quality of Hawaii's surface waters has been affected by urban and agricultural activities. For example, fish from streams in urban Honolulu have been found to have some of the highest levels of organochlorine pesticides in the nation (Oki, 2003).

Most Hawaiian islands are built of many thin lava flows from shield volcanoes, forming highly permeable aquifers. In other regions, thick lava flows that ponded in preexisting depressions form aquifers that are much less permeable (Izuka et al., 2018). Most fresh groundwater withdrawn for human use comes from freshwater lenses in the dike-free, high-permeability lava-flow aquifers. The primary limiting factor to groundwater availability is saltwater intrusion (Izuka et al., 2018).

As each island is small and surrounded by saltwater, Hawaii's aquifers have limited capacity to store fresh groundwater. Saltwater also underlies much of the fresh groundwater (Izuka et al., 2018). Therefore, groundwater resources are particularly vulnerable to human activity, short-term climate cycles, and long-term climate change (Izuka et al., 2018). Outflows from Hawaii's aquifers include withdrawals from wells and natural groundwater discharge to springs, streams, wetlands, and submarine seeps. Several indicators suggest an overall reduction in storage for most aquifers (Izuka et al., 2018).

3.6.4.2 Biological Environment

As one of the world's most isolated archipelagos, Hawaii has high endemism, with about a quarter of its marine species found nowhere else on Earth. Corals and fish create a marine assemblage that is distinct from those found elsewhere. The condition of coral reef ecosystems within the Hawaii Archipelago is fair as many MHI reefs are threatened by temperature stress, ocean acidification, overfishing, and runoff/land-based sources of pollution (NOAA & UMCES, 2018). Land-based sources of pollution impacting water quality such as urban growth and coastal developments (i.e., hotels, golf courses, etc.), failing sewages systems, and unpaved roads are focal points for coral reef degradation (NOAA & UMCES, 2018).

Marine

Hawaii has diverse marine habitats, ranging from estuaries, tidepools, sandy beaches, and seagrass beds to nearshore deep waters, extensive fringing and atoll reef systems, and smaller barrier reef systems (DLNR, 2015). Introduced mangroves exist in a number of places in sheltered embayments or along shorelines with well-developed fringing reefs or barrier reefs (DLNR, 2015). While valuable components of coral reef ecosystems in the tropics, mangroves in Hawaii are invasive, have negative ecological impacts, and have altered coastal ecosystems (Jokiel, 2008).

Island age, reef growth, water depth, exposure to wave action, geography, and latitude are all factors in the distribution of marine ecosystems in Hawaii (DLNR, 2015). Thus, the marine habitats found on and around each island depend on the type of island. For example, the island of Hawaii, a large and relatively young island, has few living structural coral reefs. In comparison, geologically older islands like Oahu and Kauai are diverse with fringing reefs and lagoons with patch or pinnacle reefs (DLNR, 2015).

Due to its isolated location, Hawaii has an extremely high rate of coastal and marine endemism (DLNR, 2015). However, marine species diversity in Hawaii is relatively low in comparison to other areas of the Pacific. For example, reef communities in Hawaii experience relatively low coral species diversity compared to other Indo-Pacific sites (Fletcher et al., 2008). Approximately 57 coral species have been documented in the MHI, and fewer than 25% of these species are dominant components of the reef ecology (Fletcher et al., 2008). These species include *Porites lobata*, *P. compressa*, *Pocillopora meandrina*, *Montipora capitata*, *M. patula*, *M. flabellata*, and *Pavona varians* (NOAA, 2009b). One study examined average coral cover across 1,682 independent transects/sites in the MHI and found it was 19.9% ± 0.6% SE, with seven of 29 coral species accounting for most of the cover (NOAA, 2009b). The same study also found that coral cover was highest in the southern part of the archipelago and lowest in the northern part, and coral cover generally decreased with increasing geologic age ($r=-0.64$) (NOAA, 2009b).

The major natural factors in the MHI that influence reef community structure include waves, currents, substrate type, depth, and island age (Jokiel, 2008). On exposed shores, wave energy is likely the principal factor contributing to coral community structure and composition as wave energy tends to suppress reef development in shallow depths (Fletcher et al., 2008; Jokiel, 2008). A continual cycle of intermediate intensity disturbances results in moderate coral cover and high diversity while high coral cover with low species diversity often occurs in embayments and reefs sheltered from wave exposure by nearby islands (Jokiel, 2008). Examples of areas with developed reefs or high coral cover include the Kona Coast of Hawaii, the south coast of west Maui, the north coasts of Lanai and Kauai, and Kaneohe Bay, Hanauma Bay, and Barber's Point on Oahu (NOAA, 2009b).

Reef formation in Hawaii is slow with potentially little accretion of living corals taking place (NOAA, 2009b). Nonetheless, a wide range of reef types occurs throughout the MHI. For example, steep unstable volcanic slopes, rocky shorelines, and beaches with basalt cobble characterize the marine habitats of the geologically young islands of Hawaii and Maui. Discontinuous apron reefs, the first phase of reef development that consists of a thin veneer of corals and calcifying organisms, tend to form the coral communities of these younger islands (Jokiel, 2008). These pioneer apron reefs will continue to accumulate carbonate materials and eventually grow seaward to form fringing reefs if conditions are favorable (Jokiel, 2008). Thus, the older islands of Molokai, Oahu, and Kauai tend to have areas of well-developed fringing reefs that are not common on Maui and Hawaii (Jokiel, 2008). Patch reefs are unique features in the MHI and are mostly restricted to Kaneohe Bay, Oahu (Jokiel, 2008). Pinnacles, stacks, and offshore islets are features that occur throughout the MHI and possess a diverse marine fauna. In the islet of Moku Manu off Mokapu Peninsula (east Oahu), for instance, there is a system of undersea caves with extremely high abundance and diversity of sponges and associated organisms (Jokiel, 2008).

Wave action has resulted in most of the open coastline of Oahu being fringed by coral reefs with low natural coral cover. The most well-developed reef assemblages are found in embayments or shelter areas, such as Kaneohe Bay or Hanauma Bay (NOAA, 2009b). Reef communities are generally healthy except for local areas where shoreline use is high or in embayments where water circulation is restricted and point and nonpoint source pollution is an issue (NOAA, 2009b).

Most coral reefs on Maui are also primarily shaped by wave action. Healthy reefs can be found off Honokowai on the western end and between Olowalu and Papawai. Here, coral cover ranges from 50-80% (depth: 10-20 m [32-66 ft]) (NOAA, 2009b). In the Auau Channel, reefs are completely sheltered from wave stress, and healthy reefs exist at 30-40 m (98-131 ft) (NOAA, 2009b). Excessive fishing and increases in invasive algae species are the two most significant environmental problems affecting coral reefs on Maui. Invasive algae growth may be related to nutrient loading, periodic natural upwelling, the low abundance of urchins, or high fishing pressure on herbivorous fishes (NOAA, 2009b).

Almost all of Lanai's reefs are healthy, but some on the northern half of the island experience episodic mortally due to sediment runoff. All of Lanai's reefs experience fishing pressure but most do not experience significant pollution (NOAA, 2009b).

The longest fringing reef in Hawaii, 56 km (184 ft) long, is found off the southern coast of Molokai. The condition of this reef varies from poor to excellent, with much of the reef degradation associated with sedimentation as a result of poor land use practices (NOAA, 2009b).

High rates of sedimentation have also historically impacted Kahoolawe's reefs as the island was used as a military target for live firing and bombing for years. The bombing stopped in 1994 and the reefs are now in a state of recovery (NOAA, 2009b).

The windward and leeward sides of the island of Hawaii support very different reefs (NOAA, 2009b). On the windward side (except in Hilo Bay), reef structure and composition is governed by wave action and is characterized by early successional reef stages like apron reefs. The leeward side of the island, however, supports rich coral reef communities (NOAA, 2009b). Humans have altered and impacted the reefs of the island of Hawaii. For example, sugarcane waste waters historically degraded the reefs on the Hamakua Coast, and excessive fishing, aquarium fish collecting, and groundwater intrusion have caused serious impacts on the reefs on the leeward coast (NOAA, 2009b).

Sedimentation likely plays a significant role in the development of reefs around Kauai (NOAA, 2009b). Sediments most heavily impact reef communities that are in shallow or enclosed areas that have restricted circulation. The healthiest reefs in Kauai are found on the exposed northeastern and northern coasts where the sediment is washed away by waves and currents or in deep water with the least exposure to sediment-laden streams (e.g., reefs of Poipu and Makahuena) (NOAA, 2009b). In addition to sedimentation, high fishing pressure, hurricanes, and poor water quality affect reefs off Kauai (NOAA, 2009b).

In addition to reef communities, other unique marine and estuarine habitats occur on the MHI. Anchialine ponds are salt water ponds in the supra-tidal zone (Jokiel, 2008). They lack a surface connection to the ocean but porous volcanic rock permits a subsurface connection to the sea (Jokiel, 2008). More than 700 anchialine ponds can be found in Hawaii with most of them occurring on young lava flows on the island of Hawaii and Maui (Jokiel, 2008). Anchialine ponds are unique Hawaiian ecosystems home to numerous organisms including endemic species of small red shrimp (*Halocaridina rubra*) (Jokiel, 2008).

Tide pools experience extreme fluctuations in temperature and salinity and are typically inhabited by hardy species, including a wide variety of algae, echinoderms, mollusks, barnacles, crustaceans, and worms. Fish species include blennies, gobies, and juveniles of certain species (Jokiel, 2008).

Over 1,200 species of fish, with approximately 580 species adapted to coral reefs, are found in the marine and estuarine waters of Hawaii (DLNR, 2015). The most commonly harvested species of coral reef-associated organisms include surgeonfishes (Acanthuridae), triggerfishes (Balistidae), jacks (Carangidae), parrotfishes (Scaridae), soldierfishes/squirrelfishes (Holocentridae), wrasses (Labridae), octopus (*Octopus cyanea and O. ornatus*), and goatfishes (Mullidae) (NOAA, 2009b).

Over 5,000 marine invertebrates are known from Hawaii, including over 100 species of hard, soft, and precious corals as well as hundreds of types of snails, crabs, lobsters, shrimps, small numbers of worms, jellyfish, sponges, starfish, and tunicates (DLNR, 2015).

The only native reptiles to Hawaii are saltwater species: the pelagic sea snake (*Pelamis platurus*) and five species of sea turtle (green, hawksbill, olive ridley, loggerhead, and leatherback) (Mitchell et al., 2005). All five species of sea turtles are listed as threatened or endangered (Appendix E).

Approximately 26 marine mammals species are considered resident or occasional visitors to Hawaii, including the Hawaiian monk seal (*Neomonachus schauinslandi*), humpback whale (*Megaptera noveangliae*), false killer whale (*Pseudorca crassidens*), and the spinner dolphin (*Stenella longirostris*) and bottlenose dolphin (*Tursiops truncatus*) (DLNR, 2015).

Terrestrial and Freshwater

Due to its isolation and climate, Hawaii has over 10,000 species found nowhere else on earth. Rates of endemism are typically 99-100% for terrestrial insects, spiders, and land snails, 90% for plants, more than 80% for breeding birds, and 15-20% for aquatic fauna (Mitchell et al., 2005).

Terrestrial and freshwater habitats vary throughout the islands. On Kauai, montane bogs, montane wet forest, lowland mesic forest, lava tube caves, long stretches of sandy beach, and many streams and rivers result in a diverse range of natural vegetation (DLNR, 2015). Due to its age and relative isolation, endemism levels are higher on Kauai than other islands (DLNR, 2015). Habitats on Oahu are composed of montane wet communities, lowland wet communities, lowland mesic communities, lowland dry communities, and coastal communities. The island also has a network of perennial and intermittent streams, many of which have been altered (DLNR, 2015). Significant habitat types on Molokai include montane wet forests and shrublands, coastal system (including dunes and grasslands), perennial streams, lava tubes and caves, cliffs, bog communities, and nine offshore islets (DLNR, 2015). The mountains of eastern Molokai are cut into deep valleys by perennial streams, and contain high-quality native habitat for stream fauna, forest birds, montane-nesting seabirds, and native snails and insects (DLNR, 2015). Lanai has a history of overgrazing by cattle, goats, and axis deer, and much of the island has suffered from extensive soil erosion and few native-dominated natural communities remain. Habitats on Lanai are primarily lowland dry communities and coastal communities (DLNR, 2015). Native vegetation dominates 30% of Maui, which supports a variety of native wildlife. Particular habitats associated with native wildlife include alpine deserts, subalpine and montane forests and bogs, lowland forests, coastal communities, anchialine pools, lava tube caves, and freshwater systems (DLNR, 2015). Native habitats on Kahoolawe include coastal dry shrubland, lowland dry grassland, mixed shrub coastal dry cliff, a high salinity anchialine pool, intermittent streams, and ephemeral pools. Two-hundred years of goat and sheep ranching, unmanaged grazing, and mostly unsustainable historical land and resource use practices were followed by decades of military training exercises and bombings, and has contributed to over 80% of Kahoolawe now being represented by barren or hardpan soil and/or alien-dominated vegetation (DLNR, 2015). Major native habitat types on the Island of Hawaii include wet montane forest, mesic montane forest, subalpine mesic forest and shrubland. Smaller areas support alpine shrubland and alpine desert, dry montane and dry lowland forests, wet lowland forest, coastal forest and coastal shrub and grasslands. Eighty percent of the known worldwide anchialine pools are on Hawaii. Forty-two percent of the Island of Hawaii is considered “converted to human use” despite this diversity of habitat types (DLNR, 2015).

There are five native fishes that occur in freshwater streams in Hawaii, and all are mostly small herbivores or omnivores (Mitchell et al., 2005). Freshwater invertebrates in need of conservation include two omnivorous shrimps, at least eight species of herbivorous snails, one endemic worm species, and one endemic sponge species (Mitchell et al., 2005).

The native terrestrial invertebrates of Hawaii include more than 6,000 arthropod species, 1,000 or more native land mollusks, and many undescribed species. Some species of conservation concern include the Blackburn’s sphinx moth (*Manduca blackburni*), Oahu tree snails (*Achatinella* spp.), the Kauai cave wolf spider (*Adelocosa anops*), and Kauai cave amphipod (*Spelaeorchestia koloana*) (Mitchell et al., 2005).

All terrestrial reptiles and amphibians on Hawaii have been introduced and are not native. For example, the cane toad (*Rhinella marina*) and coqui frog (*Eleutherodactylus coqui*) are invasive species and considered harmful to native wildlife.

There is only one native terrestrial mammal species in Hawaii, the Hawaiian hoary bat (*Lasiurus cinereus semotus*). The other 16 mammalian species present on the island (e.g., livestock, deer, wallaby, cat, dog, mongoose, rodents) were introduced either intentionally or accidentally (Mitchell et al., 2005). The Hawaii Wildlife Center lists 75 native species of birds on its site, including seabirds, shorebirds, waterbirds, birds of prey, and forest birds (Hawaii Wildlife Center, 2019).

Due to human-induced changes, it is estimated that half of the historically native bird species of Hawaii have been lost to extinction. Among other taxa, the numbers are far higher: 90% of the native land snails and thousands more terrestrial insects and spiders. These known extinctions represent 75% of the recorded extinctions of plants and animals in the United States (Mitchell et al., 2005). Hawaii has the highest number of threatened and endangered species in the United States with 79 animals and 424 plants listed as threatened or endangered (USFWS, 2019b).

3.6.4.4 Cultural Resources

Coral reefs have long played a significant cultural role within the traditional Hawaiian culture. The Kumulipo, the Hawaiian creation chant that explains how life began, has corals as among the first organisms to emerge (NOAA & UMCES, 2018). This provides a strong foundation connecting the people to the land and the sea that continues to this day (Friedlander, 2008).

The Hawaiian Islands were first settled by Polynesians sometime during the 3rd to 6th century AD during the age of transpacific migrations. The islands are relatively small and most towns and villages are located within the coastal zone. Because of this, various aspects of local and indigenous history, culture, and society are closely related to the surrounding ocean and use of its resources, including coral reefs (Gorstein et al., 2018). Hawaii's rich and varied cultural history is reflected in the 360 sites listed on the NRHP (NPS, 2019a). Numerous Native Hawaiian organizations (NHOs) exist throughout Hawaii that serve the Native Hawaiian community. The NHOs are community service driven, not-for-profit organizations chartered by the State of Hawaii and controlled by Native Hawaiians; NHO business activities principally benefit Native Hawaiians (DLNR, 2019).

3.6.4.5 Socioeconomic Environment

Land Use and Cover

More than 16% of the land on the MHI has been heavily impacted by agriculture, urban development, and resort development (Jacobi et al., 2017). Native vegetation dominates approximately 31% of the islands while 36% of the area has habitats that are somewhat disturbed, with a mix of native and nonnative plant species (Jacobi et al., 2017). Sixteen percent of the islands have less than 5% vegetation cover with most of this area found in the alpine and sub-alpine zones on the islands of Hawaii and Maui. Some relatively large non-vegetated areas are found on recent lava flows, primarily on the island of Hawaii (Jacobi et al., 2017). Most of these low to non-vegetated areas can be considered to be native dominated (Jacobi et al., 2017).

According to Jacobi et al., forest covers more than 35% of the current landscape of the MHI (Jacobi et al., 2017). Sixteen percent of the land is mapped as shrubland and approximately 17% as grassland. Non-vegetated areas compose almost 19% (Jacobi et al., 2017). The remaining area is either agriculture, developed, or "other" (wetlands and bogs) (Jacobi et al., 2017).

Table 3-8. Surface area by land cover/use.

Land Cover Type	Area (km^2)	Area (%)
Agriculture	1,190	7.2
Developed	1,032	6.3
Not vegetated	3,113	18.9
Dry forest	927	5.6
Mesic forest	1,639	9.9
Wet forest	3,039	18.4
Dry shrubland	1,478	9.0
Mesic shrubland	841	5.1
Wet shrubland	399	2.4
Dry grassland	1,537	9.3
Mesic grassland	1,010	6.1
Wet grassland	242	1.5
Wetland	37	0.2

Source: Jacobi et al., 2017

Natural Resource Economy

Much of Hawaii's economy is based on the islands' coastal and marine resources. Hawaii's coral reefs, through tourism and fisheries, are at the heart of many livelihoods. Coral reefs also serve as a natural barrier against wave erosion, storms, and coastal hazards, protecting coastal infrastructure, tourism, beaches, and human life (Cesar et al., 2002). The value of coral reefs to the Hawaii economy has been estimated to be about $385 million a year (DLNR, 2015). Hawaii's nearshore coral reef fisheries (recreational and commercial) are valued at $10.3-16.4 million (Grafeld et al., 2017).

Tourism is a critical and integral aspect of the Hawaiian economy, accounting for the majority of the state's economy. Indeed, Hawaii supports an almost $7-billion-a-year tourism and recreation industry and has over 11 million visitors per year (NOAA & UMCES, 2018; Cesar et al., 2002). Wildlife viewing opportunities are worth hundreds of millions of dollars, and Hawaii's native wildlife and their habitats also provide hundreds of millions of dollars in important goods and services to residents in the form of water quality, in-stream uses, species habitat, hunting, commercial harvest, ecotourism, and climate control (DLNR, 2015).

Gorstein et al. found that participation in non-extractive recreational reef activities varies in Hawaii, with the two activities that residents participate in most frequently being swimming (81%) and beach recreation (80%). Participation in extractive activities like fishing and gathering of marine resources was less common, with 45% of respondents indicating that they fished and/or gathered for marine resources (41% of respondents indicating that they fished, and 27% of respondents indicating that they gathered marine resources) (Gorstein et al., 2018).

Marine sport fishing is popular in Hawaii, particularly with tourists. Marine recreational fishing is not currently regulated with a permit system in Hawaii, though some exceptions exist for protected areas and gear and species restrictions. Since 2004, the overall trend for non-commercial fishing effort in Hawaii has been downward, with the estimated harvest by weight by non-commercial fishers targeting coral reef species decreasing by 29% (Gorstein et al., 2018). Non-commercial catch for nearshore coral reef species is at least nine times the reported commercial nearshore coral reef fish catch according to one study (Gorstein et al., 2018).

Pelagic waters, deep sea bottoms, and reefs are commercially fished in Hawaii. Commercial landings in Hawaii were valued at $116,422,773 for 2017 (NOAA, 2019c). Pole and line, longline, deep bottom hand line, tuna hand line, and trolling are common commercial harvest methods in the pelagic and deep sea environments. Nets, traps, hook and line, and spears tend to be used in reef fisheries (WPRFMC, 2019b). Snapper, jacks, tuna, and Hawaiian grouper are some of the most economically valuable fisheries (WPRFMC, 2019b).

In Hawaii's bottomfish fishery, the most sought-after fish species are called the "Deep 7": pink snapper (Pristipomoides filamentosus), scarlet/red snapper (*Etelis coruscans*; onaga), Hawaiian grouper (*Hyporthodus quernus*), squirrelfish snapper (*Etelis carbunculus*), Von Siebold's snapper (*Pristipomoides sieboldii*), flower/Brigham's snapper (*Pristipomoides zonatus*), and ironjaw/silverjaw snapper (*Aphareus rutilans*) (WPRFMC, 2019b). The heavy tackle, deep-sea handline gear is the dominant method for this fishery.

In 2018, the MHI Deep 7 bottomfish fishery was characterized by decreasing trends in catch and effort relative to measured averages (WPRFMC, 2019b). Data from various surveys indicate that the importance of the MHI bottomfish fishery varies among fishermen of different islands, with the differences likely relating to the proximity of productive bottomfish fishing grounds (NOAA, 2009b). Oahu landings accounted for roughly 30% of the MHI commercial landings of deepwater bottomfish species from 1998 to 2004. Maui landings from the same time period represented 36% of total MHI deepwater bottomfish landings, and Hawaii, Kauai and Molokai/Lanai represented 18, 10, and 5%, respectively (NOAA, 2009b).

The non-Deep 7 bottomfish fishery is dominated by uku (blue-green snapper; *Aprion virescens*) with a smaller contribution from white ulua (giant trevally; *Caranx ignobilis*) (WPRFMC, 2019b). Uku is commonly caught by deepsea handline, inshore handline, trolling with bait, and miscellaneous trolling. For 2018, the total number of non-Deep 7 fish caught was higher than the short- and long-term averages for this fishery, though the pounds caught was lower than the decadal average (WPRFMC, 2019b).

The Coral Reef Ecosystem Management Unit Species finfish landings generally exhibited a decline in fishing participation, effort, and catch when comparing 2018 data to decadal averages (WPRFMC, 2019b). The fishery was mostly dominated by inshore handline landing of coastal pelagic species such as akule (bigeye scad; *Selar crumenophthalmus*) and opelu (mackerel scad; *Decapterus macarellus*)

(WPRFMC, 2019b). Other gears common in the Coral Reef Ecosystem Management Unit Species fishery include purse seine, lay gill net, seine net, and spear. There are 66 different specific finfish species in the Coral Reef Ecosystem Management Unit Species group, representing a total of 12 families including surgeonfish (*Acanthuridae*), jacks (*Carangidae*), squirrelfish (*Holocentridae*), rudderfish (*Kyphosidae*), wrasses (*Labridae*), emperor (*Lethrinidae*), snappers (*Lutjanidae*), mullet (*Mugilidae*), goatfish (*Mullidae*), parrotfish (*Scaridae*), grouper (*Serranidae*), and shark (*Carcharhinidae*) (WPRFMC, 2019b).

In 2018, the MHI crustacean fishery is comprised of the Heterocarpus deepwater shrimps (*H. laevigatus* and *H. ensifer*), spiny lobsters (*Panulirus marginatus* and *P. penicillatus*), slipper lobsters (*Scyllaridae haanii* and *S. squammosus*), kona crab (*Ranina ranina*), kuahonu crab (*Portunus sanguinolentus*), Hawaiian crab (*Podophthalmus vigil*), opaelolo (*Penaeus marginatus*), and ‘a‘ama crab (*Grapsus tenuicrustatus*) (WPRFMC, 2019b). The main gear types used are shrimp traps, loop nets, miscellaneous traps, and crab traps. In 2018, the crustacean fishery showed an overall decline relative to available short- and long-term trends (WPRFMC, 2019b).

The mollusk and limu (seaweed) fishery in the MHI is comprised of algae including miscellaneous *Gracilaria* spp., limu kohu (*Asparagopsis taxiformis*), limu manauea (*Gracilaria coronopifolia*), ogo (*G. parvispora*), limu wawaeiole (*U. fasciata*), mollusks including clam (*Tapes phililippinarum*), he’e (day octopus; *Octopus cyanea*), he’e pu loa (ornate octopus; *Callistoctopus ornatus*), other octopus (*Octopus spp.*), hihiwai (river nerite; *Theodoxus* spp.), opihi ‘alina (yellowfoot; *Cellana sandwicensis*), opihi makaiauli (black foot; *C. exarata*), opihi (*Cellana* spp.), and pupu (top shell) (WPRFMC, 2019b). The top gear for this fishery is hand pick, and the secondary gear is spear. The mollusk and limu fishery had decreases in effort, participation, and pounds landed though it showed an increase in the number caught relative to short- and long-term trends (WPRFMC, 2019b).

The precious coral fishery is comprised of any coral of the genus *Corallium* in addition to pink coral (also known as red coral; *Corallium secundum*, *C. regale, C. laauense*), gold coral (*Gerardia* spp., *Callogorgia gilberti, Narella* spp., *Calyptrophora* spp.), bamboo coral (*Lepidisis olapa, Acanella* spp.), and black coral (*Antipathes griggi, A. grandis, A. ulex*) (WPRFMC, 2019b). The top gear for this species group is submersible (WPRFMC, 2019b).

The aquarium fish industry, though relatively small, is one of the largest and most commercially valuable inshore fisheries in Hawaii (Cesar et al., 2002; Jokiel, 2008). The value of this fishery is estimated between $2.3 and $3.2 million (Cesar et al., 2002; Walsh et al., 2014). The largest share of the aquarium fish collection occurs along the Kona coast. The most commonly caught fish species include surgeonfishes, butterflyfishes, and wrasses. The yellow tang (*Zebrasoma flavescens*) dominates the total catch. Among the invertebrates, feather duster worms, hermit crabs, and shrimp are the main targets (Cesar et al., 2002; Jokiel, 2008).

Natural resource production also remains important in Hawaii. Crop and livestock sales were valued at $516.1 million in 2004 (DLNR, 2015). The primary diversified agriculture crops were flower and nursery products, $94.5 million; macadamia nuts, $40.1 million; coffee, $19.8 million; cattle, $22.1 million; milk, $20.2 million (DLNR, 2015).

3.6.5 American Samoa

3.6.5.1 Physical Environment

American Samoa is the southernmost of all U.S. territories and is located approximately 4,200 km southwest of the Main Hawaiian Islands in the central South Pacific Ocean (NOAA CoRIS, 2019d). American Samoa is comprised of five volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'ū) and two coral atolls (Swains Island and Rose Atoll) (Figure 3-6) distributed over 240 km (149 mi) of ocean. Ofu, Olosega, and Ta'u are collectively referred to as the Manu'a Islands (NOAA CoRIS, 2019d; Craig et al., 2005). Island ages generally decrease from oldest in the northwest to youngest in the southeast (Birkeland et al., 2008). Rose Atoll is uninhabited and is managed as a National Wildlife Refuge by the USFWS (Craig et al., 2005).

Total land area in American Samoa is almost 200 km^2 (124 mi^2). The geography of the islands tends to be rocky with numerous mountain ranges created from extinct volcanoes. The archipelago has narrow reef flats (50-500 m [164-1640 ft]) and steep offshore banks that drop to oce-anic depths within 0.5-8 km (0.3-5 mi) from shore (Fenner et al., 2008). The shallow-water habitats are composed primarily of fringing reefs (85% of total coral reef area), a few offshore banks (13%), and the two atolls (3%) (Craig et al., 2005).

Tides in American Samoa consist of two daily highs and two daily lows, with a mean range of 0.765 m as measured in Pago Pago harbor (NOAA, 2019a).

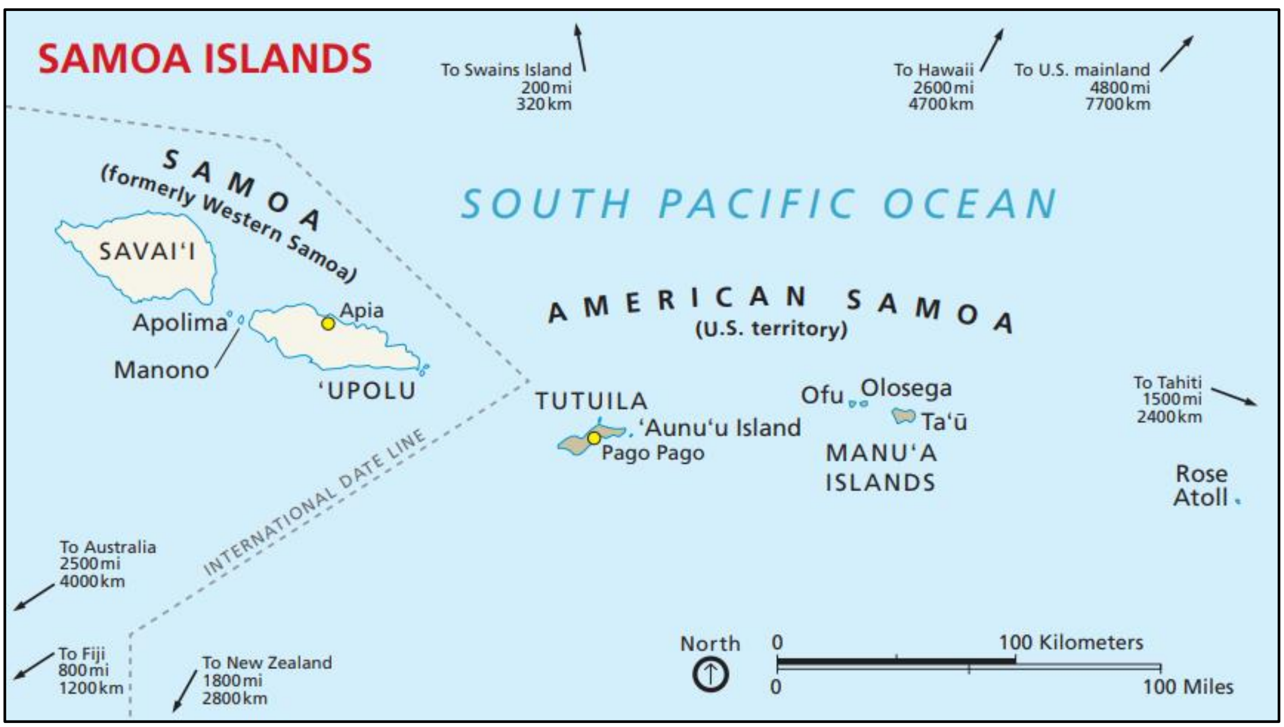

Figure 3-6. Map of American Samoa. *Source: National Park Maps, 2017*

Climate and Weather

The climate of the territory is tropical with high humidity and relatively uniform daily temperatures throughout the year (Birkeland et al., 2008). The annual temperature range across this region is 3°C (6°F);

warmer temperatures (~30°C [86°F]) occur during the summer (January to March), and cooler temperatures (~27°C [80°F]) occur during the winter (July to September) (NOAA, 2011).

The islands are known to have high annual precipitation, averaging 305 cm per year; however, rainfall can be highly variable throughout the territory due to topographic influences (NOAA, 2012). The driest months are typically from June through September, and the wettest from December through March; however, heavy rain showers occur any month of the year (NPS, 2015). Winds are generally light and variable during the summer rainy season, except during cyclones, while much stronger east-southeast trade winds prevail in other seasons (Fenner et al., 2008).

The territory is exposed to tropical storms and cyclones, typical of the South Pacific. These systems usually form when sea surface temperatures are at their highest, during the months of November through May. The most recent cyclone to hit American Samoa was Cyclone Gita, which impacted the territory in early February 2018 with maximum sustained winds of 145 mi/hr (230 km/hr) (NASA, 2018).

Relatively high and stable ocean temperatures persist throughout the year, with an average low of 27.2°C (81°F) in August and a high of 29.4°C (85°F) in March.

Water Resources

American Samoa's land mass is divided into 41 watersheds, each with an average size of 1.5 mi^2 (2.4 km^2) (Tuitele et al., 2018a). Villages in American Samoa are typically demarcated by the boundaries of the watershed and the coastal area adjacent the watershed's shoreline. The small, steep watersheds and periodic intense rainfall lead to flashy surface flows in the nearly 260 mi (418 km) of American Samoa's perennial streams (Tuitele et al., 2018b). Stream water quality is mostly impacted by development, which affects hydrology, shade, erosion, and turbidity, as well as poorly constructed and managed human and piggery waste systems (Tuitele et al., 2018a).

As articulated in the 2010 American Samoa Coral Reef Management Priority document (NOAA CRCP, 2010), the watersheds of Vatia and Faga'alu were identified as priority watersheds for focused coral reef management efforts. The watersheds were selected by American Samoa's conservation managers in consideration of each watershed's biological value, degree of risk and threat, and potential for meaningful management actions. In 2012, Faga'alu was also selected as a priority watershed by the USCRTF for collaborative coral reef management efforts.

Like many other small tropical islands with highly permeable soils, there is a freshwater aquifer floating on a layer of salt water beneath the ground of each island (Tuitele et al., 2018b). The Tafuna-Leone plain on the island of Tutuila is the most productive well site in American Samoa. However, the plain is also the most populated and industrious area in American Samoa (Tuitele et al., 2018b). Due to the porous and permeable nature of the volcanic geology, groundwater contamination is a constant risk. Rare dry periods of two to three months can result in critical drinking water shortages as salt water intrudes on the depleted fresh water lens (Tuitele et al., 2018b).

3.6.5.2 Biological Environment

Geology and oceanographic conditions have helped shape the coral reef ecosystems of American Samoa. These ecosystems include numerous species of Indo-Pacific corals, other invertebrates, and fish. Anthropogenic and environmental stressors that have influenced the communities within these ecosystems include thermal anomalies, storms, predator outbreaks, fishing, ship groundings, and land-based sources of pollution (NOAA, 2011). The coral ecosystems of American Samoa are a mosaic of areas in various stages of recovery from a number of disturbances such as crown-of-thorns predation, hurricanes, blast fishing, and bleaching from warm-water stress. In areas where the stressor impacts were more acute, recovery was able to start soon after the event. Some areas that experience chronic stressors like sedimentation at the mouths of rivers have been much slower to recover if at all (Craig et al., 2005; Birkeland et al., 2008). While coral species in American Samoa have shown resilience after acute disturbances and eventually recovered, because of serious overfishing, the coral reef ecosystems cannot be considered healthy based on the resilience of the corals alone (Craig et al., 2005; Birkeland et al., 2008). Additionally, many long-term stressors like population growth and its associated impacts and coral bleaching are increasing or becoming more frequent (Craig et al., 2005; Birkeland et al., 2008). Nonetheless, coral reefs in American Samoa are considered to be in good condition overall (NOAA & UMCES, 2018a).

Marine

American Samoa has a diversity of marine habitats, including saltwater marshes, mangrove swamps, coral reefs, and deep-water marine environments.

All of American Samoa’s islands are surrounded by fringing coral reefs with the presence of some barrier reefs. The total area of coral reefs in American Samoa is 296 km^2 (Craig et al., 2005).

The benthic communities of American Samoan coral reefs appear to be in relatively good condition (Fenner et al., 2008; NOAA & UMCES, 2018a). On reef flats and slopes, crustose coralline algae has been found to be dominant, live hard corals second in abundance, dead coral less common (and almost none recently dead), and brown macroalgae very rare (Fenner et al., 2008). Fenner et al. (2008) summarized six different studies and observed that crustose coralline algae is an important benthic component of the coral reef ecosystems in American Samoa (Fenner et al., 2008). Live coral cover as observed in these studies averaged about 22-34% with mean live coral cover at 28% (Fenner et al., 2008).

Coral cover has been found to vary from island to island in American Samoa. A multi-year study found coral coverage of 31% for Swains Island, 21% for Tutuila, 21% for Ta`u, 20% for Ofu and Olosega, and 14% for Rose Atoll (NOAA, 2011). Differences also exist in biota distributions on differently exposed sides of the islands. For instance, studies have found significantly higher coverage of crustose coralline algae on the Tutuila’s south coast than on the north coast (Birkeland et al., 2008). In contrast, filamentous algae has been found to predominate the north coast (Birkeland et al., 2008).

There are over 500 species of reef-building corals in the southwest Pacific, and more than 300 species belonging to 60 scleractinian and hydrozoan genera reported for American Samoa (Birkeland et al., 2008; NOAA, 2011). Levels of diversity also varied around the islands with the lowest generic richness reported at Swains and the highest at Tutuila (NOAA, 2011). *Montipora* was the primary genus recorded on average across the islands except at Rose Atoll (NOAA, 2011). Few endemic marine species are said to exist in American Samoa, perhaps due to the large dispersal rate of pelagic larvae.

Coral reefs also support a high diversity of other biota, including at least 945 species of fish (Fenner et al., 2008; Birkeland et al., 2008). Fish communities are dominated by small to medium-sized herbivores, like surgeonfish and parrotfish, though some planktivorous fish, such as small damselfish and fusiliers, may also be common. Reef fish biomass has been found to be higher on Swains Island and Rose Atoll compared to the Manua Islands and Tutuila (Fenner et al., 2008).

Invertebrate filter feeders such as sponges, boring clams, feather duster worms, crinoids, black corals, azooxanthellate soft corals and ascidians are generally rare, small and/or cryptic (Fenner et al., 2008). Some exceptions exist like the deeper areas of the Pago Pago harbor where sponges and sea fans are common and the inner reef flat at Leone, which is covered by a thin encrusting grey sponge.

Although two species of seagrass (both of genus *Halophila*) are found in American Samoa, their presence appears to be dispersed and most likely does not provide essential habitat or food for key species (Fenner, 2019).

Thirty-three species of marine mammals are known to occur in the tropical South Pacific. Eleven of them have been observed in the waters of American Samoa, including humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), sperm whale (*Physeter macrocephalus*), killer whale (*Orcinus orca*), short-finned pilot whale (*Globicephala macrorhynchus*), common bottlenose dolphin (*Tursiops truncatus*), spinner dolphin (*Stenella longirostris*), pantropical spotted dolphin (*Stenella attenuata*), rough toothed dolphin (*Steno bredanensis*), Cuvier's beaked whale (*Ziphius cavirostris*), and false killer whale (*Pseudorca crassidens*) (Fenner et al., 2008). Green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) sea turtles nest on beaches in American Samoa. Olive ridley turtles (*Lepidochelys olivacea*) and leatherbacks (*Dermochelys coriacia*) are rarely reported from pelagic waters (Craig et al., 2005; Fenner et al., 2008).

Federally listed threatened or endangered marine species include humpback and sperm whales, the green and hawksbill sea turtles, several fishes (humphead wrasse [*Cheilinus undulatus*], bumphead parrotfish [*Bolbometopon muricatum*], reef sharks), and six species of corals (Appendix E).

Acute episodic threats to coral reefs in American Samoa include mass coral reef mortality events from coral bleaching, cyclones, crown-of-thorns starfish outbreaks, *kaimasa* or extreme low tide events, and a 2009 tsunami. Of these, coral bleaching has been the most frequent threat with documented events in 1994, 2002, 2003, 2015, and 2017 (Fenner, 2018).

American Samoa's coral reefs exhibit unique research opportunities. The first coral reef transect ever recorded in the Pacific (and the second in the world) is the Aua Transect, first examined in 1917 (Birkeland et al., 2008). In addition, corals on the south side of the island of Ofu demonstrate resilience to extreme warm sea temperatures. The water in these pools have been recorded as high as 94.1°F (34.5°C), well above coral bleaching thresholds; however, the corals exhibit little to no signs of bleaching (Craig et al., 2001).

Terrestrial and Freshwater

Wetlands and other freshwater habitats are found throughout American Samoa, and provide food and habitat for several freshwater species of native fish and invertebrates. Two important freshwater finfish include eels (*Anguilla mauritiana*) and mountain bass (*Kuhlia rupestris*) (Utzurrum, 2006; Fishbase, 2019; Craig, 2009).

American Samoa has diverse freshwater and terrestrial gastropod fauna, many of which are endemic to the archipelago, as well as conspicuous freshwater and terrestrial crustaceans. The most abundant freshwater crustacean is the prawn (*Macrobrachium lar*). Over 2500 species of insects have been recorded in the Samoan archipelago (Utzurrum, 2006).

The herpetofauna of American Samoa is made up primarily of widespread and introduced species, and includes one introduced amphibian species and at least 13 species of terrestrial reptiles (geckos and skinks) (Utzurrum, 2006). There are no native amphibians in American Samoa, and only one species of native snake occurs, the Pacific boa (*Candoia bibroni*) (Utzurrum, 2006).

Avifauna include land birds and migratory waterbirds, shorebirds, and seabirds. By tropical standards, avifaunal diversity in American Samoa is lacking (Utzurrum, 2006).

There are only three native mammals in American Samoa, all species of bats: *Emballonura semicaudata semicaudata*, *Pteropus samoensis*, and *P. tonganus*. *E. semicaudata* is possibly extinct in the territory (Utzurrum, 2006). Other mammalian species on the island include domestic animals and feral pigs (*Sus scrofa*) (Utzurrum, 2006).

Species only found in the Samoan Archipelago include one bird (the Samoan starling), one stream fish, several land snails, and about 30% of local plant species. Endangered terrestrial species include the Pacific sheath-tailed bat (*Emballonura semicaudata semicaudata*), the mao (*Gymnomyza samoensis*), the American Samoan distinct population segment of the friendly ground dove (*Gallicolumba stairi*), two native land snails (*Eua zebrina* and *Ostodes strigatus*), and others (81 FR 65465).

3.6.5.3 Cultural Resources

The Samoan people's Polynesian ancestors settled the archipelago about 3,000 years ago. Archaeological sites dating from the early period of occupation are primarily habitation sites and are expected to be mostly coastal. No habitation sites from this period are listed on the NRHP (NPS, 2019a).

The period between about A.D. 300 and 1000 requires further definition in the study of Samoan prehistory, but one site type that was probably utilized during this period is the stone quarries. To date, four large and about six smaller quarries have been identified on Tutuila Island. One of the large quarries, Tatagamatau, is listed on the NRHP, and two others are being nominated (American Samoa Historic Preservation Office, 2019b).

Most of the prehistoric surface remains in American Samoa date to the later period of Samoan prehistory. A large defensive wall on the Tafuna Plain, Tutuila Island, is listed on the NRHP, and there are plans to nominate a fortification site on Ofu Island. The late prehistoric sites at Maloata and Fagatele Bay, both on Tutuila, and Faga on Ta'u, are village sites from this time period that are being nominated to the NRHP (American Samoa Historic Preservation Office, 2019b).

Historic properties from World War II are found throughout the islands in the form of military facilities such as medical facilities, the Tafuna Air Base, and pillboxes that are scattered along the coastlines (American Samoa Historic Preservation Office, 2019a). Overall, there are 31 sites listed on the NRHP (NPS, 2019a; American Samoa Historic Preservation Office, pers. comm., July 2, 2019).

3.6.5.4 Socioeconomic Environment

Land Use and Cover

Due to the steep topography of the volcanic islands, land suitable for human activity is restricted to a narrow band of coastal area between the ocean and the mountains. This results in a concentration of land use within several hundred yards of the shoreline, while a majority of the island remains covered in relatively dense tropical forest. Nonetheless, the islands appear dominated by disturbed or previously disturbed vegetation types as secondary vegetation types and agriculture are prevalent (DOE, 2017d). Table 3-9 lists the land cover in American Samoa.

Table 3-9. Land Cover in American Samoa (Tutuila, Ta'ū, and Ofu).

Land Use/Cover	Area (km^2)	Area (%)
Bare Land	2.8	1
Cultivated	3.9	2
Developed, open space	8.1	4
Wetland	0.9	<1
Evergreen Forest	152.2	78
Grassland	2.0	1
Impervious Surface	9.2	5
Pasture/Hay	0.2	<1
Scrub/Shrub	16.0	8
Unconsolidated Shore	<0.1	<1
Water	0.3	<1

Source: Adapted from DOE 2017d, using 2010 C-CAP data

Established marine conservation areas in the territory include Rose Atoll National Wildlife Sanctuary, National Marine Sanctuary of American Samoa, the National Park of American Samoa, and several smaller community-based marine protected areas. The largest coral reef conservation areas on the main islands are part of the National Park of American Samoa, which was authorized by Congress in 1988 and officially established in 1993 (Atkinson & Medeiros, 2010).

Natural Resource Economy

Tourism is a relatively small industry in American Samoa, particularly when compared to neighboring Independent Samoa and other South Pacific destinations such as Fiji (WPRFMC, 2019a). Ecotourism consists primarily of hiking and snorkeling and is most commonly pursued in the National Park units of American Samoa.

In 2004, the coral reefs of American Samoa were estimated to provide benefits of $5.1 million/year with the territory's mangroves adding an additional $0.75 million/year. Together, these critical natural resources accounted for 1.2% of the American Samoa GDP. Some of the important benefits provided by the reefs could be broken down as follows: $689,000/year benefit due to coral reef fisheries; $73,000/year benefit resulting from recreational uses; $70,000/year benefit deriving from bottom fishing; $447,000/year benefit relating to shoreline protection provided by the reefs (Fenner et al., 2008).

Reef fish are harvested in both subsistence and artisanal fisheries on the five main islands in the territory, though some fishing also occurs on Swains Island and Rose Atoll (Craig et al., 2005). Commercial fishing conducted in American Samoa's waters is dominated by small outboard-engine-powered catamarans, locally known as *alias*, and typically involves bottom fishing and spearfishing, longlining or trolling (WPRFMC, 2009b). Recreational and subsistence bottom fishing are rare (WPRFMC, 2009a). Coral reef fish are not currently exported to off-island markets or the aquarium trade (Craig et al., 2005).

The reef fish catch composition in American Samoa is dominated by six families: Acanthuridae (28%), Serranidae (12%), Holocentridae (12%), Lutjanidae (7%), Mugilidae (7%), and Scaridae (6%). Atule (*Selar crumenophthalmus*), a coastal pelagic species, seasonally accounts for a significant portion of the coral reef catch (NOAA, 2017b). Other commonly harvested species of coral reef-associated organisms include triggerfishes (Balistidae), jacks (Carangidae), wrasses (Labridae), octopus (*Octopus cyanea, Callistoctopus ornatus*), goatfishes (Mullidae), and giant clams (Tridacnidae) (WPRFMC, 2009b). Crustaceans are harvested on small scales throughout the inhabited islands of the Western Pacific Region. The most common harvests include the lobster species Palinuridae (spiny lobsters) and Scyllaridae (slipper lobsters) (WPRFMC, 2009b).

3.6.6 The Commonwealth of the Northern Mariana Islands

3.6.6.1 Physical Environment

The Mariana Archipelago comprises 15 islands and is politically separated into the U.S. territories of the CNMI and Guam (Figure 3-7) (NOAA CoRIS, 2019e). The 14 islands of the CNMI extend 600 km (372 mi) and have a total land area of approximately 474 km^2 (295 mi^2). The islands developed west of the Mariana Trench along the edge of the Philippine Plate (Pacific RISA, 2019).

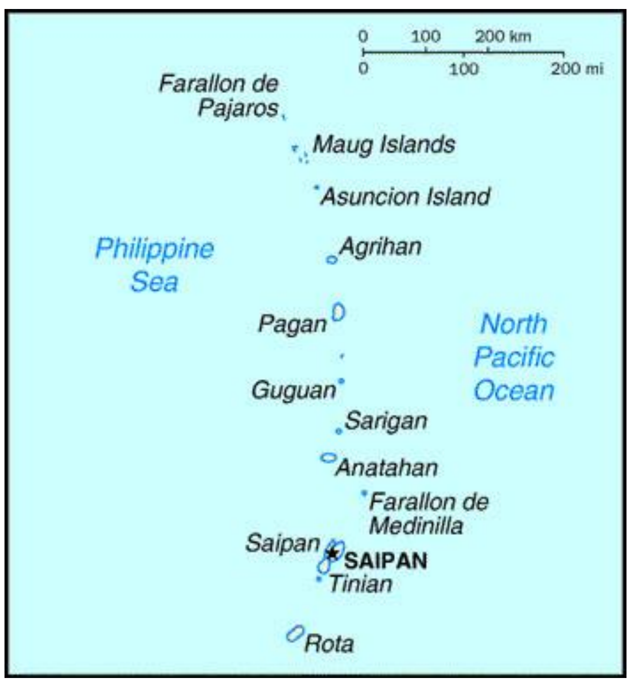

Figure 3-7. Map of the CNMI. *Source: NOAA CoRIS, 2019e*

The principal inhabited islands are Saipan, Guguan, Rota, and Tinian, and the northern, largely uninhabited islands are Farallon de Medinilla, Anatahan, Sariguan, Gudgeon, Alamagan, Pagan, Agrihan, Asuncion, Maug Islands, and Farallon de Pajaro (NOAA CoRIS, 2019e). The northern islands are high volcanic islands, and the southern islands are volcanic in origin but covered with uplifted limestone derived from coral reefs. The southern islands have the oldest and most developed reefs in the CNMI, which are predominantly located along the western (leeward) sides (NOAA CoRIS, 2019e; Starmer et al., 2005).

The largest island, Saipan, is 119 km^2 (74 mi^2) in size and supports approximately 89% of the population (Liske-Clark, 2015; Yuknavage et al., 2018). Rota and Tinian support the vast majority of the remaining 11% of the population. This uneven dispersal of CNMI's population is an important consideration in the assessment of environmental impacts as it results in great spatial variation of human uses, including anthropogenic stress on coral reef ecosystems and watersheds, as well as areas of interest for research activities. Saipan, Tinian, and Rota have consistently served as central locations for watershed conservation projects, marine protected area management, and fine-scale in-water research. The remainder of the CNMI hosts annual research cruises and occasional studies specific to the Marianas Trench Marine National Monument in the northernmost three islands (Asuncion, Uracas, and Maug).

Climate and Weather

The CNMI's climate is within the range of the inter-tropical convergence zone. There is little seasonal temperature variation; average daily temperatures are approximately 28°C (82.4°F) with a range of 24°C (75.2°F) to 30°C (86°F) (Richmond et al., 2008).

Rainfall varies between the islands and on the islands themselves. For example, average rainfall on Tinian is 109-246 cm/year (42-97 in/year), and rainfall is 86-368 cm/year (34-145 in/year) on Saipan (Riegl et al., 2008). CNMI has well-defined wet and dry seasons with 70% of the total annual rainfall occurring during the wet season from July to November (Riegl et al., 2008; Richmond et al., 2008). The wet season is characterized by calmer winds, while the dry season is characterized by consistent northeast trade winds and frequent light-to-moderate showers. Typhoons bring the most intense rainfall during this period (Riegl et al., 2008). Dry years occur approximately once every four years as a result of El Niño Southern Oscillation events in the Pacific (Riegl et al., 2008; Starmer et al., 2008). Sea surface temperatures generally vary seasonally from about 25°C (77°F) to 29°C (84.2°F) (Riegl et al., 2008). The primary ocean current influencing the region is the North Equatorial Current (Starmer et al., 2008).

Relative sea levels in the CNMI are also closely tied to El Niño Southern Oscillation conditions across the Pacific. Lower sea levels are documented during El Niño episodes while higher sea levels occur during La Niña (Snyder, 2006). Sea level change and variability are highlighted here due to the implications it poses for both thermal stress on CNMI's coral habitat, as well as the acute threat of enhanced coastal flooding during periods of higher sea levels.

Water Resources

Water does not move across the surface in streams on most of the land area in the CNMI because almost all rainwater infiltrates the porous limestone substrate where it is present in the southern islands of Saipan, Tinian, and Rota (Yuknavage et al., 2018; Bearden et al., 2014). Perennial stream reaches constitute less than three percent of the land in the CNMI, and the majority of the streams are patchily distributed around Saipan (Yuknavage et al., 2018; Bearden et al., 2014). The streams originate in the islands' interiors and drain to the coast. The most common sources of surface water quality degradation in the CNMI are failing sewer lines and other wastewater systems, as well as pollution from nonpoint sources such as secondary roads, erosion, livestock overgrazing, other storm water sources, and bacteria from livestock (Yuknavage et al., 2018; Bearden et al., 2014).

Groundwater is the main source of drinking water in the CNMI (Arriola et al., 2016). The principal aquifers in the CNMI are formed from saturated limestone. Saipan, Tinian, and Rota's limestone rocks contain a basal freshwater-lens aquifer (Carruth, 2003). This aquifer system is recharged by direct infiltration of rainfall and by inflow from perched groundwater systems (Carruth, 2003). Sources of groundwater contamination include underground storage tanks, landfills, septic tanks, failing sewer lines, and most importantly, salt water intrusion (Bearden et al., 2014).

3.6.6.2 Biological Environment

Within the Northern Marianas, climate change stressors such as ocean warming and acidification, are some of the leading threats to coral reefs. Mass coral bleaching events have occurred four of the last five years (2013-2017), resulting in reduced coral cover and changes in community composition. Recent surveys at reef resiliency sites that followed initial transects from 2012-2013 indicate that the coral ecosystems around CNMI's populated islands have not recovered from these bleaching incidents, with near 90% mortality of branching corals observed at many sites (Maynard et al., 2015).

Increased population and development in the CNMI also threaten coral reef ecosystems. Effects are most noticeable on the island of Saipan, though the other southern populated islands also have important coral reef ecosystems that are threatened by human impacts. In addition to population growth and increased development, coral reefs in the CNMI are also threatened by unsustainable fishing practices, climate change, land-based sources of pollution, overuse, and lack of enforcement. CNMI's reefs are reported to be in fair condition (NOAA & UMCES, 2018b).

Marine

There are a variety of coral reef types in the Mariana Islands, including barrier reefs, fringing reefs, patch reefs, and submerged reefs associated with offshore banks (Riegl et al., 2008; Richmond et al., 2008). Coral reef communities vary around the islands according to wind and wave action exposure. Corals and reefs on windward exposures exhibit more signs of wave activity like robust forms and skeletal characteristics and spur-and-groove formations (Richmond et al., 2008). In addition, there is a noticeable, broad-scale, reef-community zonation pattern between the northern, volcanically active islands and the southern, raised limestone islands (Richmond et al., 2008).

The younger volcanic islands in the north are still active and have little fringing and barrier reef development, while the older islands to the south, including Rota, Aguijan, Tinian, Saipan, and Farallon de Medinilla, have fringing and barrier reef systems. Coral diversity and colony surface area are significantly lower on the northern islands than on the southern islands (Richmond et al., 2008; Goldberg et al., 2008). One study examined the naturally volcanically acidified water at Maug in the northern islands as an equivalent to near-future predictions for what coral reef ecosystems will experience worldwide due to ocean acidification (Enochs et al., 2015). The study provided evidence of how acidification-related stress significantly influences the abundance and diversity of coral reef taxa, leading to a shift from coral to a non-reef forming macroalgae-dominated state. Another study in this same region of the CNMI provided further evidence that microborers, especially bioeroding chlorophytes, respond positively to low pH sites and found evidence that ocean acidification could enhance microboring flora colonization in newly available substrates (Enochs et al., 2016).

Of the inhabited islands in the CNMI, Rota and Tinian are dominated by fringing reefs, with Rota having the more developed reef system (van Beukering, 2006). Saipan has the most diverse types of coral reefs and associated habitats in the CNMI. A fringing and barrier reef system protects the majority of the beaches along the western side of the island, forming a 12.4 mi^2 (20 km^2) shallow-water lagoon system. This environment contains large assemblages of seagrass, branching corals, and the last remaining mangroves in the CNMI (NOAA CoRIS, 2019e). The windward (northern and eastern) shoreline is dominated by limestone terraces, cliffs, and fringing reef (van Beukering, 2006).

The average percent covers of live coral and macroalgae were similar in Saipan and Tinian/Aguijan: approximately 38% for live coral and 7% for macroalgae (Maynard et al., 2015). The same study found that, on average, coral cover was approximately 10% lower on Rota than in Saipan or Tinian/Aguijan (~28% versus ~38%), and macroalgae cover on Rota was twice that observed in Saipan or Tinian/Aguijan (~14% versus ~7%). The average coral cover at the forereef sites (all islands combined) was 35% (Maynard et al., 2015).

Pilot coral nurseries and associated outplantings exist in the Managaha Marine Protected Area adjacent to Saipan. In addition, restoration efforts have been initiated to install artificial reef along a former ship grounding site (Vessel Paul Russ, 2014), where coral was damaged along the Saipan Harbor ship channel.

Saipan's nearshore waters and lagoon are fairly rich in biodiversity. Fringing coral reefs border most of Saipan's coast and contain many endemic and/or endangered species (Appendix E). The Mariana Islands are reported to have 377 scleractinian corals covering 20 families. Additionally, 195 species of echinoderms, 650 crustaceans, 800 species of prosobranch gastropods, and 1,000 species of reef and shore fishes are reported from the Marianas (Richmond et al., 2008).

The Mariana Islands have three species of seagrasses, *Enhalus acoroides*, *Halophila minor*, and *Halodule univervis*, which can be found in well-developed seagrass beds, primarily in Saipan's lagoon (Richmond et al., 2008; Gourley, 2006). Saipan's lagoon system also contains a third of benthic algal species (Starmer et al., 2008) and high concentrations of endangered turtle species (Starmer et al., 2005). Green turtles (*Chelonia mydas*) reside in CNMI southern arc waters while hawksbill turtles (*Eretmochelys imbricata*), leatherbacks (*Dermochelys coriacea*), and olive ridleys (*Lepidochelys olivacea*) are also known from the CNMI (Starmer et al., 2005).

Cetacean surveys have observed spinner dolphins (*Stenella longirostris*), bottlenose dolphins (*Tursiops truncatus*), pantropical spotted dolphins (*Stenella attenuata*), short-finned pilot whales (*Globicephala macrorhynchus*), pygmy killer whales (*Feresa attenuata*), sperm whales (*Physeter macrocephalus*), and a dwarf sperm whale (*Kogia sima*) within close proximity to the Saipan Lagoon (Hill et al., 2013). Saipan is also home to two endemic fish species: wrasse (*Pseudojuloides* sp.) and goby (*Amblyeleotris* sp.) (Myers & Donaldson, 2003).

Terrestrial and Freshwater

The raised limestone bedrock of the southern Mariana Islands is extremely permeable, so most rainfall that does not directly run off into the ocean percolates into the ground. Thus, streams occur mostly in limited areas where less permeable volcanic base materials have been exposed (Arriola et al., 2016). Saipan's streams do not have perennial flow for the entire length of the streams. Rota also has several intermittent streams, but Tinian has no streams (Bearden et al., 2014).

In the CNMI, wetlands are also limited in extent, although some artificial wetlands have been created to increase wildlife habitat. These occur primarily at low elevations where the water table intersects with the land’s surface (Arriola et al., 2016). These freshwater habitats support important species like the Mariana common moorhen (*Gallinula chloropus guami*), a federally endangered bird.

The CNMI is host to hundreds of species of terrestrial invertebrates including, but not limited to, ants, mosquitoes, butterflies, scorpions, spiders, centipedes, millipedes, and snails (Berger et al., 2005). Twenty-eight species of reptiles and amphibians are known to inhabit the CNMI, including six frogs and toads, 14 lizards, two snakes, and six freshwater turtles. Most of these species are native to CNMI (Kerr, 2013).

Only two native terrestrial mammals occur in CNMI: the Mariana fruit bat (*Pteropus mariannus*) and the Pacific sheath-tailed bat (*Emballonura semicaudata*). The Mariana fruit bat (also known as the Mariana flying fox) is listed as federally threatened, and the Pacific sheath-tailed bat is listed as federally endangered (Appendix E). Other terrestrial mammals have been introduced, including the sambar deer, pigs, cows, goats, cats, and rodents (Berger et al., 2005).

The Avibase lists 166 bird species for CNMI, with many of the species listed as rare or accidental (Avibase, 2019). Native forest birds, including the Mariana fruit dove (*Ptilinopus roseicapilla*), Mariana crow (*Corvus kubaryi*), Rota bridled white-eye (*Zosterops rotensis*), golden white-eye (*Cleptornis marchei*), white-throated ground dove (*Gallicolumba xanthonura*), and rufous fantail (*Rhipidura rufifrons*), are found at their highest densities in the islands’ native forest habitat. Secondary forests are important to several native forest birds, including the nightingale reed-warbler (*Acrocephalus luscinius*) and Saipan bridled white-eye (*Zosterops conspicillatus*). Grasslands and savannas are important foraging habitats for the Mariana swiftlet (*Aerodramus bartschi*), an endemic, endangered bird. Migratory shorebirds such as plovers, whimbrel, turnstones, sandpipers, and reef herons are found in coastal mangrove habitats, estuaries, and beaches (Comprehensive Wildlife Conservation Strategy for the Commonwealth of the Northern Mariana Islands, 2005).

In CNMI, 15 animals and 11 plants are listed as federally threatened or endangered (Appendix E).

3.6.6.3 Cultural Resources

Archaeological findings cite the earliest human cultural presence in the CNMI at more than 3,500 years ago (DOE, 2017b). The art and culture of the islands’ two indigenous groups, the Carolinians and the Chamorro, can be found throughout the CNMI. Over the past 500 years, island culture has also been shaped by Spanish, German, Japanese, and American influences. The waters of the Northern Mariana Islands are littered with more than 40 sunken warships, auxiliaries, airplanes, tanks, and other military related debris (NPS, 2019b).

There are 36 individual sites in the CNMI listed on the NRHP (NPS, 2019a), two of which are also National Historic Landmarks (CNMI Division of Historic Preservation, pers. comm., July 10, 2019). An approximate count of documented cultural resources in CNMI Historic Preservation Office records by island are as follows: Saipan - 750, Tinian - 420, Rota - 420, Aguiguan - 70, Pagan - 180, Alamagan - 5, Anatahan - 1, Sarigan - 5 (CNMI Division of Historic Preservation, pers. comm., July 10, 2019).

3.6.6.4 Socioeconomic Environment

Land Use and Cover

The CNMI contains a variety of federal, territorial, and local recreational lands, ranging from units of the National Park System and Marine Protected Areas to city parks. Developed land covers less than four percent of the territory as forest and shrub still dominate the landscape. Land use is also uneven across the CNMI, as most developed and disturbed land occurs in the more populated southern islands, particularly Saipan (Table 3-10).

Table 3-10. Land Use/Cover for CNMI (Northern Islands, Saipan, Rota, and Tinian).

Land Use/Cover	Area (km^2)	Area (%)
Impervious	17.8	4
Developed, open space	18.6	<4
Cultivated Crops	2.9	1
Pasture/Hay	18.4	4
Grassland	63.0	13
Evergreen Forest	239.6	51
Deciduous Forest	21.5	5
Scrub/Shrub	40	9
Wetlands	3.7	1
Bare Land	43.6	9
Open Water	1.3	<1
Unconsolidated Shore	0.004	<1
Unclassified	0.2	<1

Source: Adapted from DOE, 2017b, using 2011 C-CAP data

Natural Resource Economy

The coral reef ecosystems of the CNMI are a critical component of the CNMI's economy. In addition to providing food, coastal defense, and cultural significance for CNMI communities, the coral reef environments and particularly CNMI's local MPAs generate significant revenue from tourists and recreational users. While there have been efforts to diversify CNMI's tourism-based economy, visitors are still predominantly engaged in activities such as swimming, snorkeling, diving, and motorized marine sports (NOAA & UMCES, 2018b).

Tourism is the largest component of CNMI's economy, excluding federal assistance, and tourist arrivals have been increasing since 2011 (NOAA & UMCES, 2018b). Tourism relies heavily upon the islands' natural resources. Particularly high commercial and recreational value has been attributed to the Saipan Lagoon, Managaha Island, publicly accessible beaches, and the barrier and fringing coral reefs surrounding Saipan, Tinian, and Rota. Ocean-related tourism produces over $40 million per year, and roughly 30% of tourist arrivals on Saipan have been attributed specifically to marine-related activities. As of 2006, more than 350,000 diving or snorkeling trips took place in Saipan annually, and these numbers are estimated to be even greater given the last four years of rapid growth (NOAA & UMCES, 2018b). These trips generate a direct economic value of over $4.9 million a year (van Beukering et al., 2006).

As a food source, Saipan's coral reef ecosystems have an estimated value between $208,000 and $1.4 million per year, based on subsistence fishing by household (van Beukering et al., 2006). Additional surveys of small boat fishermen on Saipan, Tinian, and Rota found that they primarily fished on reefs, with 93% of these fishermen perceiving reef fish as an important source of food (Hospital & Beavers, 2014).

Most fishermen in the CNMI do not own a boat, and this low level of boat ownership appears to align with the most common types of fishing techniques used by subsistence and recreational fisherman—snorkel spearfishing and hook-and-line fishing in waters less than 100 ft (30 m) deep (van Beukering et al., 2006).

While subsistence fishing is a crucial component of CNMI livelihoods, commercial fishing also provides economic benefits. In 2018, there was an estimated total of 4,612 lbs (2092 kg) sold for $21,994 in the CNMI bottomfish fishery (WPRFMC, 2018). Two distinct types of bottomfish fisheries are identified in the CNMI: shallow-water bottom fishing, which targets fish at depths down to 492 ft (150 m), and deepwater bottom fishing, which targets fish at depths greater than 492 ft (150 m). Species targeted by the shallow-water fishery include the redgill emperor (*Lethrinus rubrioperculatus*), black jack (*Caranx lugubris*), matai (*Epinephelus fasciatus*), sas (*Lutjanus kasmira*), and lunartail grouper (*Variola louti*). Species targeted by the deepwater bottom fishing depths (>492 ft [>150m]) include onaga (long-tail red snapper; *Etelis corsucans*), ehu (short-tail red snapper; *E. carbunculus*), yellowtail kalekale (*Pristipomiodes auricilla*), amberjack (*Seriola dumerili*), blueline gindai (*P. argyrogrammicus*), gindai (*P. zonatus*), opakapaka (*P. filamentosus*), and eightbanded grouper (*Hyporthordus octofasciatus*) (WPRFMC, 2018).

Considering the CNMI reef fishery, there was an estimated 29,006 lbs (11,793 kg) sold for $82,547 in 2018 (WPRFMC, 2018). Some of the common fish types found in the CNMI reef fish markets are surgeonfishes, parrotfishes, goatfishes, groupers, wrasses, soldier/squirrelfishes, jacks, scads, sweetlips, mojarras, rudderfishes, and mullets (WPRFMC, 2018).

3.6.7 Guam

3.6.7.1 Physical Environment

Guam is an unincorporated U.S. territory located at 13° 28'N, 144° 45'E and is the southernmost island in the Marianas Archipelago (NOAA CoRIS, 2019f) (Figure 3-8). With a land mass of 560 km^2 (348 mi^2) and a maximum elevation of 405 m (1,392 ft), Guam is the largest island in Micronesia and has a total shoreline length of 244 km (152 mi) (Burdick et al., 2008). Guam is a volcanic island surrounded by a coralline limestone plateau. The northern half of the island is relatively flat and composed primarily of suplifted limestone while the outhern half of the island is composed mainly of dissected, relatively impermeable volcanic formations, with areas of highly erodible lateritic soils (Burdick et al., 2008; Richmond et al., 2008). A ridge of highground runs north to south along the western coast. The slope is steep from the ridgeline to the west but more gradual to the eastern coast.

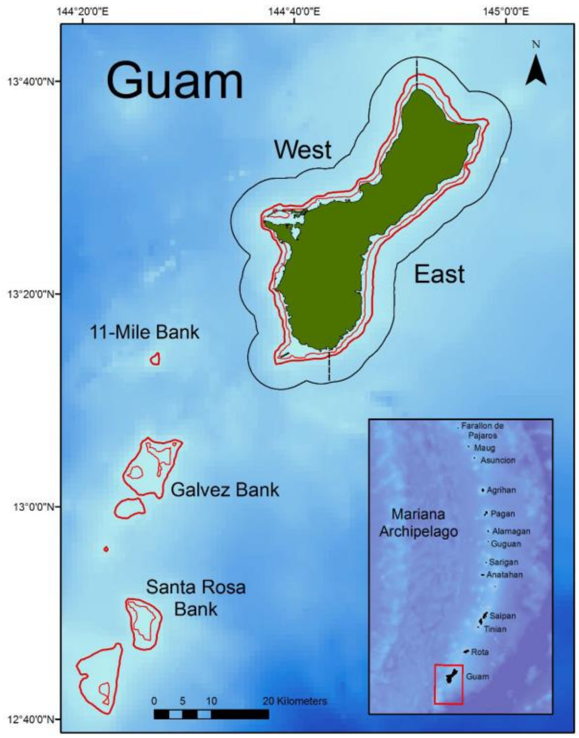

Figure 3-8. Map of Guam. *Source: Nadon, 2019*

Climate and Weather

Guam's climate is tropical wet/dry; the weather is generally hot and humid with little seasonal temperature variation. The mean annual temperature on Guam is 28°C (82°F) (Burdick et al., 2008). The coolest months are January and February, when temperatures fall to the mid to low 20s°C (70s°F) at night. Daily maximums and minimums vary no more than 6°C (10°F). Relative humidity ranges from 65-80% during the day to 85-100% at night (WERI, 2013).

Guam has distinct wet and dry seasons. Most of the average annual rainfall of 218 cm falls during the wet season from July through November when heavy rains and tropical storms are common (Riegl et al., 2008; WERI, 2013). The dry season is dominated by persistent easterly trade winds and occasional showers (Burdick et al., 2008; WERI, 2013).

Sea surface temperatures around Guam range from about 27-30°C (Burdick et al., 2008). The North Equatorial Current is the dominant oceanic circulation pattern influencing Guam (Riegl et al., 2008).

Water Resources

The hydrologic conditions of southern and northern Guam vary significantly. In northern Guam, permeable limestone allows virtually all rainfall to infiltrate the rock and recharge Guam's principal aquifer. In southern Guam, volcanic rocks are relatively impermeable and support a well-developed surface drainage network of about 100 streams and rivers (WERI, 2013a). The main ridge running along the western coast divides these watersheds into steep valleys with relatively short streams along the west and broad floodplains in coastal lowlands with longer, larger rivers to the east (WERI, 2013a).

The northern half of Guam contains the Northern Guam Lens Aquifer, which supplies 80% of Guam's drinking water. This aquifer is a carbonate island karst aquifer; the bedrock of the aquifer is primarily comprised of two major limestone units. The body of fresh water within the limestone forms an elongated lens floating atop the underlying sea water (Bendixson, 2013). Parts of southern Guam are covered by limestone and contain some groundwater bodies and perched systems that are main sources of freshwater springs (WERI, 2013a).

The primary pollutants to most waters around Guam are microbial organisms, petroleum hydrocarbons, and sediment (Burdick et al., 2008). Nonpoint source pollutants include nutrients from septic tank systems, sewage spills, and livestock and agricultural or chemical pollutants from urban runoff, farms, and illegal dumping. Such pollutants infiltrate basal groundwater, which discharges in springs along the seashore and subtidally onto reefs (Burdick et al., 2008).

3.6.7.2 Biological Environment

The health of Guam's coral reefs varies con-siderably around the island (Burdick et al., 2008); generally, the reefs in the southern part of the island tend to be in poor condition due to, among other things, the high population base, coastal development, and extensive sediment runoff from large rivers, while the reefs on the northern part of the island are typically in better condition as the population is lower and there is less development and no rivers (WPRFMC, 2009c).

Overall the island's reefs are considered to be in fair condition (NOAA & UMCES, 2018c). The resiliency to impact of many of Guam's reefs has declined over the past 40 years. The average live coral cover on the fore reef slopes was approximately 50% in the 1960s but was less than 25% by the 1990s, with only a few sites demonstrating over 50% live cover (Burdick et al., 2008).

Sedimentation, largely from road construction and development, is the major anthropogenic issue for the central and southern reefs (Richmond et al., 2008). In addition to sedimentation, recreational use and tourism, along with fishing pressure, have negatively impacted reefs in some areas. Groundings of fishing vessels, recreational watercraft, and ships carrying cargo have resulted in localized damage to reefs (Richmond et al., 2008). Marine debris also continues to affect the reefs around Guam (Burdick et al., 2008).

Coral bleaching events have previously been considered uncommon for Guam, with just a handful of reported events between 1970 and 2007. However, since 2013, coral bleaching associated with ocean warming has become the most severe threat to Guam's reefs. Widespread bleaching occurred in 2013 and 2014. Although island-wide coral bleaching did not occur in 2015, extensive mortality of coral communities in shallow reef flat areas was associated with extreme low tides during an El Nino event. As a result of these back-to-back events, Guam lost about half its staghorn corals, equivalent to about 17.5 hectares (Raymundo et al., 2019). In 2016, Guam's reef flats were severely impacted by coral bleaching, though deeper reefs did not see the same impacts (Raymundo et al., 2019). In 2017, multiple coral genera at depths to 40 m suffered moderate to severe bleaching with widespread mortality, but reef flats experienced only mild to moderate bleaching (Raymundo et al., 2019). Initial estimates suggest that live coral cover decreased by up to 60% in some areas from 2013-2017 (Raymundo et al., 2019).

Historical use and World War II operations have contributed to a number of coastal areas around Guam being contaminated with toxic chemicals. PCBs, for example, have been found in seafood caught in various locations, and monitoring indicates that PCBs remain a persistent problem in some areas (Burdick et al., 2008).

Marine

Coral reefs almost completely surround Guam. Guam has everal types of reefs, including fringing, patch, submerged, and barrier reefs, and offshore banks. Fringing reefs predominate and extend around much of the island (Burdick et al., 2008). A broad barrier reef encloses Cocos Lagoon on the southwest tip of the island (WPRFMC, 2009c). Surrounding Apra Harbor is a raised barrier reef (Cabras Island), a greatly disturbed barrier reef (Luminao Reef), and a coral bank (Calalan Bank) (WPRFMC, 2009c). Patch reefs are near Anae Island on the southwest coast and Pugua Reef on the northwest coast (WPRFMC, 2009c).

Coral cover was higher on average in shallow (25%) survey areas than in deep areas (19%) (Maynard et al., 2016). Differences in coral cover between the shallow and deep survey sites were driven by differences in macroalgae cover as coralline algae (12% shallow and 10% deep) and other cover (41% both depths) were very similar between the depths. Average macroalgae cover was 22% in the shallow and 30% in the deep (Maynard et al., 2016). Guam's are in fair condition and are moderately impacted by pollution, overfishing, and climate change (NOAA & UMCES, 2018c).

On Guam, there are over 5,000 species of coral reef organisms, including well over 300 stony corals and more than 1,000 species of reef-associated fish (NOAA & UMCES, 2018c; Porter et al., 2005; Burdick et al., 2008). Guam's reefs contain all of the major genera of reef-building corals, notably species of *Acropora, Porites, Pocillopora, Favia, Favites, Montipora, Fungia, Pavona, Montastrea, Leptoria*, *Leptastrea, Psammacora*, and *Galaxea* (Richmond et al., 2008).

Apra Harbor, which hosts the largest and most developed mangrove forest (approximately 70 ha) in the Mariana Islands, and two smaller areas in the southern villages of Merizo and Inarajan contain the extent of mangrove growth on Guam.

Three species of sea turtles have been recorded inhabiting the waters off Guam: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and leatherback (*Dermochelys coriacea*). Fourteen species of marine mammals have been reported in Guam's waters, including dugongs (*Dugong dugon*), baleen whales, and toothed whales (Guam DAWR, 2006).

Terrestrial and Freshwater

Guam is home to a variety of terrestrial habitats, including limestone and ravine forests, savanna complex, and strand vegetation. Due primarily to contrasting soil types between the north and south and anthropogenic and natural disturbances, vegetation is highly variable across the island (WERI, 2014). Vegetation in the north tends to be dominated by thick secondary scrub and urban vegetation (i.e., lawns and ornamental trees and shrubs) inland, and by strand and limestone forests in coastal areas. Vegetation in the south is generally dominated by savanna and patches of forest, which are mostly riparian and form along valleys and ravines. The low-lying portions of river valleys are occupied by swamp forests, marshes, and occasional cultivated clearings (WERI, 2014). Guam has more than 320 native plant species.

Under natural conditions, Guam hosted a diversity of native terrestrial animal species. Three native mammals were known to Guam, including the Marianas fruit bat (*Pteropus mariannus mariannus*), little Marianas fruit bat (*P. tokudae*), and Pacific sheath-tailed bat (*Emballonura semicaudata rotensis*).

However, the Marianas fruit bat is the only extant species. Six native reptiles, five skink species, and one gecko species are still found in the wild. Several native tree snail species still exist in low numbers. Over 100 species of birds have been documented on the island including migrant, wetland, seabird, and forest birds, though only a few native wetland and forest birds persist in the wild (Guam's Comprehensive Wildlife Conservation Strategies, 2006). Eighteen species of animals and 15 species of plants are listed as federally threatened or endangered in Guam (Appendix E).

Guam has also experienced high rates of extinction, and many terrestrial species are endangered due primarily to the introduction of non-native species, such as the brown tree snake (*Boiga irregularis*). Though much native habitat remains available, the introduction of the brown tree snake has resulted in the loss of many of Guam's native species of birds and lizards (Guam's Comprehensive Wildlife Conservation Strategies 2006). Historically, Guam did not have any known native species of amphibians, but introduced populations quickly colonized much of the island, and at least nine species of frogs and toads are known to inhabit the Mariana Islands Archipelago. Introduced mammals include pigs, water buffalo, Philippine deer, feral cats and dogs, shrew, the black rat, Norway rat, and house mouse (Guam's Comprehensive Wildlife Conservation Strategies 2006). The most notorious invasive plant that thrives in scrub areas is tangantangan (*Leucaena leucocephala*). After being seeded on the island by U.S. military following WWII, the tangantangan out-competed many native plants and covered large parts of the island (WERI, 2014).

3.6.7.3 Cultural Resources

Guam's oldest archaeological sites are from the Pre-Latte and Latte Periods of Chamorro occupation, prior to western contact in 1521. Other archaeological and architectural resources show evidence of Guam's status as a former possession of Spain and as an American territory, while numerous structures and relics attest to the island's occupation by Japan and subsequent reoccupation by the U.S. during World War II (DOD, 2010). There are 128 properties listed on the NRHP (NPS, 2019a).

3.6.7.4 Socioeconomic Environment

Land Use and Cover

As listed in Table 3-11, evergreen forest and grasslands account for 65% of land cover in Guam. Developed open space covers approximately 11% of the territory. Scrub/Shrub accounts for nine percent of land cover, and impervious surface covers approximately 10% of Guam.

Table 3-11. Land Cover in Guam.

Land Cover/Use	Area (km^2)	Area (%)
Bare Land	10.9	2
Cultivated	2.4	<1
Developed, open space	58.8	11
Wetlands	16.3	3
Evergreen Forest	246.5	45
Grassland	107.6	20

Impervious Surface	52.6	10
Palustrine Aquatic Bed	0.008	<1
Pasture/Hay	0.1	<1
Scrub/Shrub	46.8	9
Unconsolidated Shore	0.5	<1
Water	1.5	<1

Source: Adapted from DOE, 2017e, using 2011 C-CAP data

Approximately 20% of Guam has been designated as local or federal conservation lands. For example, there is the federally owned War in the Pacific National Historical Park, Guam National Wildlife Refuge, and two Naval Ecological Reserve Areas, Orote and Haputo (Guam's Comprehensive Wildlife Conservation Strategy, 2006). In 1997, Guam established five marine preserves, Tumon Bay, Piti Bomb Holes, Sasa Bay, Achang Reef Flat, and Pati Point, in response to declining reef fish stocks. The preserves set aside approximately 15.5% (118.4 m^2 [36.1 km^2]) of Guam's nearshore (600 ft [< 183 m]) waters, restrict fishing, and prevent taking or altering aquatic life, including living or dead coral and any other resources; however, three of the five preserves have some limited fishing, such as cultural take using traditional fishing methods or bottom fishing below 100 ft (30 m) (Burdick et al., 2008).

The Department of Defense continues to carry out training activities on Guam that may impact coastal waters and reefs. Though the frequency of these activities appears to have decreased since 2004, their cumulative impact remains a concern. The impacts are not known for the training activities occurring in the W-517 Warning Area, which encompasses Santa Rosa and Galvez Banks. The type and frequency of security training activities have continued to increase with increasing military presence in the Marianas and is expected to further increase in association with the Guam military expansion (Burdick et al., 2008).

Natural Resource Economy

Guam's reef resources provide numerous goods and services for the residents of Guam, including cultural and traditional use, tourism, recreation, fisheries, and shoreline and infrastructure protection. Coral reef-related tourism contributes $323 million per year to Guam's economy (NOAA & UMCES, 2018c). The tourism industry supports over 21,000 jobs annually (NOAA & UMCES, 2018c).

Guam's fisheries are both economically and culturally important and target a large number of fishes and invertebrates. Bottomfishing on Guam is a combination of recreational, subsistence, and small-scale commercial fishing. In 2018, in the bottomfish fishery, there was an estimated 3,557 lbs (1613 kg) sold for $17,022 (WPRFMC, 2018). There are two distinct fisheries separated by depth and species composition. The shallow-water complex (< 500 ft [152m]) makes up the largest portion of the total bottomfish harvest and effort, and primarily includes reef-dwelling snappers of the genera *Lutjanus*, *Aphareus*, and *Aprion*; groupers of the genera *Epinephelus*, *Variola*, and *Cephalopholis*; jacks of the genera *Caranx* and *Carangoides*; Holocentrids (*Myripristis* spp. and *Sargocentron* spp.); emperors of the genera *Lethrinus* and *Gymnocranius*; and dogtooth tuna (*Gymnosarda unicolor*). The deep water complex (> 500 feet [152m]) consists primarily of groupers of the genera *Hyporthodus* and *Cephalopholis*, jacks of the genera *Caranx* and *Seriola*, and snappers of the genera *Pristipomoides*, *Etelis*, and *Aphareus* (WPRFMC, 2018).

Considering Guam's reef fishery for 2018, there were 133,941 pounds sold for $392,548 (WPRFMC, 2018). Shore-based fishing accounts for most of the fish and invertebrate harvest from coral reefs around Guam. The coral reef fishery harvests more than 100 species of fish, including members of the families Acanthuridae, Carangidae, Gerreidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Scaridae, and Siganidae. Hook and line is the most common method of fishing for coral reef fish on Guam (75% of fishers and gear). Throw net is the second most common method, and other methods include gill net, snorkel spearfishing, SCUBA spearfishing, surround net, drag net, hooks and gaffs, and gleaning (WPRFMC, 2018).

3.7 Overview of Coral Reefs in U.S. Federal Jurisdiction

In addition to the U.S. coral reefs that occur within populated states and territories described in Section 3.6, the CRCP conducts activities (i.e., monitoring) in coral reef areas that are not managed by local jurisdictions but are solely within U.S. federal jurisdiction. National Marine Sanctuaries, for example, that fall within state or territory boundaries are described within the appropriate jurisdictional section of Section 3.6. Table 3-12 generally describes the coral environment for the U.S. federal jurisdictions.

Table 3-12. Broad descriptions of the coral environment for the U.S. federal jurisdictions

Designation	Agency	Ocean Basin	Coral Reef Type(s)	Ocean Temperature Range (°C)	Mean tidal range (cm)
Flower Garden Banks National Marine Sanctuary	NOAA	Gulf of Mexico	Patch	20-29	10
Papahānaumokuākea		Pacific	Patch, fringing	18-28	10
Pacific Island Remote Areas		Pacific	Patch, barrier, fringing	N/A	N/A

Source for ocean temperature data: www.nodc.noaa.gov; Source for tidal data: tidesandcurrents.noaa.gov

3.7.1 Flower Garden Banks National Marine Sanctuary

The Flower Garden Banks National Marine Sanctuary (FGBNMS) is one of 14 federally designated underwater areas protected by NOAA's Office of National Marine Sanctuaries and is the only sanctuary site completely located within the Gulf of Mexico (OMNS, 2012). The original designation, on January 17, 1992, includes West Flower Garden Bank and East Flower Garden Bank, and Stetson Bank was added to the sanctuary in 1996 (OMNS, 2012).

3.7.1.1 Physical Environment

The FGBNMS is situated 112-185 km (73-115 mi) off the coasts of Texas and Louisiana, atop three underwater mountains called salt domes (OMNS, 2012). The reef caps at East and West Flower Garden Banks are about 21 km (13 mi) apart, and Stetson Bank lies about 77 km (48 mi) to the northwest of West Flower Garden Bank. The open ocean between the individual banks has a depth of 61-152 m (200-492 ft) (OMNS, 2012). Each bank has its own sanctuary boundary (Figure 3-9). East Flower Garden, West

Flower Garden, and Stetson Banks are only three among dozens of banks scattered along the continental shelf of the northwestern Gulf of Mexico. All of these banks are part of a regional ecosystem, heavily influenced by current patterns within the Gulf. Inflows from the large watershed that drains two-thirds of the continental U.S. also plays a significant role in the health of this region.

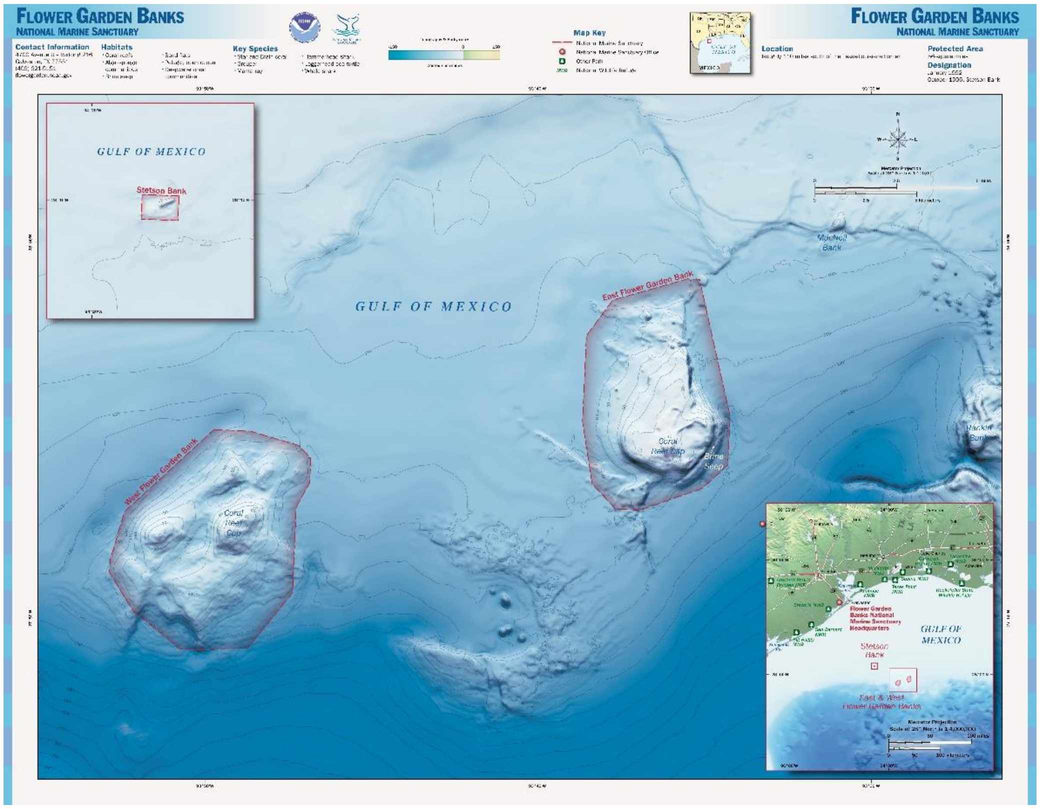

Figure 3-9. Map of the Florida Garden Banks National Marine Sanctuary. *Source: FGBNMS*

Currents

The Gulf of Mexico is fed from the south by warm Caribbean water, which enters the Gulf via the Yucatan Channel and forms the Gulf Loop Current. The Loop Current generally enters the Gulf and then curves east toward Florida's coast and becomes the Florida Current, which exits the Gulf through the Straits of Florida. The Loop Current varies after entering the Gulf either by curving almost immediately to the east or by traveling west toward Louisiana's coast before looping around to the east toward Florida. In the latter case, the main current passes directly over the banks along the continental shelf (NOAA, 2007b).

Circular eddies often form when small current formations break away from the Loop Current and move westward, across the FGBNMS and other banks to the west. The Loop Current brings animal larvae, plant spores, and other imports from the Caribbean and may account for some Caribbean species found in the northern Gulf of Mexico. Furthermore, the Loop Current also transports organisms from the northern Gulf to parts of Florida and the southern Atlantic (NOAA, 2007b).

Meanwhile, shallow, wind-driven currents flow into the Gulf from the Yucatan Channel travel to the northwest following the Mexico, Texas, and Louisiana coastlines before turning east. These currents also cross over the FGBNMS and other banks from the opposite direction of the Gulf Loop eddies and add to the Caribbean influence in the region.

3.7.1.2 Biological Environment

The East and West Flower Garden Banks coral reef communities likely began developing on uppermost portion of the salt domes 10,000 to 15,000 years ago (NOAA, 2007b). The northwestern Gulf of Mexico location provides all the habitat characteristics required for stony corals: a hard surface for attachment, clear sunlit water, warm water temperatures (between 68-84°F [20-29°C]), and a steady food supply (NOAA, 2007b). Scientists believe that corals at the Flower Garden Banks probably originated from Tampico, Mexico, which has the closest coral reefs to the Flower Garden Banks (NOAA, 2007b).

The Stetson Bank has very different habitat compared to the Flower Garden Banks. Stetson's winter water temperatures are 4°F (-15.5 °C) cooler, on average, than those of the Flower Garden Banks, which is enough to hinder coral growth enough that no true coral reef exists at Stetson Bank (NOAA, 2007b). Instead, coral colonies are interspersed with a much denser population of sponges with the siltstone bedrock showing. The predominant coral species at the East and West Flower Garden Banks include large boulder corals, such as brain coral and mountainous star coral. Coral cover is over 50% at these two banks (Johnston et. al., 2019). Corals form the basis for a complex, balanced ecosystem, that provides a regional reservoir of shallow-water Caribbean reef species such as crustaceans (e.g., crabs, lobsters, and shrimp), mollusks (e.g., clams, octopus and snails), echinoderms (e.g., sea cucumbers and starfish), fish (e.g., groupers, eels, wrasse, parrotfishes, sharks, and rays), sea turtles (e.g., loggerhead turtle and hawksbill turtle) and marine mammals (i.e., beaked whales, Atlantic spotted dolphins (*Stenella frontalis*), and bottlenose dolphins) (FGBNMS, 2018).

While the FGMNMS is relatively far offshore and more isolated than other coral reefs in the U.S. Atlantic and Caribbean, it has been impacted by similar stressors. Two invasive species, the lionfish (Johnson et al., 2013) and orange cup coral (*Tubastrea coccinea*) are found within FGBNMS (Pretch et al., 2014). During 2016, water temperatures in both the East and West Flower Garden Banks were above 30°C (86 °F) for an extended period of time, and corals within these banks showed signs of bleaching and paling stress (Johnston et al., 2019). While some seabirds may use FGBNMS, the banks are completely submerged, and there is no island habitat in FGBNMS to support any terrestrial or freshwater biota.

3.7.1.3 Cultural Resources

The FGBNMS does not have any historic properties or traditional cultural resources (ONMS, 1991).

3.7.1.4 Socioeconomic Environment

The FGBNMS provides economic opportunities for charter dive and fishing vessels, which take visitors on guided trips for either purpose. Additionally, private vessels use the FGBNMS for fishing and diving as well.

3.7.2 Papahānaumokuākea Marine National Monument

On June 15, 2006, Presidential Proclamation 8031 established the Northwestern Hawaiian Islands Marine National Monument under the authority of the Antiquities Act (54 U.S.C. 320301-320303) to protect the natural and cultural resources. The monument was later renamed Papahānaumokuākea Marine National Monument (Figure 3-10), and then expanded under Presidential Proclamation 9478 in August 2016. The area encompassed by the original designation is approximately 140,000 mi^2, and the expansion added approximately 443,000 mi^2 resulting in a total protected area of 582,578 mi^2 - roughly the size of the Gulf of Mexico. Papahānaumokuākea is the largest contiguous, fully protected conservation area in the U.S. and one of the largest marine conservation areas in the world. It is larger than all the country's U.S. national parks combined (Papahānaumokuākea Marine National Monument, 2019).

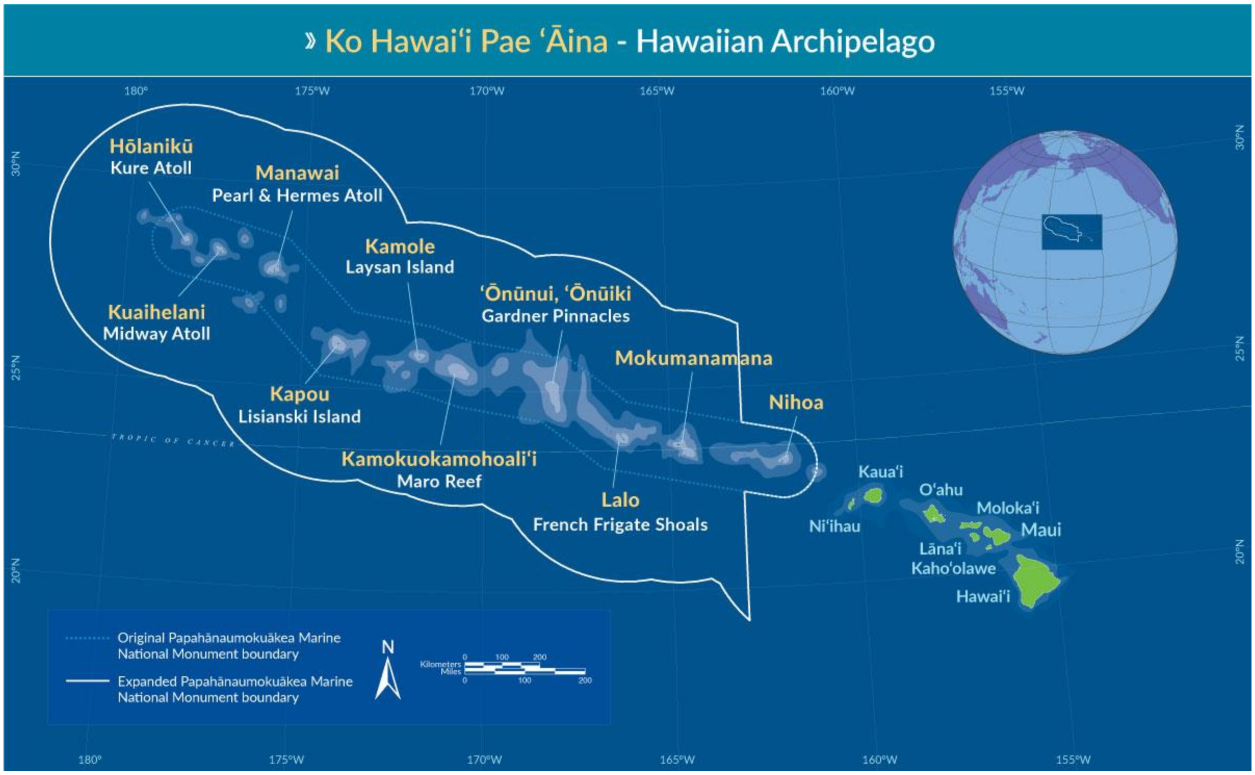

Figure 3-10. A map of Papahānaumokuākea Marine National Monument and the adjacent main Hawaiian Islands.
Source: NOAA NOS, 2019

3.7.2.1 Physical Environment

Water Resources

Access to fresh water is the primary limiting factor for terrestrial plants and animals living on the small Northwestern Hawaiian Islands. A hydrologic feature called a freshwater lens, common to atolls and other low-lying islands in the Pacific, allows terrestrial species to survive. The less-dense freshwater and rainfall percolate through the sediment on land to the sea where it then forms a convex lens that floats atop the seawater. The size and amount of the catchment area, precipitation, and saltwater inundation determine the size lens. Lenses can be as shallow as 10-20 cm (3.9-7.9 in), or as deep as 20 m (66 ft). Changes in precipitation patterns and sea level rise due to climate change are major concerns for Pacific communities that depend on these freshwater lenses for survival (Papahānaumokuākea Marine National Monument, 2019).

3.7.2.2 Biological Environment

The Papahānaumokuākea Marine National Monument is one of the largest marine protected areas in the world, encompassing 1.5 million km^2 (582,578 mi^2) of islands and water from the island of Nihoa to beyond Midway Atoll (Pew, 2017). More than 7,000 species, including 22 species of seabirds, 24 species of whales, at least a dozen species of sharks, four commercially important species of tuna, five species of endangered sea turtles, and monk seals, live in the marine protected area, and a fourth of them are endemic to the area (Pew, 2017). The monument safeguards key ecosystems, including shallow-water and deep-sea coral reefs, seamounts, and pelagic zones. The following is a general description of the biological resources found throughout the monument.

Marine

On Nihoa Island marine life is limited to the reef system surrounding the island. In deeper waters, along the Raita Bank where species of sharks and jacks are found. Limu (algae), wana (sea urchin), and opihi (limpet) live in the shallow-waters of the island (USFWS, 2018b). On Mokumanamana (Necker Island) marine life includes gray reef sharks (*Carcharhinus amblyrhynchos*) and manta rays. Shark Bay, for example, has a high diversity of sea cucumbers, sea urchins, and lobsters. Little coral life exists in the shallow areas due to run off from the heavily eroded and scoured rock surfaces of the island (USFWS, 2018b).

French Frigate Shoals, which is a classic atoll, has one of the most significant reef systems in the NWHI. The reef supports the greatest variety of coral species and over 600 species of other invertebrates such as sponges, coral worms, snails, lobsters, crabs, shrimp, clams, oysters, sea urchins, and sea stars. Many of these invertebrates are endemic to the shoals. Over 150 species of red, green, and brown algae are found on the reefs. The outer reef waters support gray reef sharks, butterflyfish, and large schools of jacks and groupers (USFWS, 2018b).

Gardner Pinnacles has many coral species and a large population of giant opihi, the endemic Hawaiian limpet. Acroporid table corals have been noted on the leeward side, while tube, stony, and soft corals have been found throughout the reef. Gardner Pinnacles' waters have high fish species richness; examples include the redlip parrotfish (*Scarus rubroviolaceus*), the double-bar goatfish (*Parupeneus crassilabris*), and the reef triggerfish (*Rhinecanthus rectangulus*) (USFWS, 2018b).

Maro Reef (Koanakoa) is a submerged open atoll with less than one acre of emergent land. At very low tide, only a small coral rubble outcrop of a former island is believed to break above the surface. The shallow-water reef ecosystem covers nearly half a million acres and is the largest coral reef in the NWHI. It is biologically rich with 95% coral cover in some areas, one of the highest observed in the NWHI. Maro Reef contains marine habitat ranging from sandy lagoons to steep reef slopes, large coral heads, ocean pinnacles, and patch reefs (USFWS, 2018b). Maro Reef has a greater diversity of coral than most any other reef system in the NWHI chain. Many areas of the reef, particularly on the west side, have a large number of coral species, including rice coral (*Montipora capitata*) and finger coral (*Porites compressa*), that grow abundantly on the reef slopes. The reefs support numerous butterflyfish and surgeonfish species. Large ulua (*Giant Trevally* [*Caranx ignobilis]*) and omilu (*Bluefin Trevally* [Caranx melampygus]) have been seen in the reef's open waters, along with white-tip and grey reef sharks. On Laysan Island, although the reef is the smallest of the NWHI, it is rich. Numerous sea turtles and monk seals (*Monachus schauinslandi*) appear on the island. Several species of Hawaiian surgeonfish and large schools of convict tangs are in the shallow, wave-washed waters around the island. Twenty-seven species of stony coral are reported, and branching corals are common (USFWS, 2018b).

Pearl and Hermes Atoll (Holoikauaua) is a large atoll with several small islets forming 80 acres (0.32 km^2) of land and nearly 300,000 acres (1214 km^2) of coral reef habitat. The atoll extends over 20 mi (32 km) across and 12 mi (19 km) wide. Pearl and Hermes reef is a true atoll, fringed with shoals, including permanent and ephemeral sandy islets. The islets provide important dryland habitat for seals, turtles, and birds in need of rest, protection from predators, or nesting grounds (ONMS, 2014). The atoll has a high diversity of fish species including saber squirrelfish (*Sargocentron spiniferum*), eels, Galapagos sharks (*Carcharhinus galapagensis*), sandbar sharks (*Carcharhinus plumbeus*), ulua (giant trevally [*Caranx ignobilis*]), angelfish, aweoweo (Hawaiian bigeye [*Priacanthus meeki*], uhu (parrotfish), and numerous lobsters (USFWS, 2018b).

Laysan Island (Kauō) has approximately 915 land acres (3.7 km^2) and is surrounded by 145,334 acres (518 km^2) of coral reef. Laysan Island's rocky intertidal habitat supports numerous invertebrate species, algae, and juvenile fishes. Surgeonfish and large schools of convict tangs (*Acanthurus triostegus*) are frequently found in the shallow waters around the island. The reef and island also support sea turtles and monk seals (*Monachus schauinslandi*). Twenty-eight species of stony coral have been identified within the reefs around Laysan Island (NOAA NOS, 2019).

Lisianski Island is over 12 miles (19 km) at its widest point and includes 400 acres of land. Lisianski is a low sand and coral island approximately 20 million years old and reaches a height of 40 ft (12 m) above sea level. The coral cover around the island, including the reef area call Neva Shoals, totals 310,000 acres (1,255 km^2) (ONMS, 2014). Nearshore reef fishes are abundant and diverse (USFWS, 2018b). Aggressive predators such as sharks are found near the reefs and Trevally jacks (ulua, *Caranx ignobilis*) have been observed. Twenty-four different species of coral were found in one major survey at Lisianski (USFWS, 2018b). In addition, a wide variety of algae are commonly found close to the island. Midway Atoll (Pihemanu) consists of three small sandy islets, also known as the "Midway Islands," totaling 1,540 acres and a large elliptically shaped barrier reef measuring approximately five miles in diameter. The atoll is surrounded by approximately 88,500 acres (358 km^2) of coral reef. Numerous patch reefs dot the lagoon. Kure Atoll (Mokupāpapa) is located at the northern extent of coral reef development. The atoll is nearly circular with a six-mile diameter enclosing nearly 200 acres (0.81 km^2) of emergent land. Kure contains 80,000 acres (324 km^2) of coral reef habitat that almost forms a circle around the lagoon except for passages to the southwest (ONMS, 2014). The only permanent land in the atoll is crescent-shaped Green Island, located near the fringing reef in the southeastern part of the lagoon.

As indicated above, a large variety of coral species are located throughout the NWHI within the monument, and coral reefs provide habitat for other marine species. A total of 57 stony coral species are known in the shallow-waters of the NWHI, of which 17 endemic species account for 37-53% of the relative abundance surveyed on each reef in the NWHI (Friedlander et al., 2005). Seven acroporid species have been documented in the central NWHI, despite their near absence from the MHI. Coral cover varies significantly across the NWHI. Most regions have low coral cover with the exception of Maro Reef and Lisianski Island having comparatively high coral cover. Despite their high latitudes, more species of coral have been reported for the NWHI (52 spp.) than the MHI (48 spp.) (Friedlander et al., 2005). Coral reef habitats harbor a diversity of macro and micro algae. Currently, a total of 355 algal species have been recorded from shallow-water coral reef habitats of the NWHI. The NWHI contain a large number of Indo-Pacific algal species not found in the MHI, such as the green calcareous algae (*Halimeda velasquezii*). Unlike the MHI where invasive species (e.g., invasive algae, *Kappaphycus alvarezii*) have overgrown many coral reefs, the reefs of the NWHI are largely free of invasive species. Approximately 98% of the monument's area is deeper than 328 ft (100 m) (ONMS, 2014).

Banks and shoals occurring within the monument also provide important habitat for marine life. There are approximately 30 submerged banks throughout the NWHI. An unnamed bank is located just to the east of French Frigate. To the west are South East Brooks Bank, St. Rogatien Bank, and another unnamed bank. Raita Bank is just west of Gardner Pinnacles. The crest or top of Raita Bank is nearly 60 ft (18 m) from the ocean surface. Pioneer Bank is only 22 nm (41 km) from Neva Shoals, and the features combine to form a major coral reef ecosystem rich in biodiversity with a variety of marine habitats. Bank areas provide extensive fish habitat, and a few are known to provide foraging habitat for endangered Hawaiian monk seals (*Monachus schauinslandi*) (ONMS, 2014).

Prior to the establishment of the monument, commercial bottomfishing had been conducted in the NWHI for over 60 years, but with the establishment of the monument, commercial bottomfishing was phased out and ultimately closed on June 15, 2011 (Monument Proclamation 8031) (ONMS, 2014). However, historic fishery data indicate which fish populations exist in the area. The fish distribution and abundance are patchy and appear to be associated with cavities or oceanic current patterns that serve as prey attractants (Kelly et al., 2004). Common fish species include onaga (*Etelis coruscans*), ehu (*E. carbunculus),* opakapaka (*Pristipomoides filamentosus*), kalekale (*P. sieboldii*), lehi (*Aphareus rutilans*), gindai *(P. zonatus*), hapuupuu (*Epinephelus quernus*), uku (*Aprion virescens*), white ulua (*Caranx ignobilis*), black ulua (*C. lugubris*), butaguchi (*Pseudocaranx dentex*), taape (*Lutjanus kasmira*), yellow tail kalekale (*Pristipomoides auricilla*), and kahala (*Seriola dumerili*). Lobster species include Hawaiian spiny lobster (*Panulirus marginatus*), slipper lobster (*Scyllarides squammosus*), green spiny lobster (*P. penicillatus*), ridgeback slipper lobster (*S. haanii*), and sculptured slipper lobster (*Parribacus antarcticus*), with the last three having low abundance (USFWS, 2018b).

In addition, many pelagic fish species benefit from the monument. An average of 10,000 sharks were caught each year in the waters surrounding the NWHIs prior to the expansion of the monument in 2016 (Pew, 2017). With their role in the food web, tiger sharks (*Galeocerdo cuvier*), gray reef sharks (*Carcharhinus amblyrhynchos*), and Galapagos sharks (*Carcharhinus galapagensis*) are ecosystem regulators, and their populations can grow in these waters (Pew, 2017).

Seabirds and Shorebirds

The NWHI are home to one of the largest groupings of tropical seabirds in the world, including 14 million birds from 22 species, with 5.5 million individuals breeding in the area annually. Eleven species are considered imperiled or of high conservation concern (Pew, 2017).

Breeding seabirds are likely to forage near colonies, though the distance they travel to feed varies, depending on the species, chick size, and dependence of their young. Papahānaumokuākea protects important seabird foraging habitat, as well as vital reproductive, nesting, and nurturing sites essential to the survival of bird species that inhabit the islands. For example, Midway Atoll, despite being heavily used by humans, boasts the largest nesting colonies of both Laysan and black-footed albatrosses in the world (ONMS, 2014). At Garden Pinnacles, scientists have observed 19 seabird species, 12 of which breed on the steep cliffs. Two species of migratory shorebirds, the ruddy turnstone (*Arenaria interpres*) and the Pacific golden plover (*Pluvialis fulva*), often stop over to rest or feed here as commonly noted in all the NWHI (USFWS, 2018b). Laysan Island has the largest, diverse bird colony in the NWHI, where huge populations of seabirds nest, and migratory shorebirds visit. Birds found at Laysan include the black-footed albatross (*Phoebastria nigripes*), the Laysan albatross (*P. immutabilis*), the Christmas shearwater (*Puffinus nativitatis*), the wedge-tailed shearwater (*P. pacificus*), and the bristle-thighed curlew (kioea, *Numenius tahitiensis*). Migratory shorebirds seen on the Lisianski Island include the Pacific golden plover, the wandering tattler (ulili, *Heteroscelus incanus*), the bristle-thighed curlew, and the Bonin petrel (*Pterodroma hypoleuca*) (USFWS, 2018b).

Terrestrial Species

On Nihoa Island, niches in rocky outcroppings provide habitat for some rare bird, insect, and plant life in the NWHI. Forty terrestrial arthropods, including a giant cricket and giant earwigs, and two endemic landbirds, Nihoa finch and Nihoa millerbird (*Acrocephalus familiaris kingi*), are found only on Nihoa. Native, endangered plants include the loulu of Nihoa fan palm and native ‘ohai shrub (USFWS, 2018b).

Terrestrial animal life on Mokumanamana includes the blue gray noddy (*Procelsterna cerulea*), land snails, and 15 endemic insects such as wolf spiders and bird ticks. Gardner Pinnacles is home to a wide array of insects and one species of plant, the succulent sea purslane (*Portulaca*) (USFWS, 2018b).

Laysan Island was formed from geologic forces pushing upward and by coral growth. It has fringing reefs, and a hypersaline lake in the middle of the island, the only lake in the island chain. Laysan has the largest, diverse bird colony in the NWHI. Several land birds became extinct including the Laysan honeycreeper (*Himatione fraithii*) and millerbird (*Acrocephalus familiaris familiaris*), but two endemic land birds remain -- the hardy Laysan finch (*Telespiza cantans*) and Laysan duck (*Anas laysanensis*). Fifteen species of endemic insects also exist on Laysan (USFWS, 2018b).

On Pearl and Hermes Atoll, sandbar islets support coastal dry grasses, vines, and herbal plants, including 16 native plant species and 12 introduced species. The plants survive because they are salt-tolerant and able to recover from frequent flooding events (USFWS, 2018b).

Marine Mammals

A total of 24 different species of marine mammals, including whales, dolphins, and Hawaiian monk seals (*Monachus schauinslandi*), have been observed in the NWHI (ONMS, 2014). Humpback whales (*Megaptera novaeangliae*) and sperm whales (*Physeter macrocephalus*) are migratory, so their presence within the Hawaiian archipelago is seasonal or occasional, respectively (USFWS, 2018b). Pods of resident bottlenose dolphins are common throughout the archipelago, and spinner dolphins (*Stenella longirostris*) are known to occupy nearshore waters of atolls for rest and socializing (USFWS, 2018b). Hawaiian monk seals are the only marine mammal solely dependent on coral reefs and are the most endangered pinniped in U.S. waters, and it is discussed in the Endangered Species section below in more detail.

Endangered Species

Twenty-three species of plants and animals known to occur in the NWHI are listed under the ESA. Of those ESA-listed species that occur in the marine ecosystem, the Hawaiian monk seal (*Monachus schauinslandi*) and the green sea turtle (*Chelonia mydas*) are discussed further as the NWHI serve as an important breeding ground for these species. Over 90% of all sub-adult and adult green turtles found throughout Hawaii originate from the NWHI. After more than 25 years of protecting nesting and foraging habitats in the Hawaiian Archipelago, the Hawaiian green sea turtle population is showing some signs of recovery. Green sea turtle nesting sites occur at Pearl and Hermes Atoll, Lisianski Island, Maro Reef, and French Frigate Shoals. French Frigate Shoals is the primary nesting site for green sea turtles, accounting for 400 nesting sites or 90% of all nesting within the Hawaiian Archipelago (ONMS, 2014). Nesting at French Frigate Shoals occurs from late April through September with a peak in June through July. Each female deposits 1-5 egg clutches (average 1-2) at 11-18 day intervals (USFWS, 2018b).

Monk seals (*Monachus schauinslandi*) live in warm subtropical waters and spend two-thirds of their time at sea, and they use waters surrounding atolls, islands, and areas farther offshore on reefs and submerged banks. When on land, monk seals breed and haul-out on sand, corals, and volcanic rock. Monk seals are often seen resting on beaches during the day. The Hawaiian monk seal was listed as an endangered species under the ESA in 1976 and is protected by the State of Hawaii under HRS 195D. While 80 to 100 Hawaiian monk seals coexist with humans in the MHI, the great majority of the population lives among remote islands and atolls within monument. Their range generally consists of the islands, banks, and corridors within the monument, although individuals have been found farther than 50 nm (93 km) from shore. Designated critical habitat for this species under the ESA encompasses all beach areas, sand spits and islets, including all beach crest vegetation to its deepest extent inland, lagoon waters, inner reefs, and ocean waters out to a depth of 20 fathoms (36.5 m) around the following: Pearl and Hermes Atoll; Kure Atoll; Midway Atoll, except Sand Island and its harbor; Lisianski Island; Laysan Island; Maro Reef; Gardner Pinnacles; French Frigate Shoals; Mokumanamana; and Nihoa (50 CFR 226.201) (ONMS, 2014).

3.7.2.3 Cultural Resources

Papahānaumokuākea is important to Native Hawaiians, with significant cultural sites found on the islands of Nihoa and Mokumanamana, both of which are on the National and State Registers for Historic Places. Mokumanamana has the highest density of sacred sites in the Hawaiian Archipelago and has spiritual significance in Hawaiian cosmology. Papahānaumokuākea is also home to historic resources associated with the Battle of Midway and 19th century commercial whaling (Papahānaumokuākea Marine National Monument, 2019).

Today, Native Hawaiians remain deeply connected to the Northwestern Hawaiian Islands on genealogical, cultural, and spiritual levels. Kauai and Niihau families voyaged to these islands indicating that they played a role in a larger network for subsistence practices into the 20th century (Tava & Keale, 1989). In recent years, Native Hawaiian cultural practitioners voyaged to the Northwestern Hawaiian Islands to honor their ancestors and perpetuate traditional practices. In 1997, Hui Mālama i Nā Kūpuna o Hawaii Nei repatriated sets of human remains to Nihoa and Mokumanana that were collected by archaeologists in the 1924-25 Bishop Museum Tanager Expeditions (Ayau & Tengan, 2002). In 2003, a cultural protocol group, Nā Kupeu Paemoku, traveled to Nihoa on the voyaging canoe Hōkūlea to conduct traditional ceremonies. In 2004, Hōkūlea sailed over 1,931 km to the most distant end of the island chain to visit Kure Atoll as part of a statewide educational initiative called “Navigating Change.” In 2005, Nā Kupueu Paemoku sailed to Mokumanamana to conduct protocol ceremonies on the longest day of the year, June 21 (the Summer Solstice).

3.7.2.4 Socioeconomic Environment

Currently, there is no public access for general visitation. Due to recent reductions in refuge staff and operational capacity, historical and eco-tour access is currently not offered (Papahānaumokuākea Marine National Monument, 2019). No private vessels have use of the monument for diving or fishing.

3.7.3 Pacific Remote Islands Marine National Monument

The Pacific Remote Islands Marine National Monument (PRIMNM) encompasses seven islands and atolls across the central Pacific Ocean (Figure 3-11). Six of the islands -- Baker Island, Howland Island, Jarvis Island, Johnston Atoll, Palmyra Atoll, and Kingman Reef -- are located between American Samoa and Hawaii, and Wake Atoll is located between Guam and the Northwestern Hawaiian Islands. The U.S. claimed most of these uninhabited islands under the Guano Islands Act of 1856 (48 U.S.C. §§ 1411, et seq.). These seven islands are National Wildlife Refuges and were made into a Marine National Monument via Proclamation 8336 (74 FR 1565) in 2009 and expanded by the 2014 Proclamation 9173 (79 FR 58645) to become one of the largest marine protected areas in the world with an area of 370,000 nautical mi^2 (1,270,000 km^2). All except Wake and Johnston are administered as National Wildlife Refuge by the USFWS of the Department of the Interior. Johnston Atoll is managed by the Department of Defense. Wake Atoll is under the jurisdiction of the Department of the Interior, and managed by the Department of Defense. During World War II, the U.S. constructed and occupied military bases at Johnston, Palmyra, Wake, Midway, and Baker. Jarvis and Howland were also briefly occupied or utilized during the war. With the closure of the military base at Johnston Atoll in 2004, only Wake Island remains an active U.S. military base (NOAA CoRIS, 2019e). Palmyra Atoll is the only refuge open for general public visitation (by special-use permit only). The entire monument is closed to commercial fishing and other resource extraction activities, such as deep sea mining (2014 Proclamation 9173 [79 FR 58645]).

3.7.3.1 Physical Environment

The islands/atolls have different sizes of landmass (0-2.7 mi^2 [4.3 km^2]) and different amounts of reef areas (0.77-36.3 mi^2 [1.2-58.4 km^2]) (Brainard et al., 2018). Their relative locations are shown in Figure 3-11.

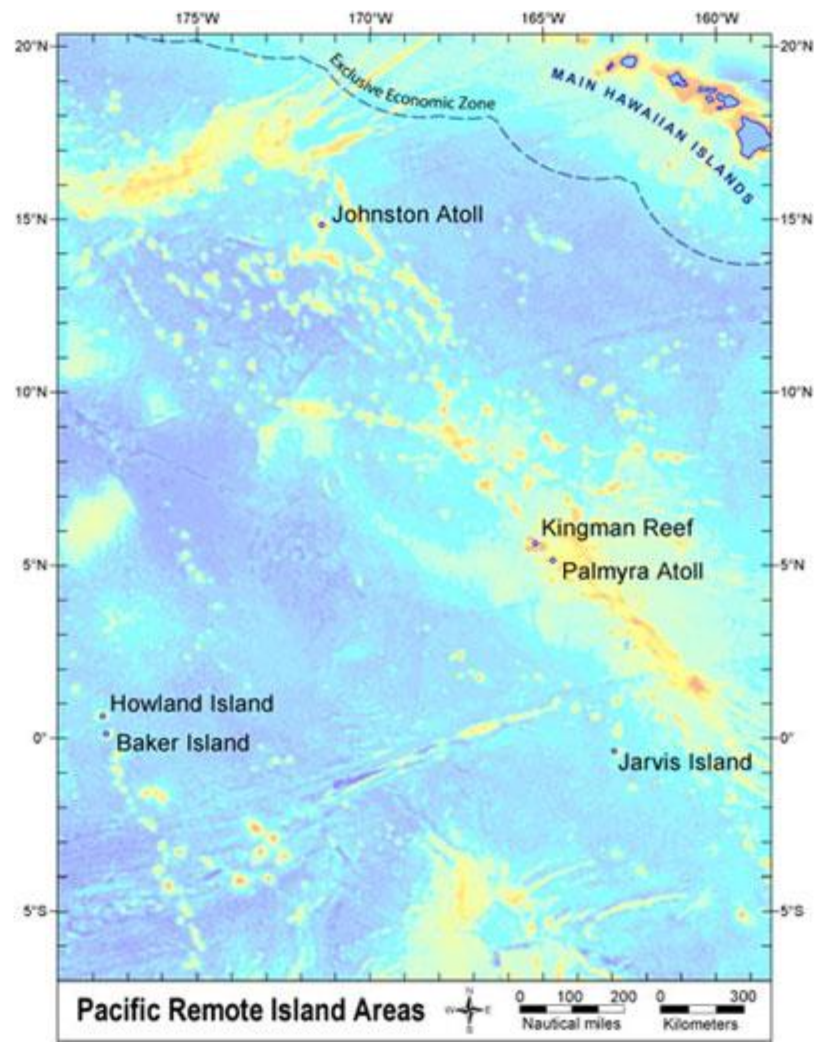

Figure 3-11. Pacific Remote Island Areas location map. *Source: NOAA CoRIS, 2019e*

3.7.3.2 Biological Environment

The PRIMNM includes seamounts, deep-sea corals, shallow-water coral reefs, and terrestrial habitats with an exceptional level of biomass and diversity. The seven islands and atolls within the PRIMNM are relatively pristine and in good health (Brainard et al., 2018).

Baker Island is a low-lying arid island surrounded by coral reefs made up of staghorn (Acroporidae), table (e.g., corals that form broad horizontal surfaces), brain (Mussidae and Merulinidae), rose (*Manicina areolata*), and plate (Fungiidae) corals. These reefs support a variety of fish such as moray eels, squirelfishes and solderfishes, sea basses and groupers, snappers, goatfishes, damselfishes, wrasses, parrotfishes, and sharks. Scientists have recorded 104 species of coral (USFWS, 2016a) and 247 species of fish (USFWS, 2016b) around Baker Island. Sea turtles and bottlenose dolphins use marine habitat near the island. Grass and herb vegetation supports nesting seabirds such as frigatebirds (Fregatidae), boobies (Sulidae), and sooty terns (*Onychoprion fuscatus*) (USFWS, 2016b). Additional terrestrial species include the snake-eyed skink (*Cryptoblepharus poecilopleurus*), the mourning gecko (*Leipidodactylus lugubris)*, hermit crabs, terrestrial mollusks, and insects.

Howland Island is also a low-lying island surrounded by coral reefs. Howland has a 109 species of stony coral (USFWS, 2016c) and 342 species of reef fish (USFWS, 2016d). Notable marine species around Howland include the giant clam (*Tridacna maxima*) and the humphead wrasse (*Cheilinus undulatus*) (USFWS, 2019c). Sea turtles and bottlenose dolphins are also frequently present. Howland Island is vegetated with grasses, herbs, and shrubs and is home to the snake-eyed skink, the mourning gecko, the strawberry hermit crab (*Coenobita perlatus*), and a variety of seabirds and shorebirds (USFWS, 2016d).

Jarvis Island is another low island surrounded by coral reefs with similar species to Baker and Howland Islands. Scientists have identified 62 species of coral (USFWS, 2019e) and 252 species of fish (USFWS, 2016f) at Jarvis Island. A 2006 survey of the Jarvis revealed a low density of macroinvertebrates, which were mostly sea urchins and sea cucumbers (Miller et al., 2008).

Johnston Atoll consists of four islands (two natural and two formed by coral dredging) and one lagoon. Scientists have documented 54 coral species, 93 species of algae, about 300 species of fish, and a variety of other marine invertebrates (e.g., worms, octopus, clams, sea urchins, starfish, nudibranchs, and sponges) around Johnston Atoll. Johnston Atoll is home to one endemic angelfish (*Centropyge nahackyi*) (USFWS, 2016g and 2016h). Green sea turtles (*Chelonia mydas*) also use the atoll for nesting and foraging. The landmass on Johnston Atoll has a variety of trees, grasses, and shrubs that supports nesting seabirds and shorebirds (USFWS, 2016h).

Palmyra atoll and Kingman Reef is 36 mi (58 km) apart. Palmyra Atoll originally consisted of approximately 50 islets and two lagoons. However, the atoll has been modified by humans and natural processes (Collen et al., 2009), and currently there are 26 islets and several lagoons (USFWS, 2017). Palmyra's land area is 0.77 m^2 (1.2 km^2) (Brianard et al., 2018) and has an extensive reef with 176 species of corals, 147 species of algae, and about 418 species of fish (USFWS, 2014). The waters around Palmyra also support green sea turtles and hawksbill sea turtles. Researchers have documented 205 species of coral and 225 species of fish around Kingman Reef (USFWS, 2013). Kingman Reef does not have any land mass but has two coral rubble ridges (USFWS, 2013). Both Palmyra and Kingman have a high biomass of fish and apex predators (i.e. snappers, jacks, and sharks) (USFWS, 2013; NOAA, 2018b). These areas are the only atolls found for thousands of miles, making them essential nesting sites and foraging areas for seabird colonies.

Wake Atoll consists of a large lagoon with three coral islands (Peale, Wake, and Wilkes). The islands are on the rim of a volcano, and the volcano's crater is in the center of the lagoon. The reefs around Wake Atoll have about 100 species of coral and 323 species of fish (Kenyon et al., 2013; USFWS, 2016i). Green sea turtles are frequently observed around the atoll. The island vegetation includes trees, shrubs and grasses. The land supports a variety of crabs (e.g., hermit crabs, fiddler crabs, ghost crabs, and rock crabs), geckos and skinks, and a variety of seabirds and shorebirds (e.g., albatross, boobies, terns, and plovers) (USFWS, 2016j and 2016k).

The PRIMNM has diverse coral and fish populations and low human influence. The condition of the reefs can be used as a baseline from which to draw conclusions about potential impacts to other Pacific reef areas from anthropogenic threats related to development. These islands also present an opportunity to study how sea level rise, ocean acidification, and warming waters affect coral reefs in the absence of substantial human influence. For the PRIMNM, the main threats to reef ecosystems are climate change and illegal fishing by international fishing boats. Widespread and catastrophic coral mortality was reported at Jarvis Island in the aftermath of the exceptionally strong 2015-2016 El Niño warming event. Hard coral cover declined from 17.8% in April 2015 (pre-bleaching) to 0.31% in May 2016 (post-bleaching), representing a catastrophic decline of 98% across all coral taxa, reef habitats, and depths (Brainard et al., 2018). This event highlights that management cannot control all threats and provides no refuge from global El Niño events.

Furthermore, some islands were used for military exercises in the past and, therefore, have highly altered landscapes. The extreme isolation of reefs in the PRIMNM and the low elevation of their islets/atolls make them easy targets for ship groundings. Grounded vessels can physically reduce large areas of healthy reef to rubble when they run aground. In addition, shifts from healthy hard coral-dominated reefs to those dominated by fleshy algae have been linked to iron leaching from wrecks. Recent shipwreck extraction projects on Palmyra Atoll and Kingman Reef have been successful at removing grounded vessels but at high monetary expense (USFWS, 2014). Management of the PRIMNM has had positive outcomes due to its protected status; however, the scale and scope of the islands, their remoteness, and limited resources and staff present challenges to management.

3.7.3.3 Cultural Resources

The PRIMNM does not have any historic properties or traditional cultural resources.

3.7.3.4 Socioeconomic Environment

There are no permanent residents of these islands, but past and current use, including illegal fishing pressure, does have an effect on the reefs. For reference, only Palmyra and Wake have any human presence, and those estimates are about 25 and 100 people, respectively, which are generally only military (Wake) or scientists (NOAA CRCP, 2018). Baker, Howland, Jarvis, Kingman, and Johnston have no human population. Due to the islands' remoteness, enforcement against illicit activities within the PRIMNM is challenging. During a routine inspection of a foreign vessel in 2010, NOAA agents found evidence of illegal fishing activities in waters off Howland and Baker Islands that were hidden from vessel tracking system (NOAA CRCP, 2018). Unauthorized entry (without illegal fishing) is also a problem because of the introduction of invasive species from ship hulls or ballast water.

4. ENVIRONMENTAL CONSEQUENCES

This chapter describes the expected environmental impacts of three programmatic alternatives for implementing the CRCP: No Action Alternative, Alternative 1, and Alternative 2. The intent of this DPEIS is to provide a document from which subsequent, project-specific actions may be tiered, followed by narrower, decision-focused reviews (40 C.F.R. §§ 1502.20 and 1508.28) to avoid repetitive broad-level analyses in the subsequent tiered NEPA reviews. Analysis of site-specific variables is beyond the scope of this DPEIS. Future project-specific environmental analysis would describe the specific effects of each project or activity if not fully addressed within this DPEIS. The scope and range of impacts of this DPEIS are more qualitative in nature than those typically found in project- or site-specific NEPA reviews.

4.1 Approach to Analysis

This analysis presents potential direct, indirect, and cumulative environmental impacts of Alternative 1 and Alternative 2 when compared with the No Action Alternative for relevant resources throughout the U.S. jurisdictions of the Atlantic Ocean (i.e., the Gulf of Mexico, South Atlantic and Caribbean Sea) and

Pacific Island Region. Proposed projects and actions related to the CRCP will undergo project-specific analysis to determine consistency with the analysis completed for this DPEIS to help determine what, if any, additional NEPA analysis is required for the project. This document is expected to serve as the basis for tiering. It may also be used for incorporation by reference to the greatest extent practicable. To determine whether an action may result in significant impacts, context and intensity of the action are considered (Table 4-1) per 40 C.F.R. § 1508.27 and NAO 216-6A.

Scope of impacts evaluated. Impact evaluations must include direct, indirect, and cumulative effects. These categories are used to describe the timing and proximity of potential impacts to the affected area only. They have no bearing on the significance of the potential impacts, as described below, and are used only to describe or characterize the nature of the potential impacts. The CEQ regulations (40 C.F.R. § 1508.8 and 1508.7) define these effects as follows:

- Direct effects are caused by the action and occur at the same time and place as the action.
- Indirect effects are caused by the action and occur later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density, or growth rate and related effects on air and water and other natural systems, including ecosystems.
- Cumulative impacts are those that result from the incremental effect of the activity, added to other past, present, or reasonably foreseeable future actions.

An impact may be significant whether it is direct, indirect or cumulative. We consider two primary factors to determine whether an impact to a resource may be significant: context and intensity.

Table 4-1. Criteria of context and intensity for considering potential impacts of actions.

Type	Context		Intensity	
	Duration	Geographic Extent	Magnitude	Quality
Direct Indirect Cumulative	Temporary Short-term Long-term Permanent	Local Larger Scale	Negligible Minor Moderate Major	Adverse Beneficial

4.1.1 Context

Context refers to duration (e.g., short- or long-term impacts) and area (local, statewide, etc.) of impacts (40 C.F.R. § 1508.27(a)).

Duration of Impact. Both short- and long-term effects are relevant. An impact lasting for a finite period and of short duration relative to a proposed project and the environmental resource is considered short-term for purposes of this DPEIS. In general, the impacts of construction and associated activities (e.g., vehicle use, use of staging areas for equipment, construction, area closure) undertaken to implement a project are expected to be short-term. Effects that persist beyond construction, such as the function of a created wetland, are expected to be long-term. These characteristics are determined case-by-case and do not refer to any specific time period.

Geographic Extent. Impacts of proposed activities can occur at a variety of geographic scales and defining the scale is important to the decision-making process (Nash, 2014). For the purposes of this analysis, impacts are assessed in two ways:

- Localized impacts are site-specific and generally limited to the immediate surroundings of a project site. Local impacts of watershed restoration and management activities would include the project area and areas with a direct nexus to the project area such as connected downstream waters and coastal waters that a sediment plume may reach. Local impacts of other activities include the project area, which would be defined prior to project implementation, based on the anticipated range of direct impacts. For example, the project area for the removal of a derelict vessel from a coral reef would be established during the permitting process to identify resources and geographic area potentially impacted.
- Large-scale impacts are those that extend beyond the project area.

4.1.2 Intensity

Intensity refers to the severity of impact (NOAA, 2009a) and could include the timing of the action (e.g., more intense impacts would be expected during critical periods like spawning, breeding, or storm events). Intensity is also described in terms of whether the impact would be beneficial or adverse. An adverse impact is one having unfavorable or undesirable outcomes for the environment. A single act might result in adverse impacts to one resource and beneficial impacts to another resource.

No quantitative guidance regarding magnitude of impacts is offered by CEQ. Therefore, further clarification is provided with respect to criteria used in this DPEIS to determine the potential significance based on differing levels of the magnitude of an impact to a resource. Our analysis defines magnitude at the following levels: negligible, minor, moderate, and major. The magnitude or intensity of a known or potential impact is defined on a spectrum ranging from no impacts to major impacts. The qualitative assessment taking into account both context and intensity is thus based on a review of the available and relevant reference material, professional judgment using standards that include consideration of the permanence of an impact or the potential for natural attenuation of an impact; uniqueness or irreplaceability of the resource; abundance or scarcity of the resource; geographic, ecological, or other context of the impact; and the potential that mitigation measures can offset the anticipated impact.

- Negligible. This relative term is used to describe *no* detectable or measurable impacts to the structure or function of a resource.
- Minor. This relative term is used to describe impacts to the structure or function of a resource that are *detectable, short-term, localized or larger scale, and not severe*. These are typically localized to the project site but may in certain circumstances extend beyond a project site.
- Moderate. This relative term is used to describe impacts to the structure or function of a resource that are *detectable, short or long-term, localized, and possibly severe* OR impacts are *detectable, long-term, extensive or localized, but not severe*.
- Major. This relative term is used to describe impacts that are *obvious, detectable and/or measurable, long-term, large scale, and severe*. They may result in substantial structural or functional changes to the resource. Generally, major impacts are those that, in their context and due to their severity, are indicators of "significance" (40 C.F.R. § 1508.27).

4.2 Issues Eliminated from Further Analysis

NEPA and CEQ regulations direct agencies preparing an EIS to "avoid useless bulk… and concentrate effort and attention on important issues" (40 C.F.R. § 1502.15) and to "identify and eliminate from detailed study the issues which are not significant or which have been covered by prior environmental review" (40 C.F.R. § 1506.3). All source documents relied upon for the NEPA analyses in this DPEIS are available to the public and links are provided in the discussion of the environmental consequences where applicable. Consequently, activities for which impacts are not expected or are expected to be negligible were eliminated from further analysis. The rationale for any resource initially considered but eliminated from further analysis is presented below.

4.2.1 No Impact Anticipated

Resource issues were eliminated from further analysis if the resource was considered outside the scope of the proposed action, irrelevant to the decision to be made regarding the CRCP alternatives, or unaffected by the proposed action or alternatives. Resources subsequently eliminated from further analysis are listed below with a brief explanation.

- **Oceanographic Processes**. Tides, winds, upwelling, and other processes in the Atlantic and Pacific oceans occur at a scale beyond the effects of the proposed activities and thus have no potential to be significantly impacted by any of the alternatives. As a result, oceanographic processes were eliminated from further analysis in this DPEIS.
- **Geology**. The geologic stability of the land and ocean bottom would not be compromised by any of the proposed activities, and no geologic hazards (e.g., landslides, earthquakes, and volcanic eruptions) are expected to occur as a result of any of the proposed alternatives. Proposed projects are limited to surficial soils and sediments, which are included for further analysis. Geologic features (e.g., beaches, cliffs, subtidal bottoms, and hard coral reef structures) would not be impacted. Vessel groundings can damage reef structure, potentially destabilizing bottom geology and fracturing reef platforms, and result in fundamental topographic shifts (Raymundo et al., 2018; Lirman et al., 2010). However, very few vessels would be involved with the in-water activities proposed under CRCP alternatives, and training and general BMPs would avoid and minimize reef damage under all alternatives. Therefore, impacts to geologic resources are not anticipated and were eliminated from further analysis in this DPEIS.
- **Environmental Justice**. EO 12898 states that, to the greatest extent practicable, federal agencies must "identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." Proposed activities are not expected to differentially impact minority or low-income populations or communities under the three alternatives and, therefore, environmental justice issues are not included for further analysis.
- **Children's Welfare**. Children are addressed specifically under EO 13045, *Protection of Children from Environmental Health Risks and Safety Risks* (62 FR 19885), because, in certain circumstances, they may be more vulnerable or disproportionately impacted when compared to an adult exposed to the same event. Children may volunteer to assist with some land-based restoration activities, such as planting native plants, cleaning up marine debris, and participating in *in-situ* educational activities; however, to the extent there may be impacts to children, there are no known disproportionate effects. Therefore, potential impacts to children's welfare were

excluded from further analysis.

4.2.2 Negligible Impacts Anticipated

A second tier of resources eliminated from further analyses was developed based on an expectation of negligible impacts. For this second tier of analysis, the rationale for eliminating the resource from further analysis is provided, consistent with the level of impact anticipated.

- **Climate**. Global climate change has been linked to human activities, especially greenhouse gas (GHG) emissions associated with burning fossil fuels (IPCC, 2007). Implementing activities outlined in this DPEIS would involve only small quantities of fuel for vehicles, equipment, and boating operations during implementation and monitoring activities, and energy requirements are not expected to result in detectable adverse impacts to resources. In general, activities supported by NOAA enhance resilience to climate change through increases in protective green infrastructure. Negligible impacts to climate are anticipated under any of the proposed alternatives and differences between the alternatives with respect to impacts would also be negligible. Thus, impacts to climate were eliminated from further analysis in this DPEIS. Subsequent environmental reviews for CRCP projects tiered from this DPEIS will include an appropriate level of analysis of GHG emissions and assess any project for site-specific considerations related to climate change.
- **Air Quality**. As described for climate, air emissions will be generated as a result of CRCP proposed activities, but not to levels higher than what currently occur under the No Action Alternative and emissions would not be outside the normal range of emissions from other activities in the Atlantic, the Pacific Island Region, and priority international areas. Additional air emissions would not be detectable in comparison with background emissions. Therefore, impacts from proposed activities would be negligible. Moreover, no differences in impacts to ambient air quality between alternatives are anticipated. Thus, this resource was subsequently eliminated from further analysis.
- **Ground Water Quality.** Ground water occurs beneath the land surface and may occur as part of an aquifer, as underground springs or connections between aquifers or springs and coastal waters, and as a source of water to surface water such as springs, rivers, and lakes. Submarine groundwater discharge can also occur, resulting in direct discharge or seepage of ground water through porous substrates into marine waters. No impacts to aquifers are anticipated as a result of any of the proposed projects and groundwater is therefore eliminated from further analysis. However, surficial groundwater that occurs close to the surface as part of the interstitial make up of soils could be influenced just as soils and surface water are. Therefore, potential impacts to these surficial waters are presented in specific resource sections.
- **Sound.** Airborne sound will be generated during CRCP activities from sources including vessel motor and mechanical equipment operation (e.g., pumps, compressors, heavy equipment) and aircraft performing LiDAR surveys. The proposed activities are of short duration, and the types of sound generated are not unusual to everyday activities and, therefore, not anticipated to impact resources in the watershed. Airborne vessel sound is also anticipated but would be negligible offshore, and there is no scientific evidence supporting a disturbance of nesting or breeding sea turtles and seabirds in the presence of vessels surveying in nearshore waters (NOAA, 2013). Airborne sound from survey and mapping activities are not likely to adversely affect marine mammals, ESA-listed species, critical habitat or essential fish habitat (EFH), cultural resources,

or other aspects of the environment (NOAA, 2013). In-water sound may be generated during proposed activities from sources such as vessels and surveying instruments. Potential in-water effects are considered negligible due to minimal overlap between acoustic echosounder frequencies and the functional hearing range of marine mammals in the area. The downward-oriented focus of the echosounder, rather than a widespread beam, also reduces the potential impacts of echosounder. Risk from in-water survey activities is further reduced by BMPs that require lowest possible power and ping rates during multibeam and single beam surveys. Potential effects of aircraft sound on marine mammals and fish, as well as sea turtles and seabirds during nesting, were also evaluated in the OCS PEA (2013). The PEA concluded that "[w]hile operations would temporarily add to the general sound in the air, aircraft sound from lidar operations would not have a long-term adverse impact on the environment based on the short duration (five hours), low intensity (aircraft flies 1,000-1,200 ft above the land and sea surface), and limited survey locations (less than one lidar survey per year)." Consequently, this DPEIS does not treat sound as a separate resource and does not include a detailed discussion of the sound environment. Rather, the impacts of sound on biological resources likely to be caused by CRCP activities, particularly impacts to marine mammals (e.g., potential impacts of echosounder on marine mammals), are addressed on a resource-by-resource basis where appropriate.

4.2.3 Activities Addressed in Previous NEPA Assessments and Incorporated by Reference

In addition to resources eliminated from further analysis, impacts from many activities are also addressed through summary analysis (i.e., impacts analyses, incorporated by reference and summarized) in this DPEIS based on evaluations and conclusions from previous NEPA documents addressing activities, resources, and impacts substantially similar to those anticipated for the CRCP. NOAA's NEPA Procedures (NAO 216-6A, Companion Manual [NEPA Manual, 2017]) state, "[d]ecision makers may use existing NOAA environmental assessments and environmental impact statements (EAs and EISs) to analyze effects associated with a proposed action, when doing so would build on work that has already been done, avoid redundancy, and provide a coherent and logical record of the analytical and decision-making process." In cases where the impacts of an activity were evaluated in a previous NEPA document on a resource addressed in the present analysis, the impact is briefly described, and the relevant document is referenced. The primary NEPA analyses relied on in this DPEIS are briefly summarized below and used throughout this DPEIS to support impacts analyses for substantially similar activities and resources.

- The 2013 Office of Coast Survey's Programmatic Environmental Assessment is cited hereafter as "OCS PEA 2013", incorporated by reference in Chapter 2, evaluated impacts of hydrographic surveys on various resources and concluded that the proposed activities would have no significant adverse impact on physical, biological, or socioeconomic resources in the Atlantic, Pacific Island Region, and priority international areas. The document is relevant to this DPEIS because of the same or similar activities and resources analyzed, particularly mapping, monitoring, and research. The OCS PEA 2013 evaluated potential survey impacts, including: risk of vessel strikes, echosounder and other sounds, light detection and ranging (lidar) surveys, vessel transit operations, anchoring, bottom sample collection, sound speed data collection, tide gauge installation and operation, and coast survey laboratory activities, and other potential impacts. The OCS PEA 2013 and subsequent FONSI concluded these activities would have no significant impacts to the coastal and marine environment, sea turtles, sea birds, seagrasses, mangroves, corals, EFH, threatened and endangered species and critical habitat, cultural environment, National Marine Sanctuaries, and others. In addition, BMPs implemented by NOAA vessels include avoidance and minimization of impacts to known reefs and hardbottom areas, anchoring in areas with documented absence of coral reefs, and anchoring in areas known to be devoid of corals.

- The NOAA *Deepwater Horizon*: Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Assessment (PDARP/PEIS) is cited hereafter as "NOAA PDARP/PEIS 2016" (NOAA 2016b) The NOAA PDARP/PEIS 2016 was prepared for the purpose of evaluating the effects of programmatic approaches to restoring natural resources injured as a result of the *Deepwater Horizon* (*DWH*) oil spill in 2010. The document is relevant to this DPEIS because its assessing impacts to the same or similar resources resulting from activities similar to those proposed for the CRCP (e.g., coral restoration activities such as coral transplants, water quality restoration activities such as reduced sedimentation, and habitat restoration activities such as debris removal and installation of mooring buoys). The NOAA PDARP/PEIS 2016 presents an analysis of proposed restoration projects for watershed, coral reef, water quality, and habitat restoration, among other project types. The Record of Decision for the NOAA PDARP/PEIS 2016 concluded that subsequent restoration plans would consider what additional NEPA analyses may be necessary, including whether the conditions and environmental effects described in the NOAA PDARP/PEIS 2016 have changed. The Record of Decision concluded that all practicable means to avoid, minimize, or compensate for environmental harm from the action had been considered programmatically, and that project-specific measures would be adopted during subsequent restoration planning efforts. Impacts of creation, restoration, and/or enhancement of coastal habitats (e.g., coastal wetlands) to physical resources were considered primarily adverse in the short term due to disturbance or entrainment during construction and replacement of existing habitat by newly restored habitat. Adverse impacts were out-weighed by long-term benefits of, for example, restored freshwater flows, sediment, and nutrient loads; restored sediment dynamics and deltaic processes; and overall coastal resiliency. The appropriate level of NEPA analysis for each subsequent restoration plan will be or is being determined by the lead federal agency for each plan. Many of the same or similar activities and resources analyzed for this DPEIS were also analyzed as part of the NOAA PDARP/PEIS 2016.

- The 2015 NOAA Restoration Center PEIS *for Habitat Restoration Activities Implemented Throughout the Coastal United States* is cited hereafter as "NOAA RC PEIS 2015" (NOAA RC PEIS, 2015). The document is relevant to the DPEIS because of the similarity in activities and resulting impacts to resources. For example, the NOAA RC PEIS evaluates the potential impacts of habitat restoration activities such as coral reef restoration (e.g., elimination of land based sources of pollution and controlling invasive species), debris removal from coastal and marine environments (e.g., derelict fishing gear and other persistent debris), invasive species removal, and wetland restoration on coastal and marine resources under the jurisdiction of NOAA. The NOAA RC PEIS 2015 assessed potential impacts of restoration projects on various resources and concluded that the proposed activities would have no significant adverse impact on physical, biological, or socioeconomic resources under U.S. jurisdictions. Potential impacts of planning, design, and permitting studies, fish and wildlife monitoring, public education and outreach, debris removal, invasive species control, bank restoration and erosion reduction, coral reef restoration, road and trail stabilization, revegetation, water conservation, wetland restoration, seagrass restoration, mangrove restoration, shoreline stabilization, and planting activities were evaluated. The NOAA RC PEIS 2015 and subsequent Record of Decision concluded that proposed activities described in the NOAA RC PEIS 2015 would have no adverse impact on physical, biological, and cultural resources. Activities anticipated to require further analysis were identified in the NOAA RC PEIS, 2015. Many of the activities and resources analyzed for this DPEIS were the same or similar to those analyzed as part of the NOAA RC PEIS 2015.

- The National Park Service General Management Plan and EIS for Biscayne Bay, referred to hereafter as the "NPS EIS 2015" (NPS EIS, 2015), analyzed the potential impacts of eight alternative management plans on Park resources (e.g., such as water quality, hardbottom habitat, seagrasses, corals, and fish and wildlife, wetlands, and cultural resources). The proposed alternatives included numerous activities to manage Park resources and visitor use and improve facilities and infrastructure. The selected alternative resulted in implementation of additional restrictions such as prohibiting anchoring in reserve zones, installing mooring buoys, building boardwalks over wetlands, and providing additional treatment of invasive and exotic species to reduce damage to Park resources. The corresponding Record of Decision concluded that activities under the selected alternative would not cause impairment (i.e., "an impact that... would harm the integrity…") of Park resources or values, including epibenthic biota, other invertebrates, fish, seagrasses, and other resources. The analysis of many activities and resources in the NPS EIS 2015 for Biscayne Bay are also relevant to activities CRCP activities considered in this DPEIS.

- The NOAA 2013 Marine Debris Program PEA is cited hereafter as the "MDP PEA 2013" (MDP PEA, 2013). The MDP PEA analyzed the potential impacts of implementing the MDP 2013 to conduct activities including marine debris research and prevention and reduction of marine debris throughout its jurisdiction (i.e., all coastal and nearshore habitats in state and territorial waters, plus offshore habitats within the U.S. Exclusive Economic Zone and high seas). The MDP PEA 2013 is relevant to the DPEIS because of similar or the same resources analyzed and the similarity in the debris removal activities analyzed here. For example, the MDP PEA 2013 analyzes impacts of research and assessment, prevention, reduction, and removal, outreach and education, and collaboration and tools relevant to the impacts of marine debris on coastal and marine resources under NOAA's jurisdiction. The proposed project targets plastics, glass, metal and rubber, derelict fishing gear, and derelict vessels and supports local, state, and national partnerships to assess and reduce marine debris and to protect and conserve the nation's marine environment and navigation safety from impacts of marine debris. The corresponding FONSI concluded that all projects would likely result in at least minor, short-term improvements and cumulatively in long-term substantial benefits. Adverse impacts of the proposed activities are expected to be minimal, and primarily associated with research and removal activities. Implementation of site-specific marine debris activities may have very localized and temporary adverse impacts over the short-term and on a small scale and would provide benefits in the long-term on a larger scale. No substantial social or economic impacts related to the proposed action, nor any social or economic impacts related to potential biological or physical environmental impacts are expected.

- The NOAA Coral Reef Ecosystem Division PEA is cited hereafter as the "CRED PEA 2010" (CRED PEA, 2010). The CRED PEA 2010 presents an analysis of potential effects of CRED research activities under the Pacific Reef Assessment and Monitoring Program component and the marine debris component, which together include monitoring, mapping, and research activities such as those described for the OCS PEA 2013. The document is relevant to this DPEIS because of the same or similar activities and resources analyzed, particularly mapping, monitoring, and research. The Coral Reef Ecosystem Division program covered all areas in the U.S.-affiliated Pacific Islands with coral reef ecosystems, including coral reefs and their associated habitats, benthic invertebrates, algae, and fish species that use these habitats. The geographic area includes populated portions of Hawai`i, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI). The marine debris component includes monitoring, assessment, and mitigation of the effects of derelict fishing gear in coral reef ecosystems. The FONSI concluded that the proposed activities would not result in significant adverse impacts to the resources evaluated, similar to the OCS PEA 2013.

- The Office of National Marine Sanctuary 2018 Draft PEA for Field Operations in the Southeast and Gulf of Mexico National Marine Sanctuaries is cited hereafter as "ONMS 2018" (NOAA ONMS, 2018b) The document is relevant to this DPEIS because of the same or similar activities and resources analyzed, particularly mapping, monitoring, and research. The ONMS PEA assesses the potential impacts of survey and monitoring activities on the condition and spatial distribution of seagrass, coral, and hard-bottom habitats to inform and develop management strategies. Activities included vessel and aircraft operations, non-motorized craft, SCUBA and snorkel operations, onshore fieldwork, sea floor equipment deployment, AUVs/ROVs, and other sampling activities, similar to the OCS PEA 2013, but in the Gulf of Mexico and Southeast Atlantic.

- The NOAA National Coastal Centers for Coastal Ocean Science is cited hereafter as "NCCOS EA 2016" (NCCOS EA, 2016) and assessed hydrographic surveying and mapping activities in Puerto Rico and the USVI addresses the collection of multibeam and split/beam acoustics echosounder data and field verification activities and tiers from the OCS PEA 2013. The document is relevant to this DPEIS because of the same or similar activities and resources analyzed, particularly mapping, monitoring, and research. Multibeam and split/beam acoustics may have potential adverse effects such as avoidance behavior of cetaceans or turtles, although potential effects are reduced due to minimal overlap in the acoustic echosounder frequencies and the functional hearing range of the marine mammals in the area and the downward oriented focus of the echosounder. The subsequent FONSI determined the proposed activities are not likely to adversely impact marine mammals, corals, seagrasses, ESA-listed species, critical habitat or EFH, cultural resources or other aspects of the environment.

4.2.4 Activities Eliminated from Further Analysis

Activities such as outreach and education, data analysis and modeling, and program and interagency coordination and administration are included in the CRCP under all three alternatives. No adverse impacts to any of the resources analyzed for this DPEIS are anticipated. The impacts of implementing these activities would be the same for all three alternatives and all the resources analyzed. Therefore, an analysis of impacts to resources is presented here rather than repeating the information for each resource. Overall, these activities are intended to result in indirect, long-term, local and larger-scale benefits to all resources. Activities would support the continued implementation of the most successful projects and, therefore, result in effective and efficient habitat restoration and coral reef resource management.

- **Public outreach and education**. Projects that provide environmental education classes, programs, and centers; encourage and maintain partnerships with local school systems; and/or fund the development of education materials would have direct and indirect, long-term, minor beneficial impacts to all resources. Benefits of educating local citizens and youth about environmental issues in the community and beyond, habitat restoration, and conservation would promote environmental stewardship, an understanding of living coastal and marine resources and environmental issues, and a sense of community pride. Educational materials developed would encourage conservation and environmental stewardship and educate the public on the benefits of habitat restoration projects. Projects conducted by youth groups would generally benefit the community both through their results and by promoting community cohesion. Additional NEPA analysis will be completed if the proposed project would have adverse effects that are beyond the scope of those analyzed here, including adverse effects that are significant.

- **Data analysis and modeling**. Data analysis and modeling provide information needed to support decision making and policies pertaining to coral reefs and other systems. Understanding how resources may be affected by local human-induced disturbances and global climate change is important to recovery of coral reefs. Ecosystem models provide information needed to account for complex reef dynamics and their responses to multiple disturbances and are needed to support planning and implementation of ecosystem-based management. Benefits of data analysis and modeling would accrue to coastal and marine sources, are focused on coral, and provide information critical to the successful management of coastal and marine resources.

- **Program and interagency coordination and administration**. The benefits of these activities include coordination among U.S. Atlantic and Pacific jurisdictions and priority international areas, and local, state, and other federal agencies to ensure resources are available for proposed activities. NOAA oversees U.S. coordination efforts through the USCRTF by serving as its co-chair and steering committee secretariat. The CRCP reviews plans, policies, and regulations related to coral reef conservation and management; supports meetings; manages CRCP data; implements and manages external funding opportunities; and supports program staff and travel to implement the program. The CRCP also provides support for international conferences such as the International Coral Reef Symposium.

4.2.5 Resources Retained for Further Analysis

The resources retained for further analysis include physical, biological, cultural, and socioeconomic resources. Resources such as sediments and soils, water quality, and ESA-listed species, occur in and are discussed with respect to both the watershed and the coastal/marine environment, as appropriate. Similarly, if a resource differs distinctly among the U.S. jurisdictions in the Atlantic, Pacific Island Region, and priority international areas, distinctions are presented. Resources expected to be impacted by the proposed action and alternatives and expected to have impacts that may range from negligible to major are carried through for further analysis. Cumulative impacts are presented separately and follow individual resource analyses.

Physical Environment

- Sediments and Soils
- Terrestrial Habitats and Biota
- Wetlands and Floodplains

- Water Resources

Biological Environment

- Seagrass
- Mangroves
- Coral and Associated Invertebrates and Algae
- Fish
- Other: Invasive Species

Regulatory Environment

- Essential Fish Habitat
- Other Protected Species

Socioeconomic Environment

- Cultural Resources
- Public Health and Safety
- Economic Environment

Potential impacts to resources are analyzed for activities described in Chapter 2 for each alternative. For organizational purposes, impacts to resources are presented for groups of activities (listed below, based on Table 2-1).

- Monitoring, mapping, and research
- Coral restoration and interventions
- Watershed restoration and management
- Reducing physical impacts to coral reef ecosystems

4.3 Physical Environment

4.3.1 Sediments and Soils

Terrigenous (terrestrial derived) and marine sediments and soils provide habitat for numerous organisms, ranging from bacteria and burrowing organisms in terrestrial and coastal environments to hard bottom and coral reefs in coastal and marine environments. Because sediments are critical to both terrestrial and seafloor habitats, excess sediments in stormwater runoff or reduced sediments due to erosion can affect land surface and seafloor. Sediment can be transported across the watershed and into downstream and coastal waters where it may accumulate or be resuspended into the water column and adversely impact habitats and biota due to the introduction of pollutants, burial of habitats, suffocation of sessile animals such as coral, and/or water quality degradation. Point and nonpoint source pollutants, such as excess sediment, nutrients, metals, and pesticides, are particularly relevant due to the potential impacts to habitats such as mangroves, seagrasses, and coral reefs. In addition, sediments and other forms of terrestrial runoff correspond with increased coral degradation and disease (Waddell, 2008). Sediments and soils can be adversely impacted by actions that would erode, transport, bury, compact, or otherwise disturb existing land surface or seafloor substrates. Terrestrial soils in the watershed are affected by upland deforestation, agriculture, development, and subsequent stormwater runoff into downstream fresh, coastal, and marine waters.

While sediments and soils vary among U.S. coral reef jurisdictions due to variation in geology, climate, and other factors, the causes of, and impacts to, sediment and soil runoff are similar. Factors affecting stormwater runoff and nonpoint source pollution include rainfall intensity, preceding wet and dry days, pervious and impervious surfaces, land use, and drainage. Runoff from more developed and urban areas includes greater concentrations of soluble metals and fuel-related contaminants (Young et al., 2018). Runoff from agricultural areas is dominated by sediments but, like urban runoff, may also include pathogens, nutrients, pesticides, and metals. Remote areas in the American Pacific are less developed, with fewer roads and smaller extent of impervious surfaces, and more agricultural runoff. Development is more expansive in the Caribbean and along the Florida coast and the runoff is correspondingly greater, especially on steep slopes, and erosion of unpaved and degraded roads is a significant source of terrestrial sediment inputs into downstream water bodies. For example, sedimentation from unpaved roads can be 300-900% higher than that of undisturbed watersheds in the USVI (Waddell, 2008) and most (83-95%) of the sediment yield reported for Saint Lucia in the Caribbean was attributable to unpaved and degraded roads (Bégin et al., 2014). Sediment runoff is also considered the leading land-based pollutant affecting reef community structure in the main Hawaiian Islands (Waddell, 2008).

4.3.1.1 No Action Alternative

CRCP activities including monitoring, mapping, research, coral restoration and intervention, watershed restoration and management, and activities to reduce physical disturbance to coral reefs (i.e., permanent boat mooring and marine debris removal; Table 2-1) have the potential to affect sediments and soils under the CRCP No Action Alternative.

Monitoring, mapping, and research. Most terrestrial sediment loss is due to erosion in channels, gullies, and streams (Bartley et al., 2014). Monitoring and research activities in the watershed may include drilling into soil or sediment via auger, vibra-core, or hand probe to remove samples for analysis or geotechnical evaluations, and/or evaluating groundwater levels and elevations. Potential adverse impacts to sediments and soils from these activities would be direct, short-term, localized, and negligible to minor (NOAA, 2016b; OCS PEIS, 2013).

Monitoring, mapping, and research activities under the No Action Alternative would result in short-term direct adverse impacts to marine sediments, such as stirring of bottom sediments due to interactions with vessel, equipment, sampling, and/or diver activities that may occur during these activities. Resuspended sediments, including any contained contaminants, may be redeposited on adjacent corals and may cause adverse effects to their health. Methods described in chapter 2 would ensure that turbidity and sediment resuspension would be minimized and that corals and other habitats would not be adversely impacted by associated activities. Adverse impacts would be limited to the duration of the activity and would be direct, short term, local, and negligible to minor. Major benefits to the understanding, sustainable use, and long-term conservation of coral reefs and coral reef ecosystems are anticipated due to data collected as a result of many of these activities (ONMS, 2018 [Section 4.1.1]; NCCOS PEA, 2016 [Section 4.1]; NOAA, 2013 [Appendix 1]). Potential benefits of these activities were also analyzed in the NOAA RC PEIS 2015, which concluded that potential benefits would be indirect, long-term, local to large scale, and negligible to major (Section 4.5.1), depending on the location (sensitive vs. less sensitive sea floor) and type (mapping vs. sampling) of an activity.

Coral restoration and interventions. Impacts to soils and sediments from coral restoration would be limited to disturbance of coastal and marine sediments during coral transplantation, *in-situ* nursery development and maintenance, and coral interventions (e.g., control of invasive species, corallivores, and disease). Potential adverse impacts and benefits to sediments would be the same as those described for vessel, equipment, and diver activities associated with monitoring, mapping, and research in coastal and marine waters. Construction of *in-situ* coral nurseries may require more vessel and diver activity than monitoring, mapping, and research due to the permanent installation of frames or other equipment used to anchor the nursery grown corals and the regular maintenance of the nurseries. Sediment disturbance may also occur during nursery construction (NAS, 2019). Resuspended sediments including contained contaminants may be redeposited on adjacent corals and may cause adverse effects to their health. Minimization and avoidance measures would ensure that turbidity and sediment resuspension were reduced during nursery construction, and that other corals and habitats were not adversely impacted by associated activities. Therefore, adverse impacts to coastal and marine sediments due to coral restoration and intervention activities are expected to be direct, short term, local, and negligible to minor.

Benefits to seafloor sediments would be expected as a result of coral reef establishment and subsequent stabilization of sediments. Expected benefits would be direct, short-term, local, and negligible to minor due to small geographic nature of individual projects.

Watershed restoration and management. Construction of watershed management projects such as culverts, baffle boxes, elevated boardwalks with pilings, and LID would result in larger-scale disturbances due to staging and cleaning areas, workers, and possibly heavy equipment to excavate or rearrange soils. Vegetation plantings would require some land clearing and possibly mechanical land clearing. Invasive species control activities may require existing vegetation to be mechanically cleared for invasive species treatment and replanting of desirable species. Construction activities would potentially impact sedimentation and soil erosion in areas where the slopes are steep and where the erosion potential is moderate to severe. Increased sedimentation in waterways may alter natural sediment transport processes and subsequently impair water and habitat quality and aquatic plants and animals. Potential construction BMPs are listed in Appendix A. BMPs, such as silt curtains, buffer zones, and water quality monitoring, would be used to minimize such effects. Although soil compaction has the potential for long-term impacts, BMPs would reduce the compaction so that plant roots and benthic infauna can inhabit the soil and create further improvements. Potential impacts caused by equipment staging, vehicle or foot traffic, and other construction-related activities would be avoided and minimized by applying BMPs related to construction activities and impacts would be negligible. When heavy equipment or motor vehicles are used for debris removal, BMPs for vehicle staging, fuel storage, erosion and pollution control, and species decontamination would prevent construction-related impacts to the extent possible

Following restoration activities, revegetation would be relatively rapid (over weeks), and vegetation would be planted to ensure recovery. Some projects would result in the replacement of invasive species with native vegetation, while some would replace disturbed areas with projects such as swales or culverts and, in some cases, a stormwater pond may be constructed. The potential for the loss of topsoil due to soil mixing during proposed activities such as grading and/or excavation is present but would also be minimal. Construction activities would also potentially impact sediment and soil resources via compaction and rutting in susceptible soils. Overall, adverse impacts would be direct, short-term, local, and negligible to minor, depending on the level of activity, for example, hand planting a revegetation site vs. constructing a stormwater pond. NOAA has previously analyzed the impacts of similar activities for the NOAA RC PEIS (2015) and the NOAA PDARP/PEIS 2016 and concluded that no significant adverse impacts to sediments and soils anticipated from these activities. The activities proposed are similar to those analyzed in Section 4.5.2 of the NOAA RC PEIS and Section 6.4.1 of the NOAA PDARP/PEIS

2016. Consequently, no significant adverse impacts to sediments and soils are anticipated as a result of these activities (NOAA PDARP/PEIS, 2016c; NOAA RC PEIS, 2015).

Watershed restoration and management activities with the potential to result in discharge of dredged material or fill into U.S. waters would be regulated under Section 404 of the CWA and would require demonstration of avoidance and minimization of impacts to sediment and water quality contained in a project specific individual permit or an applicable general permit. Therefore, potential adverse impacts to coastal and marine sediments from watershed restoration and management activities are expected to be direct, short-term, local, and negligible to minor.

Potential benefits to terrestrial (watershed) soils as a result of watershed restoration and management activities are anticipated. Many of these projects would redirect stormwater through vegetated areas (e.g., swales, rain gardens, restored and planted landscapes) and stormwater ponds, reducing the potential for sediment erosion and downstream transport. For example, a sediment reduction project in Fouha Bay, Guam, installed tree seedlings and sediment filter "socks" in eroding hillsides above the bay, capturing more than 110 tons (100 metric tons) of sediment after 21 months (Shelton and Richmond, 2016). Results suggested that treating 0.05 km^2 (0.03 mi^2) of eroding hillside would achieve the reduction needed to restore the bay to pre-sediment stress conditions (below 50 $mg/cm^2/day$), providing conditions under which coral reefs are anticipated to recover. Benefits of stabilized soils include retention of mineral and organic soil components, nutrients, and microorganisms, improved water-holding capacity during drought, and increased aggregate soil stability that further reduces the susceptibility of soils to disturbance and erosion. Benefits would include reduced amounts of stormwater runoff and associated sediments and pollutants. Negligible to minor benefits to marine sediments may occur as a result of coral reef recovery that stabilizes sediments by filling in scoured or eroded areas, although these benefits would not be realized for years. Management efforts to reduce terrestrial runoff from watersheds have led to small but significant reductions in end-of-river sediment and nutrient loads on the Great Barrier Reef (Fabricius et al., 2016). Overall, benefits to soils and sediments under the No Action Alternative are expected to result in a range of impacts: direct and indirect, short- and long-term, local, and negligible to major (NOAA PDARP/PEIS 2016 [NOAA, 2016b]).

Reducing physical impacts to coral reef ecosystems. Construction and installation of mooring buoys and other equipment, and community-based debris cleanups to reduce physical impacts to coral reefs could disturb sediments and cause temporary sediment plumes and increases in turbidity, but effects have been found to be negligible (Demers et al., 2012; Urban Harbors Institute, 2013). Permanent mooring buoys may attract more visitors and result in indirect increases in water quality and sediment disturbance due to anchorings rather than use of buoy moorings. However, permanent mooring buoys for vessels and instrumentation under the CRCP would reduce the numbers of temporary anchorings since boat users would attach to an existing mooring rather than multiple visitors dropping anchor multiple times, reducing impacts to sediments. Other benefits of mooring buoys include reduced scour and erosion that occurs when anchor chains scrape the seafloor as they are moved by tides, currents, and wind (Morrisey et al., 2018). Installation of mooring buoys would reduce losses of coral cover due to damage from anchors and chains because they would no longer be used. The NPS EIS 2015 analyzed the impacts of installing mooring buoys (e.g., Chapter 4 pages 214, 244, 262) and concluded that the installation of mooring buoys and volunteer debris cleanups would result in short-term, local, minor, and adverse impacts to submerged substrates, and mooring buoys would not be placed in corals, seagrass beds, or submerged cultural resources. Adverse impacts to sediments and soils are expected to be direct, short-term, local, and negligible to minor. Benefits of permanent mooring buoys, which would vary by location, would include continued protection of submerged sediments from unintentional vessel and anchor damage and would be direct, short-term, local, and negligible (e.g., sand bottom with few visitors) to moderate (sand bottom with frequent visitors).

The removal of marine debris may involve operation of vessels in water and motor vehicles on land (e.g., front-end tractor loaders, cranes, and light trucks), community-based volunteers, divers, and excavation to remove derelict equipment or vessels from sediments. The NOAA MDP 2013 presents an analysis of potential impacts of marine debris activities on the physical environment (Section 5.2.2) and reports that these activities may lead to direct, short-term, negligible to minor disturbance of substrates (NOAA MDP, 2013), including resuspensions of sediment and sediment-bound contaminants. BMPs to reduce disturbance during these activities are included in the CRCP and would minimize disturbance to sediments and restore sediments to pre-disturbance conditions. Support teams responsible for implementing BMPs for safety, equipment, material handling, and use of air bags to lift heavy debris and vessels would reduce the potential for these short-term impacts to the seafloor. Direct, short-term, local, minor, adverse impacts are anticipated during removal of debris due to local disturbance. The removal of marine debris would reduce the millions of tons of debris added to coastal habitats each year via runoff from the watershed, wind, and currents (Browne et al., 2015) and would result in direct, short- and long-term, localized, and minor to moderate benefits to coastal and marine sediments.

4.3.1.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals (e.g., permanent mooring buoy installation, marine debris removal) (Table 2-1) would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to sediments and soils from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Eliminating coral restoration and intervention activities would result in the continued deterioration of coral reefs and associated habitats (e.g., seagrasses and shorelines) and scouring and erosion of sediments that were formerly stabilized by the coral reef structure. Activities to address adverse impacts of coral-specific invasive species, disease, and predators would not be implemented, further reducing the potential for coral recovery and impacting coastal and marine sediments. Potential adverse impacts to sediments would be direct, long-term, local, and negligible to moderate. No benefits to sediments are expected.

Watershed restoration and management. Potential adverse impacts and benefits to soils and sediments would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of permanent mooring buoys would increase the potential for direct damage to coastal and marine sediments as a result of recreational, scientific, and other vessel operators deploying and removing anchors on multiple occasions rather than attaching to an existing mooring line and having no impacts to sediments. This would increase the physical damage due to anchors that has been reduced under the No Action Alternative. The number of anchors and anchor chains scraping along the sea floor with changing currents and winds would increase the extent of sediment disturbance and alteration, sediment resuspension, and erosion, particularly in those areas with high visitor use. In the absence of debris removal activities implemented under the CRCP, derelict fishing gear, derelict vessels, and other debris that would otherwise be removed would continue to accumulate on the seafloor and along the shoreline, resulting in physical disturbance and potential contamination of sediments. Debris removal under NOAA's Marine Debris Program would continue to address this issue. Marine debris in coastal and marine waters can damage sediments via abrasion, shearing, scour, and burial and can result in accumulation of toxins, inhibit gas exchange, and alter nutrient cycles in the sediments (NOAA, 2016b). Derelict fishing gear can scour local sediments and fishing nets can trap sediments. Plastic pellets and fragments have been shown to alter sediment structure along Hawaiian beaches (Carson et al., 2011). Plastic pellets can adsorb contaminants such as PCBs, PAHs, and organochlorine pesticides, which may accumulate in sediments as the pellets degrade. Potential adverse impacts to sediments from continued anchoring and debris accumulation and damage would be direct, short- and long-term, local, and negligible (in small areas or where marine debris is not present) to moderate (where debris is present and causing in moderate scour). Ocean currents and sedimentation would continue to influence the overall nature of the sediments. No benefits to sediments are anticipated as a result of eliminating the installation of permanent mooring buoys and debris removal.

Under Alternative 1, the benefits of monitoring, mapping, and research would continue to provide information critical to erosion management of soils and sediments and watershed restoration and management activities would continue to reduce sediment and other pollutant loads into downstream and coastal waters. However, the overall benefits to sediments would be reduced by the elimination of the components of the CRCP that directly address physical damage to, and loss of, sediments in coastal and marine waters. Therefore, overall potential benefits to sediments would be direct, short- to long-term, local, and negligible to minor.

4.3.1.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP and may further reduce the potential for adverse impacts to sediments and soils from proposed activities. Implementation of DCMMs alone would have no adverse impacts to sediments and soils. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional negligible impact reductions as a result of DCMMs, depending on the activity.

DCMMs may include increasing the capacity for greater supervision over dive activities, BMPs to control turbidity and sediment, greater restrictions on instrument mooring, prioritizing the use of recreational mooring buoys or live boating, additional training to vessel operators, and stopping restoration work during or when a storm is approaching and during coral spawning periods. These activities would further reduce physical disturbance of sediments and soils in the watershed and in coastal and marine waters and, therefore, reduce the potential for release of sediments and sediment-bound contaminants into downstream freshwaters and coastal and marine waters. Potential benefits to sediments and soils would be similar to, but negligibly greater than, those described for the No Action Alternative.

4.3.2 Terrestrial and Freshwater Habitats and Biota

Reducing land-based sources of pollution includes development of watershed management plans, implementation of projects such as water quality monitoring, upgrading wastewater treatment facilities, implementing BMPs to reduce sedimentation and runoff, partner coordination and technical assistance, and building capacity for each jurisdiction to take on and manage these activities (Table 2-1). These activities are intended to reduce the accumulation of sediments and other pollutants that enter coastal waters, subsequently affecting water and sediment quality that eventually impact coral reefs and associated habitats. This section focuses on impacts to the terrestrial habitats and associated biota throughout the watershed. Because of the programmatic level of this EIS, project types and locations to be implemented have not yet been determined and may range from water quality monitoring in state jurisdictions to water quality infrastructure in a south Pacific territory. Therefore, analysis of threatened and endangered (ESA-listed) terrestrial species critical habitat presented here is also very general are addressed here. As mentioned in Section 3.4.2, the CRCP is conducting programmatic Section 7 consultations with NMFS and USFWS. Other ESA-listed species are addressed in Section 4.12.

Potential impacts to ESA-listed species and designated critical habitat from activities similar or identical to those described in Section 2.3 were evaluated specifically in the NOAA RC PEIS 2015 (Section 4.7), NOAA PDARP/PEIS 2016 (Section 6.4), and the USFWS framework Biological Opinion/Conference Opinion (Section 6; [USFWS, 2016l]); those analyses are incorporated by reference. Based on the results of these documents, minor to major adverse impacts to ESA-listed species or critical habitat are anticipated as a result of the proposed alternatives, though impacts are anticipated to be reduced through application of minimization measures. The discussion here is limited to potential general impacts to ESA-listed species.

4.3.2.1 No Action Alternative

CRCP activities under the No Action Alternative that were evaluated with respect to potential impacts to terrestrial habitats and biota include monitoring, mapping using drones, and watershed restoration and management activities. All other mapping and research activities are limited to the marine environment, specifically to coral reefs and adjacent areas. Activities that support coral restoration and intervention and reducing physical impacts to coral reefs would occur only in coastal and marine waters and would not adversely affect terrestrial habitats and biota.

Monitoring, mapping, and research. Monitoring activities, mapping with drones, and the collection soils would be implemented in watershed areas. Data acquired from monitoring, mapping, soil collection, and water sampling would provide information to support assessments that may help prioritize areas for projects designed to reduce runoff into downstream and coastal waters. These data-acquisition activities would benefit terrestrial and freshwater fish and wildlife by providing information relevant to the management of soils and water quality and, therefore, fish and wildlife habitat. Adverse impacts to both animal and plant species would be negligible due to little or no ground disturbance during monitoring activities and the ability of animals to leave a disturbed area if necessary. Activities such as soil or water quality sampling, surveying areas for elevation or other landscape features, and identification of sensitive areas and surveys for ESA-listed species would result in little to no disturbance. The use of drones for mapping terrestrial areas may alter behavior of birds or other land species depending on the flight altitude. Potential adverse impacts to terrestrial habitats and biota would be direct, short-term, local, and negligible to minor. Potential benefits to terrestrial habitats and biota are expected to be direct, short- term, local, and negligible to moderate, primarily due to information available to support future conservation and management efforts.

Monitoring, mapping, and research activities would provide water quality and soil erosion information that would be helpful in characterizing habitats and identifying potential water quality or erosion issues relevant to ESA-listed species (Appendix E). Sediment and water quality monitoring would have little to no impact on vegetation and animals, including ESA-listed species. Most listed animal species would avoid or move away from monitoring activities that may occur. Monitoring equipment would not be intrusive and would be carried by the survey team. Pedestrian surveys are not expected to have no impact on ESA-listed species with the exception of documenting their presence or potential presence. Activities would be limited to short-term and non-invasive disturbances that are not expected to adversely impact listed species. Similarly, activities would be limited to those that would not adversely impact critical habitat (e.g., vehicles confined to roads, pedestrian travel only in sensitive areas). Potential benefits to ESA-listed species and critical habitat would be direct, long-term, local, and negligible to moderate due to occurrence and habitat documentation and application of collected data in addressing potential water quality, sediment, and erosion information that may, in turn, affect ESA-listed species or critical habitat.

Watershed restoration and management. Watershed restoration and management activities such as LID, stormwater control measures, road and trail stabilization, and erosion and sediment control practices may affect habitat and use of habitat by fish and wildlife. Depending on the activities implemented, short-term, minor adverse impacts to terrestrial habitats and biota may be anticipated during construction. For example, if construction includes earthmoving work, terrestrial vegetation and ground and tree nesting birds may be disturbed, and nests of mammals, birds, and/or reptiles damaged or destroyed. There could be adverse impacts to terrestrial and associated aquatic habitats and biota due to construction activities and subsequent disturbances to soils, hydrology, water quality, as described in Section 4.3.1 and 4.3.4), but adverse impacts would be minimized by implementing BMPs that reduce turbidity and sedimentation, avoid sensitive habitats, and are scheduled outside nesting seasons of sensitive biota. Biota such as birds, mammals, reptiles, amphibians, and fish would likely leave the area during construction, either permanently or temporarily, depending on habitats available. No loss of native habitats is anticipated as watershed restoration activities generally take place in previously disturbed areas, and sites are planted with native or naturalized plants. Herbicide applications would be consistent with labeled use to avoid potential impacts to ground or surface waters. Activities are not expected to interfere with foraging, reproduction, resting, migrating, or other factors affecting population levels. Changes to local population numbers, population structure, and other demographic factors are not anticipated because of the size of the restoration projects and sufficient habitat could persist at both the local and range-wide scales to maintain the viability of the species. Potential adverse impacts of these activities would be direct and indirect, short-term to long-term, and negligible to minor, and result from primarily temporary construction activities.

Watershed restoration and management activities are expected to benefit habitat and biota by restoring sheet flows across the watershed that may have been altered with respect to volume, timing, duration, and quality. Reductions in stormwater runoff, sedimentation, and pollutant loadings would be anticipated throughout the watershed as a result of projects such as wetland treatment ponds, stormwater ponds, and rain gardens. These activities would reduce the potential impacts associated with impervious surface cover (e.g., roads, rooftops, parking lots, and driveways), which increases the volume and rate of stormwater runoff, erosion, and degradation of terrestrial habitats. EPA, together with the states and territories, regulates and permit certain pollutant sources; however, watershed activities that reduce runoff would provide further reductions in pollution to coastal waters. Watershed restoration and management activities would include a combination of stormwater control measures, erosion control practices, agriculture conservation practices, forestry management practices, and hydrologic restoration that are not mandated by the CWA.

Benefits would accrue to terrestrial and aquatic biota under the No Action Alternative due to reduced contaminant loadings (e.g., pesticides and fuel contaminants), improved water and sediment quality, reduced runoff and associated habitat erosion and disturbance, and restored native vegetation. Long-term benefits to surface water and ground water would translate to improved terrestrial habitats in the watershed and corresponding benefits to biota that use these habitats. Expected benefits would be direct and indirect, short-term and long-term, local, and negligible to moderate.

Disturbances to ESA-listed species and/or critical habitat during watershed restoration and management activities such as construction of road stabilization, stormwater swales, culverts, or stormwater detention ponds, would include soil and possibly vegetation excavation, sound, and temporary or permanent loss of habitat. Animals would leave the area if additional habitat is available and would return once proposed activities were completed. Benefits to ESA-listed species are expected due to improved habitat, control of invasive species, and restoration of native habitats. Potential adverse impacts to terrestrial ESA-listed species would be direct, short-term, local, and negligible to minor. Expected benefits would also be direct, short-term and long-term, and negligible to moderate.

4.3.2.2 Alternative 1

Under Alternative 1, the elimination of current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would have no impacts on terrestrial habitats and biota due to the locations of those activities.

Monitoring, mapping, and research. Potential adverse impacts and benefits to terrestrial habitats and biota would be the same as described for the No Action Alternative. Potential adverse impacts would be direct, short-term, local, and negligible. Potential benefits would be direct and indirect, short-term, local, and negligible to minor, primarily due to information available to support water quality and soils management efforts.

Watershed restoration and management. Potential adverse impacts and benefits to terrestrial habitats and biota would be the same as described for the No Action Alternative. Potential adverse impacts would be direct, short-term, local, and negligible to minor. Expected benefits would be direct, short-term and long-term, and negligible to moderate.

4.3.2.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP. Implementation of DCMMs alone would have no adverse impacts to terrestrial habitat and biota. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

DCMMs related to activities in the watershed may include additional BMPs to control turbidity and sediments; prohibition of collection of birds (live or dead), their eggs, nests, or parts (e.g., feathers); and necessary precautions to prevent injury to any birds or disturbance to any bird nests. These DCMMs would be applicable to all proposed activities undertaken in the watershed and would avoid potential adverse impacts to nesting birds and bird nests during monitoring and watershed restoration and management activities included in the current CRCP. Additional DCMMs may provide further, but likely negligible, benefits to terrestrial habitats and biota when compared with the No Action Alternative.

4.3.3 Wetlands and Floodplains

Wetlands may include freshwater streams, swamps, marshes, prairies, and other areas inundated for at least a portion of the year. Wetlands are critical to the life cycles of many species of fish and wildlife and are protected under the CWA as well as EO 11990, which is intended to minimize the destruction, loss, or degradation of wetlands and requires federal agencies, in planning their actions, to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. Within the watershed, wetlands often occur within a floodplain, which encompasses the area of potential flooding from a river, stream, or other waterbody. Because of the potential flooding in these areas, floodplain management is addressed under EO 11988, which requires federal agencies to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative.

4.3.3.1 No Action Alternative

CRCP activities under the No Action Alternative evaluated for potential impacts to wetlands and floodplains include monitoring, mapping, and research, and watershed restoration and management activities.

Monitoring, mapping, and research. Monitoring, mapping, and research activities would be implemented in wetlands and floodplains. Potential impacts to wetlands and floodplains would be the same as those described for terrestrial habitats (Section 4.3.2). These activities would provide data to support management of wetlands and floodplains with respect to erosion, sedimentation, flooding, and other management efforts. Potential adverse impacts to wetlands and floodplains would be direct, short-term, local, and negligible due to pedestrian surveys limited to sediment and water quality sampling activities. Vegetation or wildlife sampling would not be included except for possible observation records. No activities that would disturb, alter, or otherwise affect hydrology, wildlife, or vegetation are anticipated. Benefits to wetlands and floodplains would occur due to the use of the information collected in addressing potential water quality, sedimentation, and erosion issues that may adversely affect wetlands and floodplains. Potential benefits wetlands and floodplains would be indirect, long-term, local to large scale, and negligible to moderate.

Watershed restoration and management. The implementation of watershed restoration and management activities that include earthmoving work may disturb terrestrial vegetation and land surfaces. Impacts would be minimized by implementing BMPs that reduce turbidity and sedimentation and avoid sensitive habitats. The implementation of watershed restoration activities is likely to affect a small area and alter riparian, wetland, or upland vegetation and soils. No loss of native habitats is anticipated as restoration activities tend to be in previously disturbed area, and would be replanted with native or noninvasive vegetation. Herbicide applications would be consistent with labeled use to avoid potential impacts to ground or surface waters. Potential adverse impacts would be direct, short-term, local, and negligible to minor due to disturbances to land surfaces, soils (Section 4.3.1), and water quality (Section 4.3.4).

Watershed restoration and management activities such as LID, stormwater control measures, road and trail stabilization, and erosion and sediment control practices would reduce erosion and sedimentation in wetlands and floodplains, potentially restore the water-holding capacity of these areas and restore wetland habitat for fish and wildlife. Management of stormwater runoff would restore some of the natural hydrology of wetlands and floodplains, resulting in wetlands and floodplains that can accommodate floodwaters during peak rainfall periods, recharge aquifers, provide forage habitat for fisheries, reduce the spread of invasive species, and reduce flooding in uplands. Wetlands and floodplains would provide detention and passive treatment of stormwater by trapping debris, sediment, and pollutants (e.g., chemicals, fertilizers, herbicides, insecticides, salts, oil, and bacteria and solids from livestock, pets, and faulty septic systems) from stormwater runoff and preventing their entry into downstream and coastal waters. Federal and state agencies regulate and permit certain pollutant sources; however, watershed activities that reduce runoff would provide further reductions in pollution to coastal waters. Implementation of these activities may include one or a combination of stormwater control measures, erosion control practices, agriculture conservation practices, forestry management practices, hydrologic restoration, and coastal and riparian conservation techniques that are not previously mandated by the CWA, resulting in a range of impacts. Potential benefits to wetlands and floodplains from these activities would be direct and indirect, short- and long-term, local, and negligible to moderate, depending on the project.

4.3.3.2 Alternative 1

Under Alternative 1, the elimination of current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would have no impacts on terrestrial habitats and biota due to the locations of those activities in the marine environment.

Monitoring, mapping, and research. Potential adverse impacts and benefits to terrestrial habitats and biota would be the same as described for the No Action Alternative. Adverse impacts to wetlands and floodplains would be direct, short-term, local, and negligible to minor. Potential benefits would be indirect, long-term, local to large scale, and negligible to moderate, primarily due to information available to support water quality and sediment management efforts focused on stormwater runoff, as described for the No Action Alternative.

Watershed restoration and management. Potential adverse impacts and benefits to terrestrial habitats and biota would be the same as described for the No Action Alternative. Adverse impacts to wetlands and floodplains would be direct, short-term, local, and negligible to minor. Benefits would be direct and indirect, short-term and long-term, local, and negligible to moderate, depending on the project.

4.3.3.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP. Implementation of DCMMs alone would have no adverse impacts to wetlands and floodplains. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated. DCMMs may require the use of only native or naturalized vegetation, reductions in pesticides, and avoiding planting during storms. The addition of these would not be expected to result in adverse impacts to wetlands and floodplains.

DCMMs related to activities in the watershed are focused on reducing water quality degradation and stormwater runoff. Additional DCMMs may provide further, but likely negligible, benefits to wetlands and floodplains when compared with the No Action Alternative.

4.3.4 Water Quality

Water quality is an issue for coral reefs around the world (Wear and Thurber, 2015). Nonpoint source runoff from agricultural, transportation, urban development, and urban sources and point source discharges, such as domestic and industrial wastewater discharges, are well known to affect local water quality. Effective pollutant reduction, typically at a local level, is critical to reducing these problems (NAS, 2019). The U.S. EPA (2019) reports sediments and nutrients from stormwater runoff and dredging for port development as concerns for Florida and Gulf of Mexico coral reefs. In 2010, the U.S. EPA increased funding to Pacific coral reef jurisdictions to a level comparable to the mainland to implement wastewater and drinking water infrastructure improvements in Guam, CNMI, and American Samoa (WWD, 2010).

4.3.4.1 No Action Alternative

CRCP activities that have the potential to impact water quality in U.S. coral reef jurisdictions include monitoring, research, sample collections, watershed restoration projects, coral restoration and intervention, and reduction in physical impacts to coral reefs (Table 2-1).

Monitoring, mapping, and research. Activities that disturb soils or sediments (see Section 4.3.1) also have the potential to introduce and transport sediments and other pollutants to downstream, coastal, and marine waters. Impacts to water quality from marine activities such as vessel use involved in monitoring, sampling, transport of biologic and geologic samples, and SCUBA and snorkeling activities associated with benthic and water quality sampling would be limited to the duration of the activity. The temporary nature of these impacts would not be expected to alter the water quality of coastal and marine waters. Geotechnical evaluations and water quality sampling prior to construction would have no impact on water quality. Adverse impacts would be small and related to disturbances from equipment, vehicles, vessels, and divers engaged in the activities, as described for sediments and soils (Section 4.3.1). Adverse impacts to water quality in the watershed would be direct, short-term, local, and negligible (small project or little to no disturbance in the watershed) to minor (larger projects). Adverse impacts to coastal and marine waters may occur due to resuspension of bottom sediments or inadvertent release of fuels, lubricants used on instruments, or sealing epoxies to reinforce a loose stake; however, they are expected to be direct, short-term, local, and negligible to minor adverse impacts to water quality (NCCOS EA, 2016 [Section 4.1.1]; NOAA, 2013 [Section 4.1.1]; CRED PEA 2010 [Sections 7.4 and 7.5]). Potential impacts to water quality from unintended fuel, lubricant, sewage and garbage spills, vessel operation, and other activities described here were also evaluated as part of the ONMS PEA 2018 and were found to have less than significant impacts on water quality (Section 4.1.1). Potential benefits to water quality would be indirect, long-term, local to large scale, and negligible for watershed monitoring (e.g., projects that sample water quality in a single stream reach) that captures data potentially critical to managing and improving water quality.

Coral restoration and intervention. Sediment disturbance and resuspension into the water column due to vessels and other in-water activities during coral restoration and intervention activities would have relatively small adverse impacts, as described for sediment impacts (Section 4.3.1.1), while the development of coral nursery areas would result in greater disturbance due to the areal extent and potential duration of activities. Coral reefs require good water quality but do not directly affect water quality because they are not filter feeders. However, coral reefs buffer shorelines and shoreline habitats from erosion and sedimentation due to storms and other events, and restoration of corals would support subsequent increases in local water quality due to stabilization of sediments and reduced scour and erosion. Adverse impacts to water quality would be direct, short-term, local, and range from negligible to minor impacts (NOAA RC PEIS 2015 [Section 4.5.2.6]; NOAA PDARP/PEIS 2016 [Section 6.4.11]) due to implementation of restoration activities. However, benefits to water quality from coral restoration and intervention would be direct, short-and long-term, local, and negligible to minor due to potential stabilization of sediments following completion of projects.

Watershed restoration and management. A nationwide assessment of streams in the U.S. found 42% of monitored stream segments in poor condition, primarily due to nitrogen, phosphorus, streambed sediments, and riparian disturbance (Paulsen et al., 2008). The poor conditions were attributable primarily to watershed development that results in changes in channel morphology, water quantity, and water quality (Richardson et al., 2011). Under the No Action Alternative, watershed activities, such as road stabilization, stormwater ponds, revegetation projects, and constructed wetlands projects, would be implemented to reduce the delivery of pollutants into nearshore waters where coral reefs are present. Potential impacts to water quality from these or similar activities were analyzed previously as part of the NOAA RC PEIS 2015 (Section 4.5.2.6) and the NOAA PDARP/PEIS 2016 (Section 6.4.1) and adverse impacts were not found to be significant.

The construction of some watershed restoration projects may alter drainage patterns. For most runoff scenarios, BMPs would be used to reduce the runoff of sediments and other pollutants into downstream waters during construction and initial implementation. Construction activities have the potential for fuel leaks or other hazardous materials spills, and response measures would be taken to avoid spills and/or clean up after a spill to avoid hazardous materials seeping into the groundwater and/or flowing into downstream waters. BMPs such as silt fences, vegetation planting, temporarily stopping work during rain and approaching rain, and other BMPs (Appendix A) would reduce potential runoff from construction activities into downstream and coastal waters. Adverse impacts to water quality in the watershed from these activities would be direct, short-term, local, and negligible to minor.

Adverse impacts to coastal and marine water quality are expected to be direct, short-term, local, and negligible to minor. Sediment from the watershed is primarily deposited in nearshore areas and subsequently resuspended by tide and wind events (Bartley et al., 2014), affecting nearshore water quality (Fabricius et al., 2014). Benefits of watershed restoration and management activities include reduced introduction of sediments, nutrients, and other pollutants into coastal waters due to reduced nonpoint source runoff and river discharges. Benefits to water quality from watershed restoration and management activities are anticipated to be direct and indirect, long-term, local, and negligible (e.g., a baffle box to capture debris from a single building) to moderate (e.g., a wetland treatment pond to capture and passively treat runoff from an entire basin) as a result of reduced pollutant loading to coastal and marine waters. These benefits would be important to improving the overall water quality by reducing nonpoint source runoff to coastal and marine environments.

Reducing the amount of sediment and other pollutants added to downstream and coastal waters will not alter the legacy accumulations of sediments and other pollutants from point and nonpoint sources that have already accumulated and may continue to adversely impact water quality in coastal and marine waters. For example, Van Meter et al. (2018) demonstrated that even with no additional agricultural nitrogen loadings to the Gulf of Mexico, it would be decades before nitrogen reduction goals were reached in the Gulf because of the historic nitrogen loadings from the Mississippi River basin. Lags in water quality improvements may range from months to years for shorter-lived contaminants such as bacteria, and years to decades for excessive phosphorus levels in agricultural soils, and decades or more for sediment accumulated in river systems (Meals et al., 2010). The time delay between implementation of projects and measurable improvements in water quality may also delay the detection of improvements in water quality for years or even decades. Groundwater travel time may also delay detection of the benefits of agricultural BMPs on water quality. Furthermore, contamination from degraded microplastics may travel also in the water column or accumulate in sediments.

Consequently, impacts of watershed project activities, while beneficial, are likely to be indirect and benefits are expected to accrue over the long-term rather than the short-term.

Reducing physical impacts to coral reef ecosystems. Permanent mooring buoys would reduce the number of temporary anchorings and, therefore, the potential for entry of sediments and sediment-bound contaminants into the water column, resulting in improved water clarity and quality. Potential adverse impacts to water quality during mooring buoy installation may occur due to sediment disturbance and resuspension and would be direct, short-term, local, and negligible to minor. Potential benefits of permanent mooring buoys, which would vary by location, would be direct and indirect, short- and long-term, local, and negligible to minor, depending on the level of activity (i.e., number of boaters) in an area and the number of boaters using mooring buoys rather than anchoring in areas where they may contact and/or physically injure coral reefs or other habitats.

Water quality can also be impacted by the removal, remobilization, and transport of debris. Creosote from pilings, fuel from abandoned vessels, chemicals from appliances, and other solid waste may be released or spread into the aquatic environment through removal activities. BMPs would minimize sediment disturbance, total suspended solids in the water column, and potential fuel releases. Removal of marine debris would directly reduce the physical impacts of the debris, as well as the potential contamination from fuel, microplastic contaminants, and other associated pollutants, as described in Section 4.3.1.1 and presented in Section 5.2.1 of the MDP PEA 2015. Potential adverse impacts of installing mooring buoys and removing debris would be expected to be direct, short-term, local, and negligible to minor. Significant adverse impacts to water quality are not anticipated (MDP PEA, 2015). Potential benefits of these activities on water quality would be direct and indirect, short- and long-term, local, and negligible to minor, depending on the amount and location of the debris being removed.

4.3.4.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals (Table 2-1) would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to water quality from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Eliminating coral restoration and intervention activities would result in the continued decline and loss of coral reefs and associated habitats (e.g., seagrasses, mangroves, and shorelines) and potential increases in resuspension of sediments into the water column that were formerly stabilized by the coral reef structure. Elimination of coral restoration and intervention activities would not significantly affect water quality, given the negligible to minor adverse impacts of these activities on water quality described for the No Action Alternative. Potential adverse impacts to water quality not in the absence of these activities.

Watershed restoration and management. Potential adverse impacts and benefits to water quality would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Elimination of coral restoration activities, including installation of mooring buoys and debris removal, would not significantly affect water quality based on the negligible to minor impacts of these activities on water quality described for the No Action Alternative. Potential impacts to water quality due to these activities are primarily due to the potential introduction of sediments and sediment-bound contaminants (Section 4.3.1.1) into the water column. Increased and multiple anchorings, corresponding increases in disturbed sediments and resuspension of sediments, and continued accumulation and persistence of debris on the seafloor would, therefore, have potential adverse impacts on the water column. Potential adverse impacts to water quality from continued anchoring, debris accumulation, and other damage would be direct, short- and long-term, local, and negligible to minor. No benefits to water quality are anticipated.

Adverse impacts to water quality under this alternative would be direct and indirect, short- and long-term, local, and negligible to minor due to continued resuspension of sediments and sediment-bound pollutants from anchoring and accumulation of marine debris, as described for sediments in Section 4.3.1.1. Benefits of monitoring, mapping, and research would continue to provide information critical to water quality improvement and management. Watershed restoration and management activities would continue to improve water quality. The overall benefits to water quality may be negligibly reduced by eliminating debris removal activities. Potential benefits to sediments would be direct, short- to long-term, local, and negligible to moderate.

4.3.4.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs already implemented under the No Action Alternative. Implementation of DCMMs alone would have no adverse impacts to water quality. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

DCMMs may include increasing the capacity for greater supervision over dive activities, BMPs to control turbidity and sediment, greater restrictions on instrument mooring, prioritizing the use of recreational mooring buoys or live boating, additional training to vessel operators, and stopping restoration work during or when a storm is approaching and during coral spawning periods. Additional reductions in sediment resuspension during in-water activities, stormwater runoff from the watershed, and turbidity and sediments during, for example, debris removal, as a result of additional DCMMs may provide further, but likely negligible, benefits to water quality when compared with the No Action Alternative. Potential benefits to water quality would be similar to, but negligibly greater than, those described under the No Action Alternative.

4.4 Biological Environment

4.4.1 Seagrasses

Distribution patterns of seagrass meadows are influenced by physical (waves, tides, light availability, etc.), geological (sediment grain size), and geochemical factors (Koch, 2001). Turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) are the most common seagrasses in tropical waters off the coast of Florida and throughout the Caribbean and the Gulf of Mexico. Shoal grass (*Halodule wrightii*) is another seagrass common to the tropical Atlantic, but its distribution also includes Africa, the Indian Ocean, and the west coast of Mexico. Seven species of seagrasses are associated with clear waters and shallow reefs in the Atlantic, while the tropical Indo-Pacific has as many as fourteen species occurring together on reef flats and in deeper waters (Short et al., 2007). Seagrasses are typically characterized by greater variability in environmental parameters when compared to coral reefs and may provide sites for coral colonization (Lohr et al., 2017). Although requirements vary among species, all depend on appropriate sediment, salinity, light, water clarity, and nutrient conditions. The CRCP activities alter these physical conditions or directly disturb or damage substrates would also have the potential to adverse impact seagrasses by reducing light availability to seagrasses. Some species are slower growing and less resistant to perturbation, such as among Pacific species including *Enhalus acoroides,* the ephemeral species *Halodule uninervis, H. ovali*, and *Cymodocea serrulata,* which may be associated with increased sediment accretion (Coles et al., 2011). Impacts presented here are consistent with those presented in the NOAA RC PEIS 2015 and NOAA PDARP/PEIS 2016. However, the CRCP activities could result in spreading of the invasive *Halophila stipulacea* under any alternative, which could be a potential long-term, minor adverse impact to coral reef and seagrass ecosystems.

Johnson's seagrass (*Halophila johnsonii*) is the only marine plant species listed under the ESA. This seagrass species occurs in coastal waters off the east coast of Florida. Johnson's seagrass is listed as threatened due to its limited geographic range and habitat loss. Johnson's seagrass is adversely impacted by boating activities, habitat degradation, storm action and sedimentation, poor water quality, and excessive algal growth.

4.4.1.1 No Action Alternative

Proposed CRCP activities that would potentially affect seagrasses include monitoring, research and sample collections, watershed restoration, coral restoration and intervention, and reductions in physical impacts to coral reefs (Table 2-1).

Monitoring, mapping, and research. Monitoring and research activities under the current CRCP may include stainless steel pin marker installation, moored sensor installation, SCUBA/snorkeling, sample collection, and vessel, ROV, and AUV use in (or in the vicinity of) seagrasses. These activities would result in minor sediment disturbance and resuspension into the water column and temporary, short-term reductions in water clarity and light availability (see Section 4.3.4) that would subside once activities were discontinued. Collection of seagrasses may occur, resulting in direct, short-term, minor, adverse loss of seagrasses because the seagrasses would grow back. Potential adverse impacts to seagrasses as a result of these activities would be direct, short-term, local, and negligible to minor (NOAA, 2013) (Sections 5.1.2-5.1.3). The CRED PEA 2010 (Section 3.3.2) concluded that these activities would have at most minor, temporary (short-term) impacts to benthic cover (e.g., seagrasses) associated with coral reefs in the U.S.-affiliated Pacific Islands. Similarly, potential impacts to seagrasses and other benthic habitats in the National Marine Sanctuaries in the U.S. southeast Atlantic and Gulf of Mexico were considered temporary and negligible to minor as a result of monitoring activities that included vessel and equipment use, deployment of equipment and monitoring buoys, and sampling activities (ONMS, 2018 [Section 4.1.1]). The similarity in our proposed activities and corresponding analyses to these previous studies support similar conclusions for the proposed activities. Under the proposed alternative, seagrasses are not directly monitored but may be included in benthic samples. Collection of sediment data would benefit seagrasses indirectly by supporting mapping that identifies sand bottom habitats safe for anchoring. Benefits would be indirect, long-term, local, and negligible to moderate benefits, based on the location and areal extent of seagrass beds with respect to the proposed activities.

Coral restoration and intervention. Equipment impacts associated with coral restoration and intervention would be the same as those described above for the No Action Alternative monitoring activities. Coral proposed activities, such as transplanting, invasive and nuisance algae control/removal, and urchin outplanting, that require crossing or traversing seagrasses would potentially result in physical damage to seagrasses proximate to coral reefs where work is being performed. However, there are minimal coral restoration project types that would require direct contact with seagrasses. Regular maintenance of moorings and the monitoring of surrounding seagrass are required to ensure that these moorings are operating effectively. BMPs would reduce damage to seagrass habitat through activities such as anchoring work vessels or preventing unintentional introduction of non-native species. Recovery of corals would eventually increase protection of seagrasses from ocean waves and storms. Overall, potential adverse impacts of coral reef restoration activities on seagrasses are expected to be direct, short-term, local, and minor due primarily to physical disturbance during in-water activities (NOAA RC PEIS, 2015[Section 4.5.2.6]; NOAA PDARP/PEIS, 2016c [Section 6.4.11]). Benefits to seagrasses from coral restoration include stabilized substrates and reduced erosion due to wave energy buffering effects of coral reefs. Benefits to seagrasses due to these activities are anticipated to be indirect, long-term, local, and negligible to moderate, depending on the extent of seagrasses and coral reefs to be affected.

Watershed restoration and management. Construction of watershed management projects such as culverts, baffle boxes, elevated boardwalks with pilings, and LID would disturb and/or remove soils due to staging and cleaning areas, workers, and possibly heavy equipment used to excavate or rearrange soils. These activities could result in the subsequent delivery of sediments and other pollutants to downstream waters during construction, which may reduce water quality and clarity and adversely impact seagrass health. Construction BMPs (Appendix A) would reduce the potential release of sediments and other pollutants from the project site, and introduction into coastal and marine waters is unlikely, depending on the distance between the project area and coastal waters. In addition, without watershed restoration and management activities, declines in seagrasses are anticipated in areas where high nutrient and sediment loads occur. The rate and extent of coastal development would not be affected by continued implementation of the CRCP under the No Action Alternative and direct adverse impacts to seagrasses due to dredging and filling, coastal development, land reclamation, dock and jetty construction, and some fisheries and aquaculture practices, would continue (Gregg et al., 2013). Implementation of these activities is expected to result in short-term erosion and sedimentation, and potential adverse impacts to seagrasses would be direct, short-term, local, and negligible.

Watershed restoration and management activities would reduce sediment and nutrient loads into coastal areas where seagrasses occur due to improved water clarity and light availability, as described for water quality (Section 4.3.4) and demonstrated for several projects. For example, regional-scale agricultural runoff from the mainland Everglades and local sewage discharges from the Florida Keys are significant nitrogen inputs that contribute to eutrophication and algal blooms in seagrass and coral reef communities in the Lower Florida Keys (Lapointe et al., 2004). Reduced stormwater runoff and freshwater flows would potentially reduce scour and erosion and shift the saltwater-freshwater interface. In Tampa Bay, Florida, point-source nutrient reductions over the past two decades reduced total nitrogen loads and water clarity by 50% and were followed by a recovery of 27 km^2 (17mi^2) of seagrasses since 1982 (Tomasko et al., 2018). Benefits to seagrasses as a result of improved water quality are anticipated to be indirect, long-term, local, and negligible to moderate.

Reducing physical impacts to coral reef ecosystems. Construction and installation of mooring buoys and removal of debris would disturb sediments and cause temporary sediment plumes and increases in turbidity; however, effects have been found to be negligible (see Section 4.3.1). During installation of mooring buoys, temporary adverse impacts to adjacent seagrasses may occur due to sediment resuspension that may occur due to installation activities and resulting sediment disturbances. Impacts may also occur due to more visitors, who may be attracted to an area due to the presence of mooring buoys, and subsequent vessel activity. Mooring buoys would not be placed in seagrass so that direct physical damage from mooring buoys would be avoided.

Permanent mooring buoys would reduce the numbers of temporary anchorings and reduce the damage due to anchors and chains that are dropped into seagrasses and/or chains that scrape the seafloor as they are moved by tides, currents, and wind (Morrisey et al., 2018), thereby reducing potential future impacts to seagrasses. The NPS EIS 2015 concluded that the installation of mooring buoys and volunteer debris cleanups would result in short-term, local, minor, and adverse impacts to submerged substrates. Disturbance at a debris removal restoration site would occur during the debris removal process, generally several minutes to a few hours, but larger items may take potentially longer. Human and equipment access to a site for debris removal may cause minor damage to habitat and species through trampling, sound, displacement, and unintentional introduction of invasive species. BMPs for vehicle staging, fuel storage, erosion and pollutions control, and species decontamination would be used to minimize impacts of construction-related impacts to seagrasses (Section 4.4.1).

Potential adverse impacts to seagrass habitat would be direct, short-term, local, and negligible to minor. Benefits to seagrasses from installation of permanent mooring buoys and removal of debris would include restored habitat, reduced potential for contamination, and reduced disturbance due to potential debris movement, resulting in potential direct and indirect, long-term, local, and negligible to moderate benefits due to the potential for sea floor, and therefore seagrass bed, stabilization.

4.4.1.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to seagrasses from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Eliminating coral restoration and intervention activities would eliminate potential disturbances due to coral nursery development, transplanting, urchin propagation, invasive and nuisance algae control, and corallivore and disease control that may also impact proximate seagrass habitat. However, the potential reduction in adverse impacts to seagrasses, like the potential impacts themselves, would be negligible. Benefits to seagrasses from the potential recovery of corals, such as stabilized sediments and protection from high energy waves and erosion, would not occur under this Alternative. Potential adverse impacts to seagrasses would be direct, long-term, local, and negligible to moderate. No benefits to seagrasses are expected.

Watershed restoration and management. Potential adverse impacts and benefits to seagrasses would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Under this alternative, sediment disturbances from continued and future anchoring would result in further damage and loss of seagrasses due to direct impacts from anchors, especially in areas with more development and/or high visitor use that would be more vulnerable to potential impacts of vessel anchoring. Corresponding sediment disturbances and resuspensions (described in Sections 4.3.1 and 4.3.4) that reduce water clarity and light availability to seagrasses, potentially leading to indirect damage and mortality among seagrasses, would also continue. Eliminating this portion of the CRCP would not affect debris removal that occurs under NOAA's extensive Marine Debris Program. However, for areas where debris removal does not occur, debris such as derelict fishing gear and vessels would remain on the seafloor, and the potential for continued physical damage to seagrasses from debris, as well as indirect loss due to degraded water quality and sediments from accumulated marine debris, would also persist. Potential adverse impacts to seagrasses from continued damage due to anchoring and debris accumulation would be direct, short- and long-term, local, and negligible to moderate. No benefits to seagrasses are anticipated as a result of eliminating the installation of permanent mooring buoys and debris removal since anchoring may still occur in seagrass beds in areas where mooring buoys are not present.

Potential adverse impacts to seagrasses under this alternative would be direct, short- and long-term, local, and negligible to moderate due to continued damage from anchoring and accumulation of marine debris. Monitoring, mapping, and research activities would continue to provide information critical to conservation and management of seagrasses. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters and therefore benefit seagrasses. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address impacts of anchoring and marine debris and coral reef restoration in coastal and marine waters. Therefore, overall potential benefits to seagrasses would be direct, short- to long-term, local, and negligible to minor.

4.4.1.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs under the current CRCP. Implementation of DCMMs alone would have no adverse impacts to seagrasses. Adverse impacts under Alternative 2 would be the same as those for the No Action Alternative but may have additional, negligible reductions as a result of DCMMs, depending on the activity.

DCMMs may include increasing the capacity for greater supervision over dive activities, BMPs to control turbidity and sediment, greater restrictions on instrument mooring, prioritizing the use of recreational mooring buoys or live boating, additional training to vessel operators, and stopping restoration work during or when a storm is approaching and during coral spawning periods. These activities would further reduce physical disturbance of soils and sediments in the watershed and in coastal and marine waters and, therefore, reduce the potential for impacts to seagrasses from reduced water quality. Additional reductions in sediment resuspension during in-water activities, stormwater runoff from the watershed, and turbidity and sediments during, for example, debris removal, as a result of additional DCMMs may provide further, but likely negligible, benefits to seagrasses when compared with the No Action Alternative. Potential benefits to seagrasses would be similar to, but negligibly greater than, those described under the No Action Alternative.

4.4.2 Mangroves

Mangroves are affected by freshwater inputs, water chemistry and salinity, sedimentation, and competition from other species such as saltmarsh cordgrass (*Spartina alterniflora*). Along shorelines, mangroves stabilize coastal sediments and habitats during non-storm conditions, while live corals and seagrasses buffer the impacts of storms (Guannel et al., 2016).

Mangroves are important habitat in their native areas of distribution but are considered an invasive species in Hawaii where their introduction (circa 1912) adversely impacts habitat quality for water birds, cultural sites, and biological communities (DLNR, 2013). Other adverse impacts of invasive mangroves in Hawaii include colonization by introduced barnacles and other nonnative macrofauna (Demopolous and Smith, 2010); altered coastal hydrodynamics, nearshore sedimentation, and benthic community structure; and mangroves have replaced native habitats that support wetland birds, including the endemic Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica americana alai*) and Hawaiian duck (*Anas wyvilliana*). Potential impacts to mangroves are presented for the analysis of consequences for both watershed and coastal and marine activities due to their location at the interface of land and coastal waters. Potential adverse and beneficial impacts to mangroves are described here and are consistent with those described in NOAA RC PEIS 2015 and NOAA PDARP/PEIS 2016.

4.4.2.1 No Action Alternative

Proposed CRCP activities analyzed for potential impacts to mangroves under the No Action Alternative include monitoring, research and sample collections, watershed restoration, coral restoration and intervention, and activities to reduce physical impacts to corals (i.e., permanent boat mooring installation, and marine debris removal activities [Table 2-1]). Mangroves are considered native unless identified as invasive.

Monitoring, mapping, and research. Mangroves are not typically monitored as part of the CRCP**.** However, monitoring, mapping, and research activities that occur in mangroves would have impacts similar to those described for soils and sediments (Section 4.3.1) due to small disturbances during activities such as diving/snorkeling, placement and retrieval of oceanographic instruments, sediment traps, or traps for collecting fish and invertebrates and associated disturbances of anchoring to sites that require boat access. Sediment sampling within mangroves may occur and therefore would temporarily disturb sediments in which mangroves grow. However, sampling would be limited in terms of numbers and volume of sediment and no adverse impacts to mangroves would be expected. Adverse impacts to sediments and soils, and thus mangroves, from these activities have been determined to be direct, short-term, localized, and negligible to minor, and not significant as a result of these activities. Benefits to mangroves from monitoring, mapping, and research activities include increased acquisition of data critical to management decisions regarding long-term conservation of these systems and would be indirect, long-term, local, and negligible to minor.

Coral restoration and intervention. Coral reef restoration activities would occur seaward of mangrove forests, and vessel, SCUBA, and other in-water activities may result in negligible increases in wave energy due to vessel activity, but exposure would be no greater than fishing and other vessels that already occur nearby and no additional impacts are expected. Therefore, no adverse impacts to mangroves from coral restoration and intervention activities are anticipated. Potential benefits to mangroves from coral reef restoration include increased stabilization of coastal sediments and corals, reduced wave energy landward of coral reefs, and reduced potential for erosion of mangroves. For example, mangroves are buffered from storm impacts by coral reefs, while mangroves have been shown to intercept and reduce the sediment load to fringing reefs by 30% (e.g., Palau) (Victor et al., 2004). In Hawaii, the buffering effect of coral reefs protects invasive mangroves. While loss of coral reefs would potentially increase erosional stress on the invasive species, it would also adversely impact native shoreline species. Mangroves were absent from Hawaii due to geographic isolation, not wave energy, and their decline in the islands from erosion is unlikely. Potential benefits to mangroves due to erosion protection from sustained and/or recovered coral reefs would be direct and indirect, short- and long-term, local, and negligible to minor.

Watershed restoration and management. In addition to small projects such as erosion control berms or swales, stormwater treatment wetlands may be constructed as part of the CRCP and may be vegetated as a marsh, mangrove, or other type of wetland, to collect and passively treat runoff from the watershed. However, these wetlands would not be constructed within a mangrove (or other wetland). Impacts to mangroves would most likely result from upstream activities that deposit sediment and other pollutant loads downstream, as described previously (Section 4.3.4). BMPs to reduce runoff from construction areas (Appendix A) would further reduce the potential for adverse impacts to mangroves (including invasive mangroves). Potential adverse impacts would be expected to be indirect, short-term, local, and negligible to minor due to the distance over which the runoff would have to be conveyed to have impacts.

Without the proposed activities, mangroves would be likely to continue to be adversely impacted by sediment and other pollutants from uncontrolled stormwater runoff. Mangroves can be damaged by fine sediments that cover prop roots, excessive nutrient loading, and/or inundation for long periods (Gregg & Karazsia, 2013). Mangrove roots can become buried from sediment in watershed runoff, resulting in reduced root and soil gas exchange, altered biogeochemical cycles, reduced microbenthic diversity, and adverse impacts to adjacent reef fisheries and other habitats (Ellis et al., 2004; Caugati et al., 2018). Sedimentation rates in unimpacted mangroves range from less than 5 mm/year (0.2 in/year) to approximately 10 mm/year (0.4 in/year) (Ellison, 1998), and within a tolerable range of elevations, new plants can survive and expand with the sedimentation. However, long periods of root inundation can also result in mangrove death due to lack of oxygen. Watershed restoration that reduces erosion and stormwater runoff would detain or redirect stormwater across/through swales, rain gardens, restored and planted landscapes, further reducing the potential for downstream sediment and other pollutant loads that may otherwise result in burial and/or contamination of coastal areas where mangroves occur. Overall, benefits to mangroves (including invasive mangroves) are expected to be direct and indirect, long-term, local and larger scale, and negligible to moderate.

Reducing physical impacts to coral reef ecosystems. Vessel activities associated with the installation of mooring buoys and debris removal in proximity to mangroves may result in temporary turbidity plumes, increased turbidity and wave action, and potential erosion of mangrove habitat, as well as possible inadvertent fuel or chemical spills or leaks. However, mangrove communities frequently absorb and dissipate wave energy from storm events greater than that anticipated from vessel activities. Increased mooring buoys may attract more visitors to areas where mangroves are present and result in physical impacts of vessels with mangroves. BMPs to reduce disturbance during these activities are included in the CRCP and would minimize potential erosion and accidental fuel spills by implementing BMPs. Potential adverse impacts to mangroves on the seaward side of the coast would be direct, short-term, local, and negligible to minor. Reducing the number of anchorings and the amount of accumulated marine debris would reduce the potential for adverse impacts to mangroves from physical disturbance of anchoring and marine debris and the potential for contamination (NPS EIS, 2015 [Section 5.1]; MDP PEA, 2013 [Section 5.2.3]). Restored coral reefs would benefit mangroves by reducing the adverse impacts of storm-related waves and erosion to mangroves. Benefits to mangroves would be direct and indirect, short- and long-term, local, and negligible to minor depending on proximity to coral reef projects.

4.4.2.2 Alternative 1

Under Alternative 1, the current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to mangroves from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Eliminating coral restoration and intervention activities would result in declines in coral reefs and coral reef recovery (Section 4.4.3) and would subsequently affect coastal mangrove communities. Potential impacts to mangroves would include increasing erosion and scour associated with reduction in the buffering of wave energy that occurs due to coral reefs (Section 4.4.3). Potential adverse impacts to mangroves would be indirect, long-term, local, and negligible to moderate. No benefits to mangroves are expected as a result of excluding these activities.

Watershed restoration and management. Potential adverse impacts and benefits to mangroves would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Excluding the installation of permanent mooring buoys would result in continued multiple anchoring and subsequent physical damage to habitats in which the anchors are dropped. In addition to physical impacts, multiple anchoring would result in resuspension of sediments and possibly sediment-bound contaminants into the water column and/or into coastal habitats such as mangroves (NPS EIS, 2015; MDP PEA, 2013). In the absence of their removal, derelict fishing gear, vessels, and other debris would continue to accumulate in mangroves, resulting in subsequent physical disturbance and potential contamination due to fuels or other pollutants (see Section 4.4). Eliminating this portion of the CRCP would not affect debris removal that occurs under NOAA's Marine Debris Program. However, without the installation of additional mooring buoys, chronic anchor damage to coral reefs, especially in highly visited areas, would not be addressed and further damage to the reef as debris such as vessels rock or are dragged across the sea floor due to wave or wind energy. Potential adverse impacts would be direct, short- to long-term, local, and negligible to minor. No benefits to mangroves would be expected.

Overall, the reduction in CRCP activities under Alternative 1 would be expected to have direct and indirect, long-term, local, and negligible to moderate adverse impacts to mangroves due to physical disturbance, damage, and/or contamination from existing and future erosion, sediment deposition, and persistent and accumulating marine debris. Monitoring, mapping, and research activities would continue to provide information critical to conservation and management of corals. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters and benefit corals and associated benthos. However, the overall benefits of watershed restoration and monitoring, mapping, and research would be reduced due to the exclusion of the components of the CRCP that directly address the impacts of anchoring and debris removal on coral reefs and associated habitats. Therefore, overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.4.2.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs under the current CRCP. Implementation of DCMMs alone would have no adverse impacts on mangroves. Adverse impacts under Alternative 2 would be the same as those for the No Action Alternative but additional, negligible reductions in impacts as a result of DCMMs are anticipated.

DCMMs may include increasing the capacity for greater supervision over dive activities, BMPs to control turbidity and sediment, greater restrictions on instrument mooring, prioritizing the use of recreational mooring buoys or live boating, additional training to vessel operators, and stopping restoration work during or when a storm is approaching and during coral spawning periods. These activities would further reduce physical disturbance of soils and sediments in the watershed and in coastal and marine waters and, therefore, reduce the potential for impacts to mangroves from reduced water quality. Additional reductions in sediment resuspension during in-water activities, stormwater runoff from the watershed, and turbidity and sediments during, for example, debris removal, as a result of additional DCMMs may provide further, but likely negligible, benefits to mangroves when compared with the No Action Alternative. Potential benefits to mangroves would be similar to, but negligibly greater than, those described under the No Action Alternative.

4.4.3 Corals and Associated Invertebrates and Algae

Coral reef ecosystems include hard corals (scleractinians) as the primary reef-building corals, soft corals, algae, sponges and invertebrates, which in turn support numerous fish species. Invertebrate fauna associated with coral reefs include anthozoans such as sea anemones, mollusks such as giant clams and snails, echinoderms such as sea cucumbers, urchins, and the crown-of-thorns seastar (*Acanthaster planci*), and calcareans (sponges). Large, fleshy macroalgae colonize any uncolonized external portions of the reef and are grazed upon by herbivorous fish, which are in turn preyed upon by larger, predatory fish species. The reef matrix, formed from skeletal remains of organisms, supports a diverse community of organisms collectively known as cryptobiota. The number of invertebrate species that live in or around coral reefs is estimated to range from one to eight million (Reaka-Kudla, 1997). Consequently, activities that may impact corals or coral reefs may influence numerous other organisms.

Macroalgae are conspicuous and naturally occurring on coral reefs and can provide shade to other sessile organisms and reduce bleaching impacts (Ceccarelli et al., 2018). However, high nutrients and turbidity, reduced grazing, and episodic disturbances such as hurricanes can shift reefs to dominance by macroalgae at the expense of corals. Low macroalgae cover appears necessary for coral propagule colonization and subsequent recovery of coral following large disturbances such as hurricanes or coral bleaching (Holbrook et al., 2016). On healthy oligotrophic coral reefs, even very low nutrient increases may shift relative dominance from corals to macroalgae (Holbrook et al., 2016).

Loss of corals is attributed to the global threat of climate change impacts including increased water temperatures, ocean acidification, increased frequency and intensity of coastal storms, sea level rise, and localized threats such as increased sedimentation, altered water quality, and increased coral disease and predation. Of the 25 coral species protected under the ESA (79 FR 53851, 79 FR 53851, and 80 FR 60560), 15 occur in the Indo-Pacific and seven in the Caribbean (no listed corals are presently known in Hawaii). Three corals are listed as endangered, which are not found in U.S. waters, and the remaining are listed as threatened. NMFS has designated critical habitat for staghorn coral (*Acropora cervicornis*) and elkhorn (*A. palmata*) (73 FR 72209), which includes water depths from the mean high water line to 30 m, to support successful larval settlement, recruitment, and reattachment of fragments around southern Florida, Puerto Rico, and the USVI. In 2015, NMFS released a recovery plan for elkhorn coral and staghorn coral (NOAA, 2015b), which includes several measures to increase abundance and protect genetic diversity while abating threats to corals, including research on coral biology (e.g., reproduction and recruitment, genetics, cellular processes, and host-symbiont relationships) increasing monitoring of disease and bleaching events, reducing local impacts of temperature stress (e.g., shading of reefs, pumping cooler waters onto reefs), researching the viability of land-based rearing and wild re-stocking of species, and testing approaches to culture resistant and/or resilient strains of corals (e.g., disease or biotoxin resistance, thermal or pH tolerance) (NOAA 2015b).

The NMFS provides the current list of corals listed as threatened or endangered under the ESA and their critical habitat. A list of the ESA-listed coral species are in Chapter 3, Section 3.4.2. Because corals are the focus of the CRCP and ESA-listed corals may be impacted by some of the proposed activities, impacts to ESA-listed corals are considered in this section. In parallel with the preparation of this DPEIS, the CRCP has initiated formal consultation with NMFS Office of Protected Resources Interagency Coordination Division.

4.4.3.1 No Action Alternative

Proposed CRCP activities analyzed for potential impacts to coral and associated invertebrates and algae under the No Action Alternative include monitoring, research and sample collections, watershed restoration, coral restoration and intervention, and activities to reduce physical impacts to coral reef ecosystems (Table 2-1).

Monitoring, mapping, and research. Adverse impacts to corals and associated invertebrates and algae may occur due to activities associated with monitoring, mapping, and research. The NOAA evaluated the impacts to corals, algae, fish, and invertebrates from monitoring, establishment of permanent transect markers, collection of coral samples and gametes, collection of reef fishes, towed diver surveys, algae collection, and mooring instruments to the seafloor concluded in the *Summary of Environmental Consequences* (CRED PEA 2010). These activities would result in "increased understanding of the science of fragile coral reefs and their ecosystems that will aid in the management of these important resources" and "Negative consequences, if any, are expected to be minimal with temporary impacts associated with field research (e.g., sample collection) and monitoring programs (e.g., installation of long-term markers)." The ONMS PEA 2018 also presented an analysis of these same and similar monitoring, mapping, and research activities on marine resources, including coral reefs, and concluded that no significant adverse impacts would be expected as a result of these activities (Section 4.1.2). Monitoring or research may result in direct contact with corals (e.g., transect tapes and calipers may have temporary contact with corals) or other reef-associated organisms or an activity may involve a direct take of coral cores, fragments, or gametes, or other invertebrates or algae.

Direct coral sampling, collection of cores or fragments, is expected to have temporary effects on colony biomass as corals can recover through skeleton and tissue replacement and/or colony growth; however, recovery varies by coral species, and lesion size and shape (NMFS 2011, Bak and Steward-Van Es 1980, Meesters et al., 1997, and Oren et al. 1997). Alizarin Red S could cause stress due to long exposures (over eight hours) and high concentrations (over 10 ppm [10 mg/L]) (Dodge, 1984; Lamberts, 1973). CRCP BMPs require that coral sampling for research take less than 20% of a colony unless it can be determined that larger amount will not negatively impact the survival of the coral or impact the local population of that species. Typically, most coral sampling for research is less than 20% and is closer to 5% or less of colony. Gamete collection is not likely to affect coral populations given the low recruitment success and the low percentage of gametes collected compared to total amount released in a spawning event (NOAA, 2009). Direct sampling may also include the collection of fragments or whole specimens of invertebrates or algae. As with hard corals, the collection of fragments or samples from certain invertebrates (e.g., soft corals or sponges) and algae is expected to have temporary effects on biomass, as these species can regenerate. For some activities, the collection of invertebrate or algal specimens may be required; however, the taking of a limited number of specimens is not expected to impact any population levels. Adverse impacts to corals and associated invertebrates and algae would be direct, short-term, local, and negligible to moderate. Temporary-to-short-term, minor, adverse effects may occur to ESA-listed corals and critical habitat due to localized disturbance and resuspended sediments from divers, installation of permanent transect makers, or by the placement of instruments on the seafloor. To the extent that adverse effects to ESA-listed coral species will rise to the level of take, avoidance and minimization measures developed through formal Section 7 consultations will be implemented. In addition, vessels typically anchor in areas with documented absence of coral reefs or in areas known to be devoid of corals, use mooring buoys, or avoid anchoring (live boating, manned vessel). Thus, negligible impacts to corals or associated invertebrates and algae from surveying or mapping vessels are anticipated. Potential adverse impacts to corals and associated invertebrates and algae from vessel transit, acoustic mapping, anchoring, AUVs, and other activities associated with monitoring, mapping, and research would be direct, short-term, local, and negligible to minor (NOAA, 2013 [Section 5.1]).

Benefits to coral and associated invertebrates and algae from these activities include acquisition of data and information on coral reef ecosystems and endangered and threatened coral species, which is critical to their recovery and conservation. Benefits of monitoring, mapping, and research activities include the collection of data that would support future management of coral reef ecosystems and would therefore be indirect, long-term, local to large scale, and negligible (some coral reefs may not be monitored) to major (due to the value of the data for management and conservation efforts of corals and associated invertebrates and algae), as described above.

Coral restoration and interventions. The CRCP supports on-the-ground restoration actions and research on intervention techniques (e.g., stress hardening and assisted gene flow) to support the creation of resilient, genetically diverse, and reproductively viable populations of key coral species. These intervention techniques are expected to facilitate the adaptation of coral reef ecosystems to evolving environmental conditions. Temporary, minor adverse effects of coral proposed activities themselves may occur due to disturbance and resuspended sediments, physical contact with corals, dispersion of adhesives used to plug the clipped coral or transplant injured corals onto the reef (although adhesives used in coral restoration are designed to have minimal dispersion and impact to the area), and other related activities. The National Academy of Sciences recently prepared a review of coral interventions (NAS, 2019) that evaluates genetic and reproductive, physiological, population and community, and environmental interventions with respect to coral reef persistence and resilience. The report provides evaluations, including methods, benefits, and potential risks, of the interventions. Many of the potential impacts described here are based on those presented in the report. Current restoration methods are not considered adequate to be “effective at larger scales needed to halt or reverse the decline in reef coral communities” (dela Cruz & Harrison, 2017). However, methods are continuously evolving and are needed to slow decline while adequate methods are developed.

The NOAA RC PEIS 2015 evaluated potential impacts to coral reefs as a result of 26 proposed restoration approaches throughout NOAA’s jurisdictions. Many of the same restoration techniques evaluated in the NOAA RC PEIS 2015 are included in this DPEIS.

- Propagating a genetically and species-rich collection of coral fragments in nurseries, with an emphasis on threatened and endangered species.
- Transplanting (outplanting) coral fragments from nursery or an impacted location to appropriate targeted locations.
- Managing invasive species (invasive fish and algae) through removal and appropriate maintenance techniques (e.g., release of natural predators such as urchins or continued removal). For example, removal of invasive macroalgae by mechanical means (e.g., vacuum), followed by control with sea urchins has been successful at controlling algae in Kāne‘ohe Bay, Hawaii (Neilson et al., 2018). This also includes the removal of nuisance species, such as corallivores, algae, or octocorals, to reduce predation on corals or to improve habitat quality.
- Re-attaching or moving broken corals or stabilizing rubble substrates in areas impacted by events such as vessel groundings or storms, sometimes in conjunction with proactively relocating corals to more appropriate locations, which may include a coral nursery.
- Improving infrastructure such as mooring buoys, navigation aids, or enhancements to piloting or salvage operational capabilities to prevent vessel groundings in coral habitats (discussed under activities for reducing physical impacts to corals).

Stress hardening may be more likely under some conditions than others and can weaken the coral rather than strengthening it, possibly due to the over-expenditure of energy needed to respond (NAS, 2019). This approach is limited by the ability to scale up the restoration in space and time and is more likely to persist under the conditions the coral was exposed to for the stress-hardening.

Transplanting wild coral fragments onto natural reefs and outplanting nursery grown corals into restoration areas are used for mitigating or enhancing damaged or depleted coral populations (see Young et al., 2012 for a review of restoration of the threatened *Acropora* corals in the Caribbean).

Removal of nuisance species would result in death of those specimens but would not have any adverse effects at the population level. Instead, their removal, along with the removal of invasive species, would benefit the coral reef ecosystem.

Risks of managed relocations include the introduction of nonnative pathogens, parasites, algae, microbes, commensal invertebrates, and corallivores (e.g., gastropods) that might overwhelm local controls on their abundance and the translocated type itself might become “invasive” or predominant if it is released from the pressure of a natural enemy or predator. Potential risks of transplanting coral also include damage to donor and recipient corals, loss of genetic diversity, and the introduction of disease and/or invasive species to recipient sites (dela Cruz & Harrison, 2017). However, recent studies (Zayasu et al., 2018) indicate that nursery grown *Acropora tenuis* have the same genetics as corals in the surrounding natural area, and restoration using farmed coral may be preferable to transplanting of wild colonies to avoid damaging donor corals. Nursery-grown corals grow quickly, do not damage donor and recipient corals, and the possibility of disease transmission and introduction of nonnative species are lower than for wild transplants, making them preferable for coral propagation and ecological reef restoration in the Caribbean and Western Atlantic (Young et al., 2012). Afiq-Roslia et al. (2017) documented three to five times faster growth in nursery-raised corals of *Pachyseris speciosa* and *Pocillopora damicornis* when compared with direct wild colony transplants. Young et al. (2012) report that fragment survival of transplants ranged between 43% and 95% during the first year, with increases in biomass of up to 250% for transplanted *Acropora* spp. Young et al. (2012) also reported on some studies that found more than 50% fragment mortality within the first year, typically due to fragment dislodgement or storm damage, and mortality often increased to 80-100% after five years. Monitoring is crucial to knowing what will be successful, however, and only two Caribbean studies of *Acropora* spp. transplantation and fragment stabilization have monitoring data over more than 10 years (Young et al., 2012).

There is also potential for disease transmission from the laboratory (*ex-situ*) to the field, although no cases have been reported in the U.S. laboratory-grown corals must be certified as disease-free and require USDA veterinary certification prior to transplanting (Lirman & Schopmeyer, 2016), thereby reducing this risk. Additionally, regarding field work with diseased corals, the CRCP BMPs under the No Action Alternative require decontamination of equipment to reduce the potential for transmission the disease agents from one site to another.

Application of antibiotics to corals as a means of disease prevention can destabilize the coral microorganism community (microbiome), resulting in greater susceptibility of other coral reef ecosystem species to disease. Impact assessment of applying antibiotics to coral ecosystems would be needed on a case-by-case basis to determine suitability of use. Concerns over antibiotic resistance and overuse in environmental settings indicate the need for additional research to make an informed decision. Site-specific NEPA analysis would be required before use of this technique in the field. Restoration would enhance coral cover and production on the reef, which would benefit reef fish and other organisms. Fish and invertebrates that rely on coral reefs for shelter also benefit from coral restoration activities. Enhancing natural recruitment of coral larvae by increasing available hard substrate would potentially lead to increased coral cover and habitat area for living coastal and marine resources (Ladd et al., 2019). Potential benefits to corals and associated invertebrates and algae as a result of these proposed activities would be expected to be direct and indirect, short- and long-term, local to large scale, and negligible to moderate.

The implementation of coral restoration and innovation activities provides an opportunity to replenish important reef-building coral species and improve coral reef habitat. Adverse impacts to corals and associated invertebrates and algae, would be expected to be direct, short- or long-term, local, and negligible to moderate. Benefits to corals and associated invertebrates and algae would be direct and indirect, short- and long-term, local to large scale, and negligible to moderate.

Watershed restoration and management. Stresses such as nutrient enrichment and physical disturbance can disrupt the balance of coral reef systems and result in injury or loss to small or large portions of the reef. For example, while in normal numbers, crown-of-thorns are not an issue, outbreaks of the large crown-of-thorns seastar, a corallivore, in the Indo-Pacific region have caused up to 90% mortality in localized areas of corals of the Great Barrier Reef, Guam, American Samoa, and Japan (Leray et al., 2012). Triggers for crown-of-thorns outbreaks are not fully understood, but are thought to be related to disturbances such as predator removal and nutrient discharges. Macroalgae dominance on reefs has been associated with nutrient increases in both subtropical and temperate zones, including the Florida Keys (Collado-Vides et al., 2007). In Kaneohe Bay, Hawaii, nitrogen limited nine of ten macroalgae species studied (Neilson et al., 2018). Reducing nutrient loadings to coastal waters would reduce the nutrients available to support increased growth by macroalgae and the potential for macroalgae to outcompete corals on the reefs. Sedimentation alone, particularly anthropogenic sedimentation, is considered the greatest impact on energy acquisition in corals because it impedes their feeding and ability to photosynthesize (Fourney & Figueiredo, 2017). A sedimentation rate of more than 10 $mg/cm^2/day$ is considered to be detrimental to the more sensitive species (Afiq-Roslia et al., 2017).

Watershed restoration and implementation activities may result in the temporary discharge of sediments and other pollutants into coastal and marine waters, as described for sediments (Section 4.3.1) and water quality (Section 4.3.4). Potential adverse impacts of sediments to ESA-listed corals and non-listed corals include reduced light reaching symbiotic zooxanthellae of corals and subsequent reductions in energy availability to corals, as well as increased prevalence of coral disease and other indicators of poor coral health (Pollock et al., 2014). The turbidity and sediment BMPs (Appendix A), and others would reduce these potential impacts further. Potential adverse impacts to corals and associated invertebrates and algae from watershed restoration and management activities would be direct, short-term, local, and negligible to minor.

Watershed restoration and management activities would benefit corals and associated invertebrates and algae through improved water quality due to reduced sediment, nutrient, and other pollutant loadings into coastal waters. Improved water quality would increase the availability of light and corals would benefit from increased photosynthesis by zooxanthellae and subsequent energy; increases in coral cover, density, and diversity through improved settlement habitat; improved three-dimensional structure to coral reefs; and greater possibility for recovery and conservation of coral reef ecosystems. Benefits would be expected to be indirect, long-term, localized, and minor to moderate as a result of watershed restoration and management activities that improve coastal water quality.

Reducing physical impacts to coral reef ecosystems. Adverse impacts to coral reefs and associated invertebrates and algae due to installation of mooring buoys are anticipated to be minimal. One study predicted a 7-12% loss of coral cover due to anchors and anchor chains, and up to 2% loss due to recreational diver contact (Saphier & Hoffmann, 2005). The NPS EIS 2015 concluded that the use and maintenance of navigational markers and mooring buoys would be expected to protect corals from unintentional vessel groundings and anchor damage (see Section 4.3). Potential adverse impacts to corals and associated invertebrates and algae from the addition or relocation of mooring buoys and boundary markers may result in temporary adverse impacts due to temporary sediment resuspension that may reduce water clarity and adversely affect coral health, and drilling sounds that can alter the behavior of invertebrates. However, direct impacts would not be expected since mooring buoys would not be installed on or directly proximate to a coral reef. Potential adverse impacts to corals and benthic habitat would be direct, short-term, local, and minor due to underwater installations.

Potential adverse impacts to corals and associated invertebrates and algae from debris removal may include sediment resuspension and accidental or direct intentional contact with or breaking of corals, sessile invertebrates, or algae by volunteers or professionals. Marine debris removal would primarily occur on a small scale, and local effects would be minor and short-term because such marine debris removal is done by hand (e.g., heavy items are typically lifted with airbag to the surface). Potential adverse impacts to corals and associated invertebrate and algae would be direct, short-term, local and negligible to minor, depending on the size and type of debris. Reductions in physical impacts to corals and associated invertebrate and algae would result in potential direct, long-term, local, negligible to moderate, benefits.

4.4.3.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to corals and associated invertebrates and algae from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. As described previously, natural recovery of coral communities is not expected in the foreseeable future without unprecedented, major global changes in climate, sea level, and species composition and abundance (Young et al., 2012). Burke et al. (2011) estimate that by 2050, 75% of remaining coral reefs will be under high to critical threat. Under Alternative 1, activities to address adverse impacts of coral-specific invasive species, disease, and predators would not be implemented, further reducing the potential for coral recovery. Therefore, implementation of Alternative 1 would be expected to result in a reduction in efforts to recover and/or conserve coral reefs with a commensurate decline in coral reef ecosystems for the foreseeable future relative to the No Action Alternative.

Eliminating on-the-ground coral restoration and associated research related to enhancing coral resilience along with the application of intervention activities would reduce the information available to make decisions regarding management of this resource and eliminate the intervention actions needed to recover corals. Potential adverse impacts would be direct and indirect, long-term, local and large scale, moderate to major, adverse impacts to corals, and associated invertebrates and algae. Associated benthic communities would be expected to experience long-term adverse effects of the loss of reef structure and a subsequent loss of the complex and diverse community of benthic organisms, many of which are critical to the ecological integrity of the reef ecosystem.

Eliminating coral restoration and intervention activities would also eliminate the temporary and negligible impacts of the activities associated with coral nursery development, transplanting, urchin propagation, invasive and nuisance species control, and disease mitigation activities and disturbances described under the No Action Alternative. However, the potential reduction in adverse impacts to corals and associated invertebrates and algae due to eliminating these restoration actions, like the potential impacts themselves, would be negligible. No benefits to corals and associated invertebrates are expected as a result of excluding these activities.

Watershed restoration and management. Potential adverse impacts and benefits to corals and associated invertebrates and algae would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Under Alternative 1, the installation of permanent mooring buoys that presently occurs as part of the CRCP would be eliminated, increasing the potential for impacts physical damage to coral and associated invertebrates and algae from multiple anchorings and contact with marine debris. Eliminating this portion of the CRCP would not affect debris removal that occurs under NOAA's extensive Marine Debris Program. However, without the installation of additional mooring buoys, chronic anchor damage to coral reefs, especially in highly visited areas, would not be addressed and further damage to the reef as debris such as vessels rock or are dragged across the sea floor due to wave or wind energy. For example, a study of corals in highly and rarely anchored sites in the British Virgin Islands (Flynn, 2015) found that coral cover, density, and conditions were markedly lower in the highly anchored sites; cover of hard corals and sea fans were both reduced by about seven percent, hard corals were approximately 40% smaller in size and 60% less dense, and species richness was 60%

lower at the highly anchored sites. The same highly anchored sites supported only 45% of the fish density as those rarely anchored, with some fish functional groups more affected than others.

The exclusion of debris removal activities under Alternative 1 would result in a reduction in the removal of derelict fishing gear, vessels, plastics, and other debris on the sea floor and in benthic habitats, with the potential for continued physical damage to coral and associated invertebrates and algae, as well as indirect loss due to degraded water quality and sediments from accumulated marine debris. In a study of the adverse impacts of plastic debris on 159 Asia-Pacific coral reefs, Lamb et al. (2018) found that plastic debris increased the susceptibility of corals to disease, from 4 to 89%, possibly due to physical damage, conditions conducive to disease, and/or delivery of disease-causing microorganisms. Potential adverse impacts to corals and associated invertebrates and algae from continued anchoring and debris accumulation would be direct and indirect, short- and long-term, local, and negligible (e.g., little or no physical contact with debris) to major (e.g., accumulated plastic covering a portion of a reef), depending on the size of the project. No benefits to corals from the proposed elimination of these activities is anticipated.

Monitoring, mapping, and research activities would continue to provide information critical to conservation and management of corals and associated invertebrates and algae. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters and benefit corals and associated invertebrates and algae. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address coral restoration and physical impacts to corals. Therefore, overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.4.3.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP and may further reduce the potential for adverse impacts to corals and associated invertebrates and algae from proposed activities. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

DCMMs may include increasing the capacity for greater supervision over dive activities, BMPs to control turbidity and sediment, greater restrictions on instrument mooring, guidance for anchoring with a priority for using mooring buoys or live boating, additional training to vessel operators, and stopping restoration work during or when a storm is approaching and during coral spawning periods. These activities may further reduce the potential for release of sediments and sediment-bound contaminants into coastal and marine waters and improve water quality (Section 4.3.4), thereby benefiting corals and associated invertebrates and algae.

DCMMs may further reduce potential risks to corals and associated invertebrates and algae from physical damage during transplanting, potential for disease transmission and corallivore and invasive species introduction, and thereby increase the likelihood of coral survival and recovery from impacts of climate change, land-based sources of pollution, anchoring and debris accumulation, and over-fishing.

Benefits due to additional reductions in impacts of stormwater runoff in the watershed and to coastal and marine waters would include increased coral survival, health, and increased potential success of coral transplants and reef recovery. Potential benefits to corals and associated invertebrates and algae would be similar to, but negligibly greater than, those described under the No Action Alternative.

4.4.4 Fish

Coral reefs support nearly two million marine species, amounting to more than one third of all marine species of fish (Holbrook et al., 2015). Of these species, tropical reef fishes are the most diverse marine vertebrate group, including over 6,300 species worldwide (Quimbayo et al., 2019). Tropical reef species include numerous commercially important fishes such as grouper, snapper, and lobster.

Under the MSA, a 200-mile EEZ and eight regional Fishery Management Councils were created to manage U.S. marine fishery resources. FMPs are used to manage fish and shellfish such as reef fish, ground fish, crustaceans, pelagic fish, live coral and other fisheries for commercial, recreational, and subsistence fishing. FMPs provide stock assessments, fishery evaluations, regulation reviews, and other information for each fishery. Four of the eight Fishery Management Councils (i.e., South Atlantic, Caribbean, Gulf of Mexico, and Western Pacific Regional) have shallow-water coral reef ecosystems within their jurisdictions and the FMPs are available on each individual Council's website.

Highly migratory species (HMS) of pelagic fishes such as tunas, billfish, swordfish, and sharks consume fish, crustaceans, cephalopods, and molluscs in the open ocean and are not reef-dependent but may occur at reefs. Some of these fish mix with juvenile individuals of other tuna species forming large schools along convergence zones, upwelling areas, and near thermal fronts, but not necessarily islands (Venegas et al., 2018) and spawn in warmer waters such as the Gulf of Mexico and the western Pacific. Large sharks such as hammerheads and bull sharks may visit a reef and consume fish there and are not critical to the function of the reef, although they are vulnerable to altered nutrient upwelling caused by warm waters (Goreau et al., 2005; Vanegas et al., 2018). These reef-associated shark species are, along with a diverse group of reef fish, predators of other reef fish (Roff et al., 2016; Goreau et al., 2005). These HMS fish are not expected to be impacted by the proposed monitoring, research, restoration activities, and reduce physical impacts activities and are not addressed further.

The potential for impacts to threatened and endangered fish species was also examined. In the Pacific, species include the threatened giant manta ray (*Manta birostris*), oceanic whitetip shark (*Carcharhinus longimanus*), and the Central and Southwest Atlantic distinct population segments of endangered scalloped hammerhead shark (*Sphyma lewini*). In the Atlantic, species include the threatened giant manta ray, Nassau grouper (*Epinephelus striatus*), oceanic whitetip shark, scalloped hammerhead shark, and smalltooth sawfish (*Pristis pectinata*). Except for the Nassau grouper and smalltooth sawfish, these species are oceanic and impacted primarily by loss of non-coral habitat and overfishing. The Nassau grouper and the smalltooth sawfish have the potential to be affected by the proposed activities.

For ESA-listed fish species, reef restoration would support the recovery of the Nassau grouper, which uses coral reefs, and the coastal smalltooth sawfish. The giant manta ray is more pelagic. Hammerhead sharks and oceanic whitetips are pelagic and may visit coastal waters and coral reefs but would not be expected to benefit directly from reef restoration activities. Overfishing and capture for their fins are the primary threat to both sharks. Benefits to ESA-listed fish species would be variable, but direct, long-term, local, and negligible to moderate. There may be direct adverse direct, short-term, minor-to-moderate impacts to ESA-listed fish through collection of fish for life history assessments, tagging, and/or monitoring of spawning aggregations. No adverse impacts to the other ESA-listed fish would be anticipated.

No critical habitat is designated for Nassau grouper or smalltooth sawfish. The CRCP initiated an informal programmatic consultation with the NMFS Office of Protected Resources, Interagency Cooperation Division under the ESA for these species. This section of the PDEIS addresses reef-dependent and other marine fish. Freshwater fish are addressed under Section 4.3.2 Terrestrial and Freshwater Habitats and Biota.

4.4.4.1 No Action Alternative

CRCP activities that result in injury or loss of reef habitat or associated fish and invertebrates may adversely impact reef fish. For example, loss of the three-dimensional reef structure would reduce the abundance and diversity of fish communities (Holbrook et al., 2015). Loss of mature corals would result in the loss of corresponding source of reef organisms and a decrease in recruitment of fish and invertebrates due to the absence of suitable substrate or chemical stimulants for settling of larvae, reduction in coral habitat would reduce the food source available to other reef species, and loss of coral diversity could result in a greater risk of extinction for habitat-specific fish, especially in diversity "hotspots" where diversity and numbers of fish are high, such as in the Indo-Pacific region (Holbrook et al., 2015).

The proposed CRCP activities analyzed for potential impacts to fish under the No Action Alternative include monitoring, research and sample collections, watershed restoration, coral restoration and intervention, and activities to reduce physical impacts to corals (Table 2-1).

Monitoring, mapping, and research. Fish may be directly collected as part of research activities, resulting in direct loss of individual fish. However, the number of fish collected would be negligible and fish populations would not be expected to be affected. Fish tagging, such as coded wire tags (e.g., external spaghetti tags), elastomer T-bar anchor tags, dart identification tags, visible implanted fluorescent elastomer tags, and acoustic transmitters, could negligibly alter fish behavior, growth, and survivability (Hoey & McCormick, 2004; Berumen & Almany, 2009; Cote et al., 1999; Righton et al., 2006; Anglea et al., 2004). The physical presence of divers/snorkelers can alter fish behavior. Sediment disturbance and water turbidity from vessel and in-water activities may result in temporary indirect impacts to fish (see Section 4.3.4). Sounds in the high-frequency range (25-135 kHz) may also alter behavior, such as disrupting reproductive or feeding activity, in fish such as herrings, menhaden, and anchovies, (NOAA, 2013 [Section 5.1.1.5]). Temporary displacement of prey species from in-water activities could affect feeding routines of predatory fishes and marine mammals. Sound sources from vessels are below levels that can cause temporary hearing loss or injury, but masking and short-term changes in behavior are possible. However, individual surveys would be temporary and spatially limited, and fish that are likely accustomed to other vessels would be expected to experience negligible or minor impacts. Adverse impacts to reef fish behavior from in-water and vessel activities are expected to be directt, short-term, local, and minor.

The CRCP has identified a consistent need across the U.S. coral reef jurisdictions for better data on current stock status and vulnerability to fishing impacts to inform fisheries management actions. For example, data are scarce on historical Nassau grouper numbers because all grouper were combined for fisheries landings data, environmental conditions necessary for the fish are not well known, and it is threatened due to historical over-harvest. The Nassau grouper is now monitored by the Caribbean Fishery Management Council and Caribbean Coral Reef Institute. It is expected that monitoring, mapping, and research activities would benefit this species along with other fish species by providing information critical to management recommendations and regulations. Therefore, anticipated benefits to fish species and populations would be indirect, long-term, local to large scale, and negligible (data not collected in particular areas) to major (data acquired is critical to support to management and conservation of reef fish), depending on the species and the extent of monitoring.

Coral reef restoration and intervention. Adverse impacts to fish from these activities may include temporary disturbances to individual fish from vessel and other in-water activities and would be the same as described above for monitoring, mapping, and research. The effects of *in-situ* antibiotic application to diseased corals on coral reef fish are unknown at this time. Site-specific NEPA analysis would be required before use of this technique in the field. Potential adverse impacts of other coral restoration and intervention activities would be direct, short-term, local, and negligible to minor. Potential benefits to reef fish from transplanting or outplanting corals, and other intervention activities would be anticipated, resulting from recovery of coral abundance, diversity, and structural complexity and subsequent restoration of habitat for reef-dependent organisms and species assemblages, as well as a source of fish recruitment. The extent of the benefits would depend on the fish species affected, whether a project was undertaken, and the success of a restoration project. Most coral species support distinctive fish communities, demonstrating the strong link between coral species and reef fish community structure (Komyakova et al., 2018). For example, new recruits of at least four damselfish species (*Chrysiptera parasema*, *Pomacentrus moluccensis*, *Dascyllus melanurus,* and *Chromis retrofasciatus*) showed a strong preference for a limited number of *Acropora* species (Komyakova et al., 2018) rather than total coral cover. In the Caribbean, coral proposed activities that used out-planting resulted in an increase in fish species richness within a week of outplanting *Acropora cervicornis*, compared with areas not planted (Opel et al., 2017). Potential benefits to reef fish from coral restoration would be direct and indirect, short- and long-term, local and larger scale, and negligible to major due to the need for or the extent of the restoration and success of the restored habitat with respect to improved habitat for foraging, refuge, and spawning.

Watershed restoration and management. During construction of watershed restoration projects such as stormwater treatment wetlands, road and trail stabilization, LID, and culverts, stormwater runoff and associated sediment and other pollutant loading into downstream and coastal waters may occur, potentially degrading water quality and adversely impacting reef fish and nursery habitat. BMPs for turbidity and sediment control would be implemented during construction activities, and areas would be planted with vegetation to stabilize soils following completion of these activities, reducing the potential for the introduction of sediments and other pollutants into downstream and coastal waters. Potential adverse impacts to reef fish and nursery habitat from watershed restoration and management activities would be direct, short-term, local, and negligible to minor. Watershed restoration and management activities are intended to reduce stormwater runoff and sediment and other pollutant loadings into coastal and marine waters, resulting in improved water and sediment quality (Sections 4.3.4 and 4.4.1). Reductions in land-based pollutants into coastal waters would improve water and sediment quality conditions for reef fish nursery habitat. Benefits of improved water quality may accrue to reef fish and nursery habitat and would be direct and indirect, short- and long-term, local and larger scale, and negligible to moderate.

The listed smalltooth sawfish occurs in a variety of coastal habitats depending on life stage, including mangrove habitats as juveniles and deep-water reefs for adults. The smalltooth sawfish would benefit from these activities due to potential increases in sediment quality and reduced sediment loads. The

Nassau grouper would benefit indirectly due to improved water quality and subsequent potential improvements in coral reef habitat. Benefits to listed species would be the same as those for non-listed species: direct and indirect, short- and long-term, local and larger scale, and negligible to moderate.

Reducing physical impacts to coral reef ecosystems. Adverse impacts to reef and other fish may occur during installation of mooring buoys and removal of marine debris but would be temporary and minimal. Fish may be disturbed by in-water activities of vessels and divers and leave the area but would return once activities were completed. Potential adverse impacts to fish from these activities may occur due to installation and associated activities (see monitoring, mapping, and research). The use and maintenance of mooring buoys would be expected to protect coral reefs and therefore provide habitat for reef fish.

Adverse impacts to reef fish from debris removal and associated sediment disturbance and resuspension and possible fragmentation of corals by divers, equipment, and vessels may occur during removal, especially for debris such as derelict vessels, if removal occurs near a coral reef (described in Section 4.4.3). Accidental fuel spills that may occur as a result of these activities would likely be floating oils are unlikely to impact the seafloor but may directly impact an organism due to toxicity. Application of BMPs and implementation of terms and conditions of programmatic and project-specific consultations and permits (MDP PEA, 2013) would further reduce potential adverse impacts.

Removal of marine debris would directly reduce further physical impacts of marine debris and associated potential contamination from fuel, microplastics, and other pollutants, as well as potential impacts of “ghost fishing” (uncollected or lost fishing traps that continue to trap and result in the death of fish and shellfish), and physical habitat disturbance (MDP PEA, 2013). Marine debris, including derelict nets, ropes, and fishing gear, may also entangle fish and wildlife. For example, the listed smalltooth sawfish continues to be adversely impacted due to bycatch, especially in gillnets, as well as fishing line and other debris. A study of the species from 1998-2005 found smalltooth sawfish entangled in PVC pipe, monofilament line, elastic bands, and netting in Florida (Seitz & Poulakis, 2006). In addition, removal of derelict vessels would remove potential source of contamination and physical impacts to coastal and marine habitats that support listed fish species.

Potential benefits to reef fish and ESA-listed fish species as a result of installing permanent mooring buoys and removing marine debris would be direct and indirect, short- and long-term, local, and negligible to moderate. Potential adverse impacts to fish during implementation of these projects would be direct, short-term, local and negligible to minor, depending on the amount, size, and type of debris removed and the habitat from which the debris is removed.

4.4.4.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to fish from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Decline in coral cover has been shown to result in a parallel decline in fish biodiversity both in marine reserves and in areas open to fishing (Jones et al., 2004). Therefore, if coral reef cover continues to decline, a corresponding decline diversity, and potentially abundance of reef dependent fish is anticipated under Alternative 1. Activities to address adverse impacts of invasive species, disease, and predators would not be implemented, further reducing the potential for coral reef ecosystem recovery. Potential adverse impacts to fish as a result of excluding these activities would be direct and indirect, long-term, local, and negligible to moderate. No benefits to fish as a result of excluding these activities are anticipated.

Watershed restoration and management. Potential adverse impacts and benefits to fish would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of permanent mooring buoys and eliminating removal of marine debris under the CRCP would result in continued chronic damage and loss of reef habitats and fisheries, as described for coral reefs (Section 4.4.3). Corresponding sediment disturbances and resuspensions (Section 4.3.1) due to wave and wind induced movement of debris would reduce water quality, subsequent impacts to coral reefs, and corresponding adverse impacts to fish. Persistent debris such as derelict fishing gear and vessels would remain on the seafloor, and the potential for physical damage to reef fish habitat, ghost-fishing, and entanglements would persist. Loss of reef fish habitat due to physical damage from plastics, conditions conducive to disease, and/or delivery of disease-causing microorganisms would also persist under this alternative. Potential adverse impacts to fish would be direct, short- and long-term, local, and negligible to moderate. No benefits to fish are anticipated.

Overall, monitoring, mapping, and research activities would continue to provide information critical to conservation and management of fisheries. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters, benefiting fish habitat and fish. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address impacts of coral reef habitat loss and anchoring and marine debris in coastal and marine waters. Therefore, overall potential benefits to fish would be direct, short- to long-term, local, and negligible to minor.

4.4.4.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

Additional training with vessels and equipment, additional limitations and precautions for mooring buoy and equipment installation, and guidance for anchoring would be expected to further reduce the negligible adverse impacts to reef fish due to monitoring, research, coral restoration, vessel operation and buoy installation, debris removal, and other in-water activities described under the No Action Alternative (NOAA, 2013). No adverse effects of DCMMs on fish are expected. Benefits of DCMMs that reduce the risks associated with coral restoration and intervention would also benefit fish due to the increased likelihood of coral reef habitat persistence. Potential benefits to fish would be similar to, but negligibly greater than, those described under the No Action Alternative.

4.4.5 Invasive Species

Executive Order 13112 addressing invasive species includes requirements to identify federal actions that may affect the status of invasive species and that federal agencies "do not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the U.S. or elsewhere, unless such actions clearly outweigh the potential harm caused by invasive species"

(EO 13112 - 2. Federal Agency Duties). Although not a resource to be protected, the management of invasive species is critical to the conservation of coral reefs and associated biota. Therefore, potential impacts of invasive species and their management relevant to the CRCP are addressed here. Impacts of invasive species and invasive species control to previously examined resources are presented here.

The CRCP activities are intended to remove, reduce, and control invasive species in both the watershed and in coastal and marine environments. Invasive species are a significant issue because they can impact native species through predation, competition for food and space, and hybridization, as well as the introduction of pathogens and parasites. Normal ecosystem functions such as hydrology, nutrient cycling, or productivity may also be altered by biological invasion. Invasive species control measures and BMPs to avoid and minimize potential impacts to non-target species are detailed in the NOAA RC PEIS 2015. The CRCP activities that result in land disturbance or clearing and in-water activities that include equipment or transit across land or water are potential mechanisms for the introduction and spread of invasive species. Potential impacts of the CRCP activities on invasive species control and, by inference, on native species, are presented for both the watershed and coastal and marine waters.

The National Academies of Sciences, Engineering, and Medicine (NAS, 2019) reports that invasive seaweed species have become established in a variety of locations including Florida, Hawaii, and the eastern Caribbean. Several species of invasive corals, such as *Tubastrea* spp., occur in the Atlantic and the globally distributed, temperature-hardy micro-algae coral symbiont (*Durusdinium trenchii*) appears to be present in the Caribbean. Terrestrial invaders such as rats, which consume eggs from nests of seabirds, have been shown to harm coral reefs by reducing the numbers of seabirds, thereby reducing nutrient inputs in the ocean and resulting in less algae initially, fewer algae-consuming fish, and later an increase in algae at the expense of coral (Graham et al., 2018). Once established, invasive species are extremely difficult to eradicate, and management efforts often rely on volunteer efforts, are labor intensive and expensive, and require constant management.

4.4.5.1 No Action Alternative

CRCP activities included in the No Action Alternative that may affect invasive species include monitoring, research, coral nursery and interventions, watershed restoration and management activities, and outreach and education. Under the No Action Alternative, invasive species control would be implemented as part of both watershed restoration and coral restoration and intervention activities and is intended to control invasive species and enhance or support the recovery of native species and habitats.

Monitoring, mapping, and research. In-water activities supporting monitoring, mapping, and research activities have the potential to introduce invasive species to coral reefs and other habitats if equipment and vessels are not adequately decontaminated following work in previous areas. While the majority of marine invasive species are from ballast water and aquaculture release, the majority of tropical marine invasive species are from aquaria releases (Padilla and Williams, 2004). Potential adverse impacts to native species and habitat from invasive species would be direct and indirect, long-term, local to large scale, and negligible to moderate. Data collected and analyzed would support control and management of invasive species and the conservation and recovery of native species. Benefits of monitoring, mapping, and research would be indirect, long-term, local to large scale, and negligible to major benefits due to the information collected and compiled for invasive species.

Coral restoration and interventions. Transplanting and coral interventions may lead to introduction and spread of invasive species to the detriment of native corals and other coastal and marine habitats, as described in Section 4.4.3.1. Coral transplants and research activities that involve coral or coral fragment relocation also have the potential to introduce invasive species into the target area. Introduction of non-native pathogens, parasites, algae, microbes, commensal invertebrates, and corallivores poses a risk to both the translocated species and the entire recipient community. The CRCP specifically targets invasive and nuisance species removal, including removal of algae, seagrass, and fish, and corallivore control, as part of coral interventions. Potential adverse impacts of invasive species removal are direct and indirect, short- and long-term, local with the potential to be larger scale, and negligible to moderate. However, adverse impacts to invasive and nuisance species would benefit coral reef ecosystems.

Benefits to coral reef ecosystems are anticipated as a result of the removal of invasive and nuisance species such as algae, lionfish, and crown-of-thorns. Removal of these and other invasive species would reduce threats to coral reef habitats. NOAA's recovery plan for elkhorn and staghorn coral (NMFS, 2015) identifies the lionfish (native to the Indo-Pacific) as a contributor to the shift to macroalgae dominance in some coral reefs in the Bahamas because it feeds on herbivorous fish (e.g., parrotfish) that control the growth of macroalgae on elkhorn and staghorn corals in the Bahamas. Removal of this species would restore macroalgae control by grazers and improve reef conditions. Removal of nuisance or invasive species from reef habitat would restore coral reef habitat and function, natural species composition and diversity, and enhance recreational opportunities. Benefits anticipated would be direct and indirect, long-term, local and large-scale, and negligible to moderate.

Watershed restoration and management. Adverse impacts to native species as a result of invasive species control may occur in the watershed as a result of land clearing and creation of gaps in which invasive species may become established and spread. Adverse impacts to native species and habitats may also occur due to herbicide drift or poor application that results in harm to non-targeted native species. Adverse impacts to native species from herbicides and surfactants (used to enhance the intended effects of the herbicide on the plant) would potentially occur due to contamination of soils or water the plants use. However, herbicide use is restricted to activities conducted in accordance with approved application methods and BMPs are designed to prevent exposure to non-target areas and organisms, reducing herbicide drift, and reduced use of surfactants. Therefore, potential adverse impacts of invasive species would likely be direct, short-term, local to large-scale, and negligible to moderate.

Using native plants to restore the landscape can help to reverse the trend of species loss by improving the viability of native habitats (Dorner, 2002). Native species will, in most cases, eventually become self-sustaining due to adaptations to weather, disease, and herbivores in the native area. Establishment of vegetation on bare soils or revegetation of an area is important to reducing soil erosion and runoff on its own or following other proposed activities that disturb an area. Following construction activities, vegetation would be planted that would be consistent with the habitat created. In areas reclaimed from previous agriculture, for example, establishing ground cover such as using native species or naturalized vetiver grass (a nonnative but noninvasive species) would be used to reduce erosion.

Controlling invasive species would benefit most living resources, especially threatened and endangered species that are typically at greater risk from these impacts. Potential impacts to aquatic and terrestrial biota would be avoided and minimized by implementing BMPs, including the use of the least toxic herbicides, surfactants, and spray pattern indicators available. Benefits are anticipated to be direct and indirect, short- and long-term, local to large-scale, and negligible to minor.

Reducing physical impacts to coral reef ecosystems. Potential adverse impacts to resources may include introduction of invasive species as a result of mooring buoy installation and marine debris removal would occur due to contaminated vessels or equipment. Therefore, potential adverse impacts of mooring buoys and debris removal on resources are the same as those described for monitoring, mapping, and research activities. Potential adverse impacts to native species and habitat from invasive species introduced during these proposed activities would be direct and indirect, long-term, local to large scale, and negligible to moderate. Benefits to resources may occur due to reduced disturbances and subsequent fewer opportunities for invasive species to become established. Potential benefits would be direct, long-term, local, and negligible to minor.

4.4.5.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and interventions and reduce physical disturbance to corals would be eliminated.

Monitoring mapping and research. Potential adverse impacts and benefits to native habitats and species from monitoring, mapping, and research activities would be the same as described for the No Action Alternative. Potential adverse impacts to native species and habitat from invasive species would be direct and indirect, long-term, local to large scale, and negligible to moderate. Benefits of monitoring, mapping, and research would be indirect, long-term, local to large scale, and negligible to major benefits due to the information collected and compiled for invasive species.

Coral reef restoration and interventions. Under Alternative 1, proposed activities that include invasive species removal and/or control as a means of restoring coral and coral reefs would be eliminated and coral reef degradation would continue. While invasive species control alone may not be adequate for recovery of corals, it is critical to recovery of coral reefs and associated native habitats. In the absence of coral research, restoration, and intervention techniques, invasive species control would be limited to decontamination of equipment and vessels. The removal and/or biological and chemical control of invasive species such as algae, seagrass, and fish would not occur, and these invasive species would continue to establish and spread to the detriment of native corals and other coastal and marine habitats. As described in Section 4.4.3, recovery of coral reefs would not be expected in the foreseeable future without intervention. Invasive species are already considered a significant threat to coral reefs. Potential adverse impacts of invasive species removals are direct and indirect, short- and long-term, local with the potential to be larger scale, and negligible to moderate.

Eliminating coral restoration and intervention activities would also eliminate potential adverse impacts of coral restoration and intervention activities (Section 4.4.3). However, the potential reduction in adverse impacts to corals, like the potential impacts themselves, would be negligible. No benefits to native habitats and species are expected as a result of excluding coral reef restoration and intervention activities because this would exclude invasive species control.

Watershed restoration and management. Potential adverse impacts and benefits to corals and associated benthos would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of permanent mooring buoys and the removal of marine debris would result in continued damage and loss of coral reefs and other native habitats. Disturbances and debris would provide potential opportunities for invasive species introduction and establishment by removing or stressing native species and/or serving as a carrier for the introduction of invasive species and further loss of native habitats. Potential adverse impacts to native species and habitat from invasive species introduced during these proposed activities would be direct and indirect, long-term, local to large scale, and negligible to moderate. No benefits to native resources with respect to invasive species are expected under this alternative.

Potential adverse impacts to native habitats and species due to the introduction and expansion of invasive species would be direct and indirect, short- and long-term, local and large scale, and minor to moderate due to the persistence of invasive species and the continued introduction of others. Monitoring, mapping, and research activities would continue to provide information critical to conservation and management of invasive species. Watershed restoration and management activities would support healthier native habitats and reduce opportunities for invasive species establishment. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address invasive species impacts. Therefore, overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.4.5.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP. Implementation of DCMMs alone would have no adverse impacts to natural resources. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

DCMMs would be expected to further reduce the opportunities for invasive species introduction and establishment due to additional protocols for decontamination of vessels, equipment, coral transplant materials, and other activities. Watershed restoration and management activities would also reduce opportunities for invasive species introduction and establishment by using only native vegetation during revegetation projects. Benefits of the additional DCMMs to native habitats and species under Alternative 2 would be direct and indirect, short- and long-term, local, negligible to major, and No Action Alternative.

4.5 Regulatory Environment

4.5.1 Essential Fish Habitat (EFH)

The MSA recognizes the importance EFH as areas where fish spawn, breed, feed, or grow to maturity; EFH includes aquatic habitats such as wetlands, coral reefs, seagrasses, and rivers. NOAA Fisheries protects more than 800 million acres (~324 million km^2) of habitat under EFH, which supports a $200 billion U.S. fishing industry (NOAA Fisheries, 2019a). EFH for every life stage of each federally managed species has been identified in FMPs that are prepared by the Fishery Management Councils and implemented by NMFS. Descriptions, geographic boundaries, and links to additional information about EFH are available through the NOAA *Essential Fish Habitat Mapper*, which provides visual spatial representations of fish species, their life stages, and important habitats (NOAA Fisheries, 2019b). The protection and restoration of EFH is critical to supporting fisheries, rebuilding depleted fish stocks, and aiding in coral reef recovery in the U.S.

This DPEIS focuses on demersal habitats (including hard bottom and soft bottom) from the shoreline to the open ocean in the throughout U.S. coral reef jurisdictions and priority international areas. Adverse effects to EFH are defined as any reduction in quantity or quality of EFH and may include direct or indirect physical, chemical, or biological alterations of the water or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components. In parallel with the preparation of this DPEIS, the CRCP has initiated early coordination for potential impacts to EFH and intends to complete a programmatic consultation with NMFS Office of Habitat Conservation. HAPCs, a subset of EFH, are considered high priority areas for conservation, management, or research because they are rare, sensitive, stressed by development, or important to ecosystem function by NOAA. Examples of coral reef HAPCs are East and West Flower Garden Banks and the Dry Tortuga Ecological Reserve. The HAPC designation does not necessarily confer additional protections or restrictions upon an area but can help to prioritize and focus conservation efforts. Because they are a subset of EFH, HAPCs are within the regulatory protection of EFH.

4.5.1.1 No Action Alternative

CRCP activities with the potential to impact EFH under the No Action Alternative may include vessel and in-water activities, mapping with echosounder, introduction of sediments or other pollutants into coastal and marine waters from construction activities, sea floor disturbance, accidental spills, and introductions of invasive species or disease during transplanting or outplanting.

Monitoring, mapping, and research. Potential adverse impacts to EFH from echosounder, aircraft activity, vessel transit, surveys, anchoring, sea bottom sampling, and other monitoring, mapping, and research activities were evaluated under the OCS PEA 2013 and the MDP PEA 2018. Preferred anchor sites do not include coral reefs, seagrass beds, and other sensitive areas and the footprint of anchoring would be small enough that it would be unlikely to alter water column habitat for managed fish species. Although sensitive areas such as coral reefs are avoided, many areas remain uncharted. In such cases, vessels will typically anchor in areas with documented absence of coral reefs or in areas known to be devoid of corals, use mooring buoys, or avoid anchoring (live boating, manned vessel). Coral reef ecosystem assessment, monitoring, and sampling may result in direct contact and negligible to minor adverse impacts to EFH if sampling gear makes physical contact with the seafloor or coral reefs. Instruments temporarily moored to the seafloor may alter EFH by shading areas and modifying habitat structure. NOAA's OCS PEA 2013 concluded that none of the proposed activities are expected to reduce the quantity or quality of EFH and, therefore, would not adversely impact EFH, either individually or cumulatively (Section 5.1.1-5.1.3). The ONMS PEA (2018) (Section 5.1.1) also evaluated the potential impacts of these same activities (e.g., vessels, instrument and vehicle deployment, SCUBA and snorkel, and other sampling activities) and concluded that the adverse effects on EFH from these activities would be minimal due to the relatively low number of events, divers, and equipment deployments, in addition to the BMPs and training protocols in place. Therefore, potential adverse impacts to EFH are anticipated to be negligible. If any CRCP project -specific activities are found to have the potential to adversely impact EFH that are not considered in the CRCP's programmatic EFH consultation, NOAA would contact the Office of Habitat Conservation to reevaluate the impacts to EFH and potentially initiate EFH consultation under 50 C.F.R. §§ 600.905-930.

Some in-water activities may disturb the seafloor, alter habitat structure, and can have localized impacts to demersal fishes and EFH. The area affected during installation of permanent transect markers, temporary placement of instruments, and sampling is insignificant relative to the total benthic habitat in the U.S. coral reef jurisdictions (NOAA, 2013). The National Coral Reef Monitoring Plan includes the collection of coral cores once every 10 years and the infrequent sampling and small sample size.

Additionally, research activities may involve the collection of coral fragments and cores. Multiple samples are generally collected from different donor colonies throughout a coral reef ecosystem. The collection of coral samples may have minor, temporary, localized adverse impacts to EFH. Additionally, instruments temporarily moored to the seafloor may alter EFH by shading nearby areas and modifying habitat locally, which could cause minor, temporary, localized adverse impacts. Finally, floating oils from accidental spills are unlikely to impact the seafloor, but may impact organisms such as corals and seagrasses due to toxicity. Pollutant discharge or hazardous materials release from vessels may also adversely affect pelagic habitat in the water column, as described in Section 4.3.4. However, most activities planned for coral reefs in coastal waters are conducted from small vessels so that adverse impacts from an oil spill are expected to be negligible to minor if they occur.

Consequently, adverse impacts to EFH from these activities would be direct, short-term, local, and negligible to minor. Benefits to EFH would include data relevant to EFH in the water column and on the seafloor that would be critical to EFH conservation and management efforts (NOAA, 2013). Benefits to EFH would be expected to be indirect, long-term, local to large scale, and negligible to major benefits.

Coral restoration and intervention. Activities such as vessel transit, collection, diving, and nursery development may disturb EFH due to travel or work in the area or in adjacent areas and impacts would be the same as those described for the monitoring, mapping, and research activities described above. Coral nurseries may be developed on or adjacent to healthy reefs and could disturb existing coral reefs designated as EFH. Transplanting wild colonies or nursery-reared corals back onto damaged coral reefs could result in temporary damage to EFH if those colonies are injured, making them susceptible to disease and possible death. There are associated risks such as introduction of invasive species and predators (Section 4.4.3). Indirect benefits would include sediment stabilization and reduced wave energy that would benefit EFH such as mangroves (Section 4.4.2), seagrasses (Section 4.4.1), and the water column. Adverse impacts to EFH from coral reef proposed activities are expected to be direct, short-term, local, and negligible to minor. Coral restoration and intervention activities are expected to result in direct and indirect, long-term, local, and negligible to moderate benefits to EFH as a result of directly restoring EFH such as coral reefs.

Watershed restoration and management activities. Adverse impacts to EFH from these activities may occur if activities result in erosion and runoff of sediments and other pollutants into downstream and coastal waters, resulting in temporary degradation of water column and other EFH as described previously (Section 4.3.4). However, results of these activities would be temporary and local to the activities, and BMPs (Appendix A) would avoid and minimize sediment runoff and water column turbidity. Adverse impacts to EFH from these activities are expected to be direct, short-term, local, and negligible to minor. Potential benefits to EFH from proposed activities include improved water quality and subsequent direct benefits to coral reefs, mangroves, seagrasses, the water column, and other EFH. Benefits would be direct and indirect, long-term, local, and negligible to moderate.

Reducing physical impacts to coral reef ecosystems. Potential adverse impacts to EFH from disturbed substrates may occur during activities to reduce physical impacts, e.g., mooring buoy installation and marine debris removal, and would be direct, short-term, local, and minor due to disturbance and potential resuspension of submerged substrates (Section 4.3.1). Adverse impacts to EFH from debris removal and associated sediment disturbance and resuspension during removal, especially for larger derelict vessels, would be anticipated if the removal required work in or near EFH. Debris removal may temporarily increase turbidity and reduce water clarity, which may reduce the quality of EFH. Direct, short-term, local, and negligible to minor adverse impacts would be expected but would be minimized with the application of BMPs. In addition, potential impacts to ESA-listed coral species would require ESA consultation and would include implementation of terms and conditions of project-specific consultations and permits (MDP PEA, 2013).

Installation of mooring buoys and removal of marine debris would directly reduce the amount of vessel anchoring, many of which may be EFH, and therefore reduce the potential for further physical impacts from these activities. Debris removal would remove trash and other debris that could otherwise result in physical impacts to EFH from plastic materials that may smother coral, derelict vessels that may be carried by waves into seagrass beds) and potential contamination of sediments and water column EFH from fuel that may be released during derelict vessel removal or microplastics and other associated pollutants that occur as part of the debris (MDP PEA, 2013 [Section 5.2.2]). Potential benefits to EFH from marine debris removal would be direct and indirect, short- and long-term, local, and negligible to moderate.

4.5.1.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to EFH from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. As described earlier (Section 4.4.3), recovery of coral reefs would not be expected in the foreseeable future without unprecedented, major global changes in climate, sea level, and community composition and species abundance (Young et al., 2012). Activities to address adverse impacts of invasive species, disease, and predators would not be implemented, further reducing the potential for coral recovery. Therefore, the continued direct loss of coral reef EFH is anticipated under Alternative 1. The subsequent reduction in coral reef EFH may result in further sediment and shoreline erosion due to increased wave energy along shorelines, resulting in adverse impacts to other EFH such as mangroves, seagrass, other benthic habitats, and the water column. Potential adverse impacts to EFH under Alternative 1 would be expected to be direct and indirect, short- and long-term, local and large scale, and minor to moderate.

Eliminating coral restoration and intervention activities would also eliminate potential adverse impacts of coral restoration and intervention activities (Section 4.4.3). However, the potential reduction in adverse impacts to corals, like the potential impacts themselves, would be negligible. No benefits to EFH are expected as a result of excluding coral reef restoration and intervention activities.

Watershed restoration and management. Potential adverse impacts and benefits EFH would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of permanent mooring buoys and the removal of marine debris from the current CRCP would result in increases in damage and loss of EFH, especially coral reef habitat, due to increased sediment resuspensions, wave and wind induced movement of anchors and debris, and subsequent adverse impacts of physical damage and contamination (MDP PEA, 2013). The exclusion of debris removal activities would result in continued accumulation of derelict fishing gear, vessels, plastics, and other debris on the seafloor and in benthic habitats, with the potential for continued physical damage to EFH, as described for coral reefs (Section 4.4.3) and mangroves (Section 4.4.2). Physical damage, in turn, can create conditions conducive to disease, and/or delivery of disease-causing microorganisms (Lamb et al., 2018). Potential adverse impacts to EFH from continued anchoring and debris accumulation would be direct, short- and long-term, local, and negligible to moderate. No Benefits to EFH are anticipated from the elimination of these activities.

Monitoring, mapping, and research activities would continue to provide information critical to conservation and management of EFH. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters and benefit corals and EFH. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address coral restoration and physical impacts to corals. Therefore, overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.5.1.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP. Implementation of DCMMs alone would have no adverse impacts to EFH. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

Additional training with vessels and equipment, additional limitations and precautions for mooring buoy and equipment installation, and reduced anchoring due by prioritizing mooring buoy use or live boating would be expected to further reduce the negligible adverse impacts to EFH due to monitoring, collection, vessel operation and buoy installation, debris removal, and other in-water activities described under the No Action Alternative (NOAA, 2013). No adverse impacts of implementing DCMMs on EFH are expected. Benefits of DCMMs that reduce the risks associated with coral restoration and intervention would also benefit EFH due to the increased likelihood of coral reef habitat persistence. Potential benefits to EFH would be similar to, but negligibly greater than, those described under the No Action Alternative.

4.5.2 Protected Species

This section describes the impacts to other federally threatened and endangered species (referred to as ESA-listed species) and designated critical habitat described in Chapter 3 that were not described in previous sections. ESA-listed seagrasses (Section 4.4.1), corals (4.4.3), fish (Section 4.4.4), terrestrial (Section 4.3.2), and wetland and floodplain (Section 4.3.3) species have been discussed in their respective sections. ESA-listed species are federally protected under the ESA, with all marine mammals being protected under the MMPA whether they are ESA listed or not. Similarly, the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act provide federal protection to many bird species that are not protected by the ESA. For protected species that might occur within or near areas of proposed activities, a comprehensive table of NOAA ESA-listed species is in Section 3.4.2, a list of USFWS ESA-listed species anticipated is presented in Appendix E, and a list of all marine mammals is in Appendix F.

ESA-listed species that may be impacted, adversely or beneficially, by the CRCP activities inhabit marine, coastal, riparian, and terrestrial habitats. Many of the marine and coastal species reside or temporarily migrate through areas where proposed activities may occur. The ESA provides for the conservation of species in danger of extinction throughout all or a significant portion of their range, presently or in the foreseeable future, as well as designation of critical habitat for these species.

Potential impacts to these other ESA-listed species from activities similar or identical to those in the current CRCP activities (Section 2.3) have been evaluated in previous EISs and EAs, specifically NOAA RC PEIS 2015 (Section 4.7), OCS PEA 2013 (Section 4.2.2), NOAA PDARP/PEIS 2016 (Section 6.9.1), the programmatic Biological Opinion (Opinion) on the Preferred Alternative within the Deepwater Horizon Oil Spill Programmatic Damage Assessment and Restoration Plan and Programmatic Environmental Impact Statement (NOAA PBO 2016 [Section 6.12]), ONMS PEA 2018 (Section 5.3), CRED PEA 2010 (Section 7.2), MDP PEA 2013 (Section 5.2.3), NCCOS EA 2016 (Section 4.1), and the USFWS framework Biological Opinion/Conference Opinion (Section 6.0; [USFWS, 2016l]). These documents outlined levels above which adverse impacts would require further individual consultation and can be referred to for such documentation. Based on the results of these documents, no significant adverse impacts to ESA-listed sea turtles, marine mammals, or birds are anticipated as a result of the activities included in any of the three alternatives. Potential impacts to ESA-listed sea turtles, marine mammals, and birds in or near areas of interest to this DPEIS are summarized here based on the results of these previous evaluations and as related to proposed activities.

Sea turtles, marine mammals, and protected birds are distributed across U.S. coral reef jurisdictions with some species such as the sperm whale (*Physeter microcephalus*) potentially occupying all jurisdictions, and other species, such as the Hawaiian monk seal (*Neomonachus schauinslandi*) being limited to one jurisdiction. There are a few differences among jurisdictions in ESA-listed species and critical habitat, as described in Chapter 3, Section 3.4.2. For example, the Pacific Islands jurisdictions (Hawaii, American Samoa, Guam, and the CNMI) are typically more species-rich and diverse than the Caribbean (i.e., Florida, Puerto Rico, and the USVI) and Gulf of Mexico jurisdictions, and U.S. Remote Pacific Island Areas have fewer development impacts when compared with the Florida coast or the MHIs. All the CRCP jurisdictions have ESA-listed sea turtles, marine mammals, and birds, including designated critical habitat for many species, and are impacted by CRCP activities in the same manner regardless of jurisdiction for this analysis.

While there is the potential for incidental take of ESA-listed sea turtles, marine mammals, and birds as the CRCP activities are implemented, NOAA does not anticipate the activities and potential impacts discussed below to result in adverse impacts to any of these ESA-listed species or result in the destruction or adverse modification of designated critical habitat. Because of the programmatic nature of this DPEIS, individual projects would likely require a project-specific consultation with NOAA NMFS or USFWS if the programmatic consultations do not consider all effects of an individual project. Adherence to any project modifications or avoidance and minimization measures would be identified through additional ESA Section 7 consultations, as appropriate.

Management and conservation efforts similar or the same as those implemented under the CRCP (e.g., monitoring, research, watershed restoration, coral restoration, and marine debris removal activities) were evaluated in the NOAA PDARP/PEIS 2016 and also addressed in the corresponding NOAA PBO (2016) with respect to potential adverse impacts to all of the listed species addressed in this section. These documents are referenced as appropriate in the following sections. The Programmatic Biological Opinion (Opinion) on the Preferred Alternative within the Deepwater Horizon Oil Spill Programmatic Damage Assessment and Restoration Plan and Programmatic Environmental Impact Statement (NOAA PBO, 2016) concluded that restoration activities proposed under the NOAA PDARP/PEIS 2016 are “not likely to jeopardize the continued existence of any listed endangered or threatened species under the jurisdiction of NMFS and not likely to destroy or adversely modify any designated critical habitat” (Section 11).

4.5.2.1 No Action Alternative

The CRCP activities included in the No Action Alternative that have the potential to affect these other protected species are related to monitoring, mapping, and research; coral restoration and intervention; watershed and management activities; and reduction of physical impacts to coral reefs. Each of these activity groups includes a component that has been known to impact protected coral, fish, terrestrial and marine mammals, birds, amphibians, reptiles, invertebrates, and/or plant species through habitat loss, habitat degradation, water quality degradation including turbidity and contamination, handling and direct contact, displacement, and sound and reverberations (NOAA RC PEIS, 2015). Adverse impacts can be indirect: for example, an activity might cause disruption in behavioral patterns or loss of the availability of habitat; or an adverse impact may be direct: for example, an activity such as a vessel strike, may incidentally result in harm or injury to a species. When one or more individual's fitness to breed and reproduce as a result of these direct or indirect adverse effects is reduced, an adverse effect can occur at a population level. Minimization and avoidance efforts for particular impacts, such as vessel strikes or disturbance due to construction activities, can be implemented to reduce the likelihood of interaction with ESA-listed marine turtles, marine mammals, and birds performing essential behavioral functions such as migration, breeding, and nesting. The NOAA RC PEIS 2015 described mitigation measures that could be implemented during marine debris removal in riverine and coastal habitat restoration projects. For example, mitigation measures include using experienced personnel and type of equipment during debris removal activities, avoid direct interactions with ESA-listed species, schedule debris removal during appropriate tide cycles to avoid unnecessary water quality impacts, and implement BMPs related to construction activities to avoid impacts during equipment staging, vehicle or foot traffic.

Because impacts to protected corals, fish, plants are discussed above, the following analysis of other protected species includes three categories: sea turtles, marine mammals, and protected birds. Though all sea turtles and some marine mammals are ESA-listed species, because of their specialized characteristics and habitat, regulatory protection, and similarity of impacts within each activity group, they are presented separately from other listed species.

Monitoring, mapping, research. Adverse impacts to sea turtles, marine mammals, and protected birds would be direct, indirect, short- and long-term, local, and negligible to minor, based on the proposed activities and the type of habitat in which the activity occurs. Potential adverse impacts of monitoring, mapping, and research activities may include activities associated with the use of in-water vessels and land-based surveys related to vessel transit, sea floor mapping using echosounder, benthic sampling, and deployment of equipment, and drones. Subsequent impacts to sea turtles, marine mammals, and protected birds that may be in the path or vicinity of vessels may include physical interactions due to accidental strikes or groundings, behavioral changes or physiological impacts due to sounds from vessels, echosounder, and potential entanglement or harmful contact with sampling, anchors, or other equipment. Chemical releases (primarily oils) from vessels, improperly sanitized dive equipment, and contaminated sampling equipment could result in temporary, short-term, minor impacts to sea turtles, marine mammals, and protected birds if there is contact with the chemical. Research and mapping activities may also affect behavior through the physical presence of divers and snorkelers, and sound. Impacts may range from negligible due to absence of a species in an area and/or no increase in vessel transit or activities, to minor, due to the presence of ESA-listed species.

The OCS PEA 2013 (Section 5.1) and the ONMS PEA 2018 (Section 4.1-4.4) include analyses for the potential impacts to sea turtles, marine mammals, and birds (Sections 5.1.1 and 5.1.3) from monitoring, mapping, and research activities, including vessel activities, similar to or the same as activities included in the CRCP. The NOAA RC PEIS 2015 (Section 4.5.13) concluded that adverse impacts to ESA-listed species may include effects of monitoring from handling, sound, turbidity, displacement, and mortality. The OCS PEA 2013 and FONSI concluded that adverse impacts to the environment would be temporary, non-significant, and low impact. Examples of these effects include avoidance behavior of whales in the presence of a survey vessel or disturbance of wildlife while drilling during tide gauge installation, which produces sound levels lower or similar to mooring buoy installation and drilling coral cores. The ONMS PEA 2018 indicates less than significant adverse physical impacts to ESA-listed sea turtles, marine mammals, and birds as a consequence of monitoring, mapping and research activities (does not address overall benefits to management and conservation).

- **Sea turtles.** Sea turtles use the pelagic zone either permanently or transitionally, are highly migratory, and do not rely directly on coral reefs. Sea turtles can use coral reefs for food, such as the hawksbill sea turtle, which consumes sponges on coral reefs, but they are not confined to a coral reef and spend most of their life stages away from coral reefs. Food sources range from seagrasses and algae for the green sea turtle, to squid, shrimp, crabs, and jellyfish for the leatherback sea turtle. Adverse impacts to sea turtles and associated critical habitat due to monitoring, mapping, and research activities such as vessel use, sound, anchoring, turbidity, and bottom sampling are described in the OCS PEA 2013 (Section 5.1). Sea turtles that spend time in coastal habitats can be impacted by increased vessel traffic associated with monitoring activities; however, those impacts are temporary, localized, and short-term. Similar to other NOAA programs, the CRCP implements BMPs to prevent vessel collisions and sound impacts to sea turtles, which include restricting vessel speeds and direction, placing vessels in neutral in the presence of animals, and moving away when animals are observed within specific distances of the vessel; Appendix A (NMFS, 2008; NOAA, 2013). The nesting beaches of sea turtles would largely be unaffected by the proposed activities, which will occur during daylight hours. The research that is being conducted could have long-term beneficial impacts to species management, BMP development, habitat protection, vessel restrictions, or conservation areas by gathering data to inform future habitat management decisions to benefit species as described in NOAA RC PEIS 2015 (Section 4.5.2).

- **Marine Mammals.** Monitoring, mapping, and research activities have the potential to impact marine mammals in a manner similar to those described for sea turtles in the marine environment. Many marine mammals are migratory, including humpback whales, fin whales, sei whales, and sperm whales, which spend the winter months in proximity to temperate, subtropical or tropical locations and summer months in cooler locations. Dolphins are much more frequent visitors to coral reefs but do not rely directly on coral reefs. Hawaiian Monk seals use coral reef and other areas as foraging and breeding habitat. The transitory nature of marine mammals can increase the potential for vessel strikes and sound impacts since the exact location of these species is unknown and activities can be conducted in any open waterbody. Most of the CRCP activities are conducted within coral reef ecosystems where many marine mammals may feed and/or breed during part of their lives.

  Active echosounders result in sound in the water column that creates the potential to behaviorally disturb certain marine mammals. Disturbance depends on whether the functional hearing range of the marine mammal overlaps with the acoustic range of the hydroacoustic survey sources employed. Many marine mammal species can occur in the CRCP's action area (see Appendix F). The OCS PEA 2013 evaluated the potential impacts of hydrographic surveys, including bathymetric surveys using side scan echosounder and multibeam echosounders similar to those employed by CRCP. NMFS's Northeast, Pacific Islands, Southeast Fisheries Science Center PEAs and accompanying MMPA analyses assessed the potential impacts of hydroacoustic surveys for fish aggregation (NMFS, 2019; NMFS, 2016; NEFSC, 2016; PIFSC, 2015; SEFSC, 2016). Sound from these units analyzed ranges from 50-500 kHz, and single beam echosounders range from 12-100 kHz. Single-beam echosounders can operate as low as 12 kHz, but due to the narrow, downward facing orientation of the beam, the beams are narrowly dispersed, providing opportunity for mammals to avoid impacts. Mysticete cetaceans (baleen whales) typically hear in the range of 7 Hz-25 kHz, while otariids (eared seals and manatees) hear in the 75 Hz-30 kHz range underwater. The hearing of odontocetes (e.g., toothed whales, sperm whales, and dolphins) have a hearing range of 150Hz-160 kHz, and some porpoises and dolphins hear frequencies up to 180 kHz. Therefore, baleen whales, eared seals, and manatees cannot typically hear in the 50-500 kHz frequency range underwater and are not at risk for acoustic harassment from side scan echosounder and multibeam echosounders. Phocids (true seals), including the Hawaiian monk seal, can hear in frequencies greater than 50 kHz and may exhibit avoidance behavior in the presence of high frequency sound from side scan echosounder and multibeam echosounders (NOAA, 2013). Many of the activities covered under this DPEIS are focused on coral reefs, not deep-water environments where many of the more sensitive marine mammal species, such as beaked whales, are often found and it is unlikely that proposed activities will overlap with ESA-listed whales.

Adverse effects are anticipated to be limited to temporary, minor behavioral disturbances. As analyzed by NOAA, the most likely response to these sound sources is behavioral disturbance, which may include a variety of effects, including subtle or minor changes in behavior (e.g., minor or brief avoidance of an area or changes in vocalizations). CRCP does not anticipate more sustained and/or potentially severe reactions, such as displacement from or abandonment of high-quality habitat. Because the survey vessel is itself moving and because of the directional nature of the sources considered here, repeated exposures are unlikely, and behavioral reactions are expected to be of short duration and low severity. As such, we conclude that the impacts to marine mammals from hydroacoustic survey activities would be temporary and negligible to minor. For these reasons, NOAA has determined that no incidental take authorization is required for the proposed programmatic action. CRCP will review future specific hydrographic survey proposals to determine whether effects might occur that would require additional NEPA review, and MMPA and ESA compliance.

The CRCP supported in-water research and monitoring activities do not directly target marine mammals; however, the implementation of these activities may alter behavior due the presence of SCUBA divers in the water or sounds associated with installing moored instruments or drilling coral cores. Transect tapes that are temporarily laid across coral reefs and associated ecosystems are removed once the divers collected need information and are not likely to pose an entanglement threat. Additionally, the CRCPs BMPs requires observers for protected species, and if a protected species moves into the area, the work stop until the animal leaves on its own. The adverse impacts of the in-water monitoring and restoration activities would be negligible to minor, local, and short-term.

The temporary use of echosounder, the limited probability of species co-occurrence with these activities, implementation of BMPs and mitigation measures, and the ability of the marine mammal to avoid the survey area limits adverse impacts for mapping, monitoring and research activities. These activities would benefit marine mammals by providing information critical to management recommendations and regulations related to fishery management, coral health and restoration, and water quality. Though research from the proposed activities does not specifically address marine mammals, data collected related to water quality, sediment, and fish can be applied to marine mammal management and habitat protection.

- **Birds.** Monitoring, mapping, and research activities may include temporary disturbance to marine seabirds during increased vessel activity and drone use for mapping coral reef ecosystems and terrestrial habitats. However, these species are likely to temporarily disperse during these activities. The OCS PEA 2013 evaluated impacts of hydrographic surveys on various biological resources and found that activities associated with survey, including vessel activity, would have no significant adverse impact on seabirds, ESA-listed species, and other birds. The OCS PEA 2013 states there is no scientific evidence supporting a disturbance of nesting or breeding seabirds in the presence of vessels surveying in nearshore waters.

Coral restoration and intervention. In-water coral restoration and intervention techniques could stress, injure, or harm sea turtles, marine mammals, and protected birds. Chemical releases (primarily oils) from vessels, improperly sanitized dive equipment, and contaminated sampling equipment could result in temporary, short-term, minor impacts to sea turtles, marine mammals, and birds if there is contact with the chemical. Lines used in nurseries may pose entanglement hazards for sea turtles and marine mammals that may result in injury or harm to these species. Similarly, entanglement could occur when lines become detached during storms and other disturbances. Sound caused by installation of anchors (e.g., duckbill anchors, helix ground anchors, rebar, anchor screws, heavy weights, or eye bolts cemented into hard-bottom) to hold nursery systems in place may temporarily alter the behavior of sea turtles or marine mammals near the area of installation. The use of BMPs to reduce or minimize impacts to protected species during vessel operations would reduce potential adverse impacts to sea turtles and marine mammals.

Antibiotics used to treat disease corals may leach into the water and become bioavailable to other species. There are concerns about the rise in antibiotic resistance bacteria and how this will not only impact human health, but also other species. Using antibiotics on corals may add to antibiotic background level currently in the system from other sources such as sewage, waste-water disposal, fish aquaculture, and animal horticulture (Gaw et al., 2014). Antibiotic resistant bacteria have been found in several marine species including sea turtles, sharks, fish, and marine mammals (Al-Bahry et al., 2009, Ahasana et al., 2017, Blackburn et al., 2010 and Stewart et al. 2014.). The compound that is used to mix the antibiotics to treat corals is silicone based and slowly leaches the antibiotics into the corals and likely into the water. Potential impacts to sea turtles, marine mammals and birds of antibiotic application in the field are unknown at this time. Site-specific NEPA analysis would be required before use of this technique in the field.

With the exception of the unknown impacts from antibiotics in the field, potential adverse impacts to sea turtles, marine mammals, and birds would be direct or indirect, short-term, local, and negligible to moderate. Benefits to these species would be direct and indirect, short-and long-term, local to large scale, and negligible to major.

- **Sea turtles.** The CRCP proposed restoration and intervention activities may result in temporary disturbances to sea turtles due to vessel and other in-water activities, as described above, and there is potential for entanglement in coral nurseries that could lead to injury or harm. Benefits of coral reef restoration and intervention activities that would likely result in indirect benefits by improving sea turtle habitat and food resources.
- **Marine mammals.** Potential impacts to marine mammals due to coral restoration and interventions would be increased vessel activity, interactions with lines in coral nurseries, and minor disturbance from SCUBA and snorkel activities. Consequently, potential adverse and beneficial impacts would be similar to those described above for sea turtles.
- **Birds.** The impacts to birds would be similar to those listed for vessel impacts under monitoring, mapping, and research. Beneficial impacts are anticipated as a result of coral reef restoration and intervention techniques that would likely lead to increases in abundance and composition of reef and fish assemblages, increasing the food supply, and improved water quality.

Watershed restoration and management. Watershed restoration and management such as monitoring, trail and road stabilization, stormwater control activities, and associated vegetation plantings could potentially result in adverse impacts to sea turtles, marine mammals, and protected birds as a result of disturbance, burial, sound, displacement, turbidity, and habitat loss. Adverse impacts of these activities would be limited to the duration of implementation of restoration projects, and BMPs would reduce any potential adverse impacts of water quality on species. Other projects, such as creation of stormwater treatment wetlands, clearing and revegetating large areas of invasive species, and bank erosion control, may involve the use of heavy machinery for excavation, land clearing, herbicide applications, and hydrologic alterations, and would potentially result in loss of terrestrial habitat due to excavation, contamination due to herbicide use, flooding or drying due to water diversions, and potential mortality of terrestrial species due to physical impacts. Potential adverse impacts to sea turtles, marine mammals, and protected birds as a result of these activities would be indirect, short- and long-term, local, and negligible due to the majority of the work being conducted in terrestrial and wetland habitats.

Benefits to sea turtles, marine mammals, and birds from these watershed restoration and management activities would be direct and indirect, long-term, local to large scale, negligible to moderate. Benefits include restored native terrestrial and aquatic habitat due to erosion reduction and removal of invasive species, greater biodiversity due to removal of invasive species, planting of native species, improved water quality due to reduced sediment and other pollutant runoff, and reduced physical disturbance due to stabilized stream flows.

- **Sea turtles.** Watershed restoration and management activities may result in discharge of sediments and other pollutants into coastal and marine waters, as described for sediments (Section 4.3.1) and water quality (Section 4.3.4). Potential adverse impacts of watershed restoration and management activities include construction along sea turtle nesting beaches that would involve sediment disturbance, temporary sound, and light pollution that could affect emerging juvenile sea turtles in the unlikely event that night operations were utilized. Nest loss or reduced nesting could have long-term impacts on sea turtle populations. The adverse impacts could result in direct, short-term, local, negligible to moderate impacts to sea turtles. BMPs, including stopping work on nesting beaches during the nesting season, daylight operations only, turbidity and sediment control measures (Section 4.3.4), would reduce these impacts. Overall, there would be benefits to sea turtles from watershed restoration and management activities by reducing erosion and sedimentation of a watershed and improving water quality in adjacent coastal and marine waters.

- **Marine mammals.** Potential impacts to marine mammals due to watershed-related activities would also be related to sediment and other pollutants discharging into coastal and marine waters, similar to those for sea turtles, as described above. However, due to the location of most watershed restoration projects on land, most marine mammals will not likely be affected adversely. Marine mammals may benefit by long-term reduction of erosion, improved water quality, reduced pollutant runoff, and increased research to improve watershed management.

- **Birds.** Potential impacts to birds due to watershed-related activities are related to construction activities that could potentially disturb, displace, or harm nesting birds or disrupt normal behaviors, such as foraging or mating. Terrestrial, wading, and shore birds that nest in shrubs and trees within wetlands, riparian habitats, and coastal forest could be displaced during construction of stormwater control measures. Adverse effects would be local, short-term to long-term, direct and indirect, negligible to moderate. Benefits to birds would be through improved habitat and water quality, and increased research to improve watershed management.

Reducing physical impacts to coral reef ecosystems. Adverse impacts due to mooring buoy installation and marine debris removal activities would be temporary and minimal. As described in Section 4.6.1, the use and maintenance of navigation markers and mooring buoys are expected to protect coral reef and benthic habitats from unintentional vessel and anchor damage (NPS EIS, 2015). Sea turtles, marine mammals, and birds may be disturbed by in-water activities (i.e., temporary increase in vessel traffic and sound), but they are less likely to be impacted due to the mobility of these species. Debris removal reduces exposure potential and susceptibility of entanglement, ingestion to ESA-listed marine species or damage to coral reef habitats (CRED PEA, 2010 [Section 7.1]).

Potential adverse impacts due to the installation of mooring buoys and removal of marine debris to sea turtles, marine mammals, and protected birds would be direct, short-term, local, and negligible to minor. The fixed lines associated with mooring buoys are highly unlikely to pose an entanglement threat to sea turtles and marine mammals because it is a single, taut line. During the installation of mooring buoys, sound can alter animal behaviors and disrupt normal activities.

Adverse impacts to sea turtles, marine mammals, and protected birds from marine debris removal are related to operation of vessels and divers, and potential sediment resuspension during the activity. These disturbances, however, would primarily be local, and the effects would be minor and short-term. However, leaving large debris results in further damage to the reef as debris can re-mobilize further impacting reefs by moving back and forth in place, move across a reef by wave or wind energy or break apart thus spreading debris to a broader area (MDP PEA, 2013 [Section 5.2]). Furthermore, not removing marine debris can be an entanglement hazard to ESA-listed species and other marine life. Therefore, reducing the potential entanglement hazards by removing marine debris and damage to benthic habitats from anchors and grounding, the potential benefits to sea turtles, marine mammals, and protected birds would be direct and indirect, short- and long-term, local, and negligible to major.

- **Sea turtles.** Sea turtles could be impacted by increased vessel and equipment use for installation of mooring buoys and/or debris removal contributing to unintentional vessel strikes. However, those instances would be localized, and short-term and would be mitigated by the implementation of the CRCP's BMPs. Sounds from buoy installation or removal of marine debris can alter behavior (e.g., disrupt foraging) if a sea turtle is in the area during installation or removal activities. Removing marine debris also reduces potential entanglement and ingestion hazards to sea turtles. For example, rope, chain, nets, or other loose material can trap sea turtles to a point that their movement is restricted, and they cannot surface for air, search for food, or avoid predators.
- **Marine mammals.** Potential adverse and beneficial impacts to marine mammals due to mooring buoy installation and marine debris removal are consistent with potential impacts to sea turtles described above, including the benefit to reduce potential entanglement hazards to species such as the Hawaiian monk seal.
- **Birds.** Adverse impacts to listed birds due to mooring buoy installation and marine debris removal would be negligible due to implementation of the BMPs and their ability to move away from in-water construction activity. Benefits to reducing marine debris would be direct, short-term, local, and negligible to major due to the reduction in entanglement hazards, contamination, and decreased potential to ingest marine debris.

4.5.2.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to sea turtles, marine mammals, and protected birds from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. The continued direct loss of coral reef habitat is expected under Alternative 1 due to elimination of coral proposed activities and activities that reduce the impacts of coral-specific invasive species, disease, and predators (Section 4.4.3). Potential adverse impacts to sea turtles, marine mammals, and protected birds under this alternative would be direct and indirect, short- and long-term, local and large scale, and minor to moderate due to the continued loss of coral reefs. No benefits to sea turtles, marine mammals, or protected birds are expected as a result of excluding coral reef restoration and intervention activities.

Watershed restoration and management. Potential adverse impacts and benefits to sea turtles, marine mammals, and protected birds would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of mooring buoys and components of the marine debris removal currently conducted by the CRCP could result in continued damage and injury to sea turtles, marine mammals, and birds. Eliminating this portion of the CRCP would not affect debris removal that occurs under NOAA's extensive Marine Debris Program and would only eliminate debris removal in a relatively small number of the CRCP project areas. Increased anchoring, without a mooring buoy, can lead to increased sediment disturbances, resuspension of debris, and direct injury to listed species. Results include continued impacts of marine debris on sea turtles, marine mammals, and protected birds in marine and coastal habitats. These species can be impacted by debris, including plastics, in the marine environment through entanglement and ingestion (Wilcox, 2018). Entanglement of sea turtles, marine mammals, and birds in marine debris, at sea or on beaches, can reduce the movement of an animal, restricting its access to air and food. Ingestion of plastics can cause mortality in juvenile and adult sea turtles, marine mammals, and birds if the object cannot pass through the digestive tract (Wilcox, 2018). According to the United Nations Environmental Programme, more than 260 species of animals worldwide—including marine mammals, birds, turtles, crustaceans, and fish—have been reported entangled in marine debris or have ingested it (Kershaw et al., 2011). In the U.S., at least 115 different marine species have become entangled in plastic marine debris (MDP PEA, 2013). In particular, fishing line and nets, plastic ribbons on balloons, and similar types of trash can easily entangle animals. Derelict fishing gear is an important threat to endangered species, such as the Hawaiian monk seal, and causes significant mortality for other marine mammals, seabirds and invertebrates. Ghost fishing, which traps marine biota in derelict fishing gear, is a chronic stressor for fisheries, with direct economic losses through target and non-target species mortality (MDP PEA, 2013). Potential adverse impacts would be direct and indirect, short- and long-term, local, negligible to moderate. No benefits to sea turtles, marine mammals, or protected birds are anticipated as a result of eliminating these activities.

Monitoring, mapping, and research activities would continue to provide information critical to conservation and management of listed species. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters and benefit listed species. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address coral restoration and physical impacts to coral reefs. Therefore, overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.5.2.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to the BMPs that are part of the current CRCP and may further reduce the potential for adverse impacts to sea turtles, marine mammals, and protected birds from proposed activities. Implementation of DCMMs alone would have no adverse impacts to these protected species. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions as a result of DCMMs, depending on the activity.

Additional training with vessels and equipment, additional limitations and precautions for mooring buoy and equipment installation, and reduced anchoring due to use of permanent mooring buoys would be expected to further reduce the negligible adverse impacts to sea turtles, marine mammals, and birds due to monitoring, collection, vessel operation and buoy installation, debris removal, and other in-water activities described under the No Action Alternative (NOAA, 2013). Benefits of DCMMs that reduce the risks associated with coral restoration and intervention would also benefit coral reef habitats and their potential value to sea turtles and marine mammals. Additional DCMMs may provide further, but likely negligible, benefits to wetlands and floodplains when compared with the No Action Alternative.

4.6 Socioeconomic Environment

4.6.1 Cultural Resources

Cultural resources include a variety of physical resources protected by Federal statute and Executive Orders and include archaeological resources, antiquities, shipwrecks, historic properties and resources of importance to federally recognized tribes and NHOs. Activities conducted under the CRCP would continue to comply with applicable statutes, Executive orders and NOAA policies addressing cultural resources as those activities are proposed, planned and implemented. Of primary importance to the CRCP is the NHPA, which provides a legal framework for identifying the foregoing resources, to the extent they meet certain criteria; predicting effects; and in consultation with specified stakeholders, resolving adverse effects. The NHPA defines a historic property as "any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on the National Register [of Historic Places]." Also included are any artifacts, records, and remains (surface or subsurface) that are related to and located within historic properties and any properties of traditional religious and cultural importance to Tribes or NHOs. These resources may be above ground, below grade, or submerged in waterways and include resources listed in, or eligible for listing in the NRHP.

Examples of terrestrial cultural resources may include buildings, structures, sites, and objects. Examples of marine cultural resources may include shipwrecks, navigation landmarks, traditional fishing areas, and relic weapons and ammunition. Effects to cultural resources that are considered adverse, including those under the NHPA, include physical destruction, damage, or alteration, including moving the property or cultural resource from its historic location; isolation from, or alteration of, the setting; and introduction of intrusive elements. Proposed activities could have direct, permanent, minor to moderate adverse impacts to cultural resources during restoration or other on-the-ground activities. While they are derived from impacts to the characteristics that may qualify the site for inclusion in the National Register based on the following definitions (adapted from NOAA RC PEIS 2015), we apply them to all cultural resources. For this DPEIS, the intensity of adverse impacts to cultural resources are described below.

- Minor: the effect is detectable but small and effects are limited to the area of a site, structure, or group of sites or structures. Impacts to any of the characteristics that qualify the site(s) for inclusion in the National Register may diminish the integrity of the site(s). For purposes of Section 106, the determination of effect would be adverse impact.
- Moderate: the effect is measurable and detectible and may alter one or more of the characteristics that qualify the site(s) or structure(s) for inclusion in the National Register and diminishes the integrity of the site(s) but does not jeopardize its National Register eligibility. For purposes of Section 106, the determination of effect would be adverse effect.
- Major: the impact to the site or structure, or group of sites or structures, is substantial, noticeable, and permanent, alters one or more characteristics that qualify the site(s) for inclusion in the National Register, diminishing the integrity of the site(s) or structure(s) to such an extent that it is no longer eligible for listing in the National Register. For purposes of Section 106, the determination of effect would be adverse effect.

Given the nature of cultural resources, adverse impacts are generally considered permanent, except when impacts are restricted to proposed activities that temporarily prevent the use of a site for culturally important practices or impair a viewshed. When there is a potential for impact to archeological or historical resources, NOAA consults with the appropriate state and local officials, federally recognized tribes, NHO, and potentially the Advisory Council on Historic Preservation and considers their views on effects to cultural resources and resolves adverse effects prior to making a final project implementation decision. The proposed action and alternatives analyzed in this DPEIS are programmatic in nature and, therefore, do not trigger any specific NHPA Section 106 compliance requirements. However, any CRCP activities that might affect cultural resources would undergo project-specific NHPA Section 106 consultations in the future. Such consultation frequently results in a letter from (SHPO) or Tribal Historic Preservation Officer (THPO) with a determination of "no historic properties affected" or with stipulations to reduce the adverse impacts such as the following:

- Archival quality photographs of structures prior to removal and documentation on appropriate state-designated forms,
- Immediate notification of SHPO/THPO if previously undocumented historic properties or sites are discovered during the project;
- Interpretive signs,
- Development and implementation of unanticipated discovery plans,
- Installation or remediation of structures in accordance with the Secretary of the Interior's Standards for Rehabilitation, and
- Monitoring of excavations and site disturbance by a historian or archaeologist who meets the Secretary of the Interior's Professional Qualification Standards.

4.6.1.1 No Action Alternative

Cultural resources have the potential to be affected by any ground-disturbing activities or other activities that may diminish the integrity of the structure or site. Impacts to cultural resources resulting from the implementation of CRCP activities are dependent on site-specific conditions.

Monitoring, mapping, and research activities. Monitoring, mapping, and research activities have the potential to impact cultural resources due to disturbances due to soil or sediment sampling in the marine and terrestrial environments. However, sediments samples would be small and would be located as to not impact known cultural resources. Adverse impacts to marine cultural resources from anchoring, monitoring and sampling equipment, and diving activities may also occur due to disturbances by vessels and other in-water activities. Potential adverse impacts are expected to be direct, short-term, local, and negligible to minor. Discovery or recovery of cultural or historic resources would allow their future protection. Benefits of these activities include reduced erosion of soils covering archaeological sites, or increased use of the site for culturally important practices, such as subsistence harvest, and data to support greater protection for cultural resources. Potential benefits would be indirect, long-term, local to large scale, and negligible to minor due to the potential for identifying cultural resources during surveys for other resources.

Coral restoration and interventions. Potential impacts to cultural resources due to coral restoration and interventions would be limited to associated vessel activity, equipment use, and SCUBA and snorkel activities. Consequently, potential impacts would be the same as those described for monitoring, mapping, and research, activities, described above.

Watershed restoration and management. Construction activities associated with watershed restoration and management activities may impact cultural resources due to land surface disturbance, excavation, and construction of stormwater management projects. Consultation with the appropriate SHPO/THPO and other consulting parties prior to project construction would minimize or preclude the likelihood of disturbance or damage to a known cultural or historic site or structure. If an undocumented cultural or historic structure or site is discovered, construction activities would cease, the local SHPO/THPO office would be notified, and consultation would proceed as appropriate. In this case, there is potential for initial damage to the integrity of a site or structure, but it is likely that the disturbance would result in adverse effects of an intensity that would preclude it from eligibility for listing in the National Register due to a loss of integrity. Consequently, potential adverse impacts to cultural resources from these activities would be direct and indirect, long-term, local, and negligible to minor. Benefits would be direct, long-term, local, and negligible to moderate, due to the potential for identifying and preserving cultural resources.

Reducing physical impacts to coral reef ecosystems. Potential impacts to cultural resources due to mooring buoys and debris removal would also be limited to associated vessel activity, equipment use, and SCUBA and snorkel activities. Therefore, potential impacts would be the same as those described for monitoring, mapping, and research activities, described above.

4.6.1.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to cultural resources from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Eliminating coral restoration and intervention activities under Alternative 1 would also eliminate the potential for adverse impacts to cultural resources that may occur as a result of these activities. For example, eliminating coral reef intervention activities may also eliminate some opportunities to visit these reefs and observe sites that may have the potential to be a site of historical or cultural significance. Adverse impacts may result from the loss of coral reefs and subsequent reductions in coastal resource protection (including cultural resources) from wave and storm energy, and the potential damage. Potential adverse impacts to cultural resources would be expected to be direct, short- to long-term, local, and negligible. Benefits to cultural resources may occur due to reduced disturbance under this alternative, but the potential reductions would be negligible. In addition, recovery and preservation of such coastal resources may be reduced as a result of reduced coastal activities that may include the documentation of cultural resources encountered during their implementation. Potential benefits would be indirect, long-term, local, and negligible.

Watershed restoration and management. Potential adverse impacts and benefits to cultural resources would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of permanent mooring buoys under the No Action Alternative would have the potential for direct damage to cultural resources from continued multiple anchorings and anchors dragging along the sea floor where resources may occur. Without removal of marine debris, derelict fishing gear, vessels, and other debris would continue to accumulate and/or move across the sea bottom with currents and waves, resulting in physical disturbance to cultural resources that may be present, as well as potential contamination due to fuels or other pollutants (Section 4.3.4). Adverse impacts to cultural resources would be direct, short- to long-term, and negligible to major. However, in the absence of debris removal, the potential for disturbing, or recovering, any potentially present cultural resources is also eliminated, as is the potential for the identification of the same resource. Benefits to cultural resources as a result of Alternative 1 would be indirect, long-term, local, and negligible to minor.

4.6.1.3 Alternative 2

Under Alternative 2, there are no DCMMs (Appendix B) that directly address cultural resources. However, additional DCMMs under Alternative 2 that have the potential to affect cultural resources include addition controls to reduce turbidity and sediment, management plans to ensure activities are completed and equipment removed when no longer in use, greater restrictions on instrument mooring, prioritizing the use of recreational mooring buoys or live boating, and additional training for vessel operators. These activities would further reduce erosion and runoff into coastal and marine waters that may bury or damage cultural resources. No adverse impacts are anticipated as a result of these additional DCMMs. Adverse impacts would be the same as for the No Action Alternative.

Overall, additional activities included under Alternative 2 would further contribute to the reductions in adverse impacts to cultural resources that may occur under the No Action Alternative. Benefits due to additional reductions in stormwater runoff and in-water activities anticipated as a result of additional DCMMs would be negligible under the No Action Alternative.

4.6.2 Public Health and Safety

Potential impacts to human health and safety associated with implementation of activities under the proposed alternatives may include exposure to or increased likelihood of oil and hazardous materials, occupational hazards, flooding, and/or shoreline damage, as well as physical injury due to heavy machinery or vessels. Workers are protected under the federal Occupational Safety and Health Administration, which mandates that employers protect their employees from occupational hazards that may result in injury and are therefore not addressed here.

4.6.2.1 No Action Alternative

Under the No Action Alternative, projects that involve the use of vessels, diving, and other in-water activities, as well as the use of heavy machinery in the watershed have the potential to result in accidents and injury.

Monitoring, mapping, and research. Under the No Action Alternative, areas proposed for monitoring, mapping, and research would remain open to visitors during work to implement proposed activities. Boater safety practices and signs/markings to indicate work areas would reduce the risks of injury and/or vessel groundings. Possible introduction of invasive species or coral diseases into new areas may also adversely impact public health and safety by reducing the potential recovery among coral reefs, which could reduce shoreline protection. However, the CRCP’s BMPs (Appendix A) include decontamination protocols to reduce the likelihood of spreading coral diseases. Pollutant spills from boats or other vehicles (e.g., paint, fuel) may travel offsite and expose visitors to the pollutants. Risks would be mitigated by the use of BMPs that reduce opportunities for trespass into work areas and reduce the possibility of pollutant release. Potential adverse impacts to public health and safety would be direct, short- to long-term, local, and negligible.

Benefits of these activities include acquisition and information to improve public health and safety. For example, data collected in coastal and marine waters would support fishing and other recreation management and help identify areas that may be impacted by flooding due to surface water runoff, sea level rise, or storm-related risks. Potential benefits to public health and safety would be indirect, long-term, local to large scale, and negligible to moderate.

Coral restoration and intervention. Potential adverse impacts to public health and safety due to coral restoration and intervention activities would include those described for monitoring, mapping, and research. The potential for introduction of invasive species, disease, or corallivores into new areas may also adversely impact public health and safety by reducing the potential recovery among coral reefs, subsequently reducing shoreline protection due to coral reefs. However, the CRCP's BMPs (Appendix A) include decontamination protocols to reduce the likelihood of spreading coral diseases. Adverse impacts would be direct, short-term, local, and negligible to minor. Benefits to the public from coral restoration and intervention include recovery of coral reefs, associated fisheries, and shoreline protection. There would likely be a benefit to public health and safety due to natural storm protection to surrounding communities from persistent or recovering coral reefs. Benefits to public health and safety would be direct and indirect, long-term, local, and negligible to minor.

Watershed restoration and management. Watershed restoration and management activities may result in mobilization of contaminants from machinery, fuels, or other materials associated with excavation or construction of stormwater treatment wetlands, LID, road stabilization, and other activities. Exposure of humans or other sensitive receptors such as plants and wildlife to contaminant levels could result in health effects. Herbicide applications for invasive species, if not implemented correctly, may pollute surface or groundwater or soils and may travel offsite, although herbicides would be applied by a licensed applicator according to the label and established protocols for the locality. Excavation or land-clearing activities could disturb soils and mobilize legacy contaminants. However, assessment of historic or potential environmental contamination and/or documented environmental issues would provide information to prepare for the potential presence of, for example, soil or groundwater contamination, unsafe ground conditions, erosive soils, or other conditions with the potential to compromise public health and safety. Construction BMPs (Appendix A) would reduce the likelihood of surface water moving offsite. Volunteers would be trained to follow BMPs and other safety protocols to ensure public health or safety issues. Potential adverse impacts to public health and safety due to watershed restoration and management activities would be direct and indirect, short- to long-term, local, and negligible to minor.

Benefits to public health and safety from these activities include reduced risk of potential hazards to visitors, residents, and workers due to improved shoreline and flood protection and improved water quality in downstream and coastal waters. Subsequent benefits to fisheries from improved water quality would improve the number and quality of fish available for recreational and subsistence fishing. Restored native habitats may reduce the spread of invasive species and subsequent impacts to local agriculture and gardens. Potential benefits would be direct and indirect, short- and long-term, local and larger scale, and negligible to minor.

Reducing physical impacts to coral reef ecosystems. The addition of mooring buoys would benefit public health and safety by providing safe sites for visitors to stop for recreation and/or fishing and reducing vessel crowding by installing buoys in safe locations. As a result, the potential for vessel groundings and interactions with other vessels and anchors would be reduced. Debris removal activities would have the same impacts described for monitoring, mapping, and research activities, above, due to in-water activities involving vessels, equipment, and divers. Large derelict shipwrecks may offer dive exploration opportunities but may also be a safety issue. Potential adverse impacts of contamination from debris due to inadvertent fuel spills or other chemicals and subsequent water degradation that may result in beach advisories for beach goers (see Section 4.3.4) or physical harm to visitors due to persistent debris such as derelict fishing gear or remains of derelict gear or vessels and the potential for contact with the debris may also adversely impact public health and safety. Adverse impacts from debris removal would be direct, short-term, local, and negligible to minor. Marine debris removal activities would improve public health safety by removing and preventing the accumulation of marine debris by improving navigation safety. In addition, these projects can create new recreational opportunities and waterfront revitalization, provide sediment to nourish beaches, and decrease safety and liability concerns. No adverse impacts to public health or safety concerns are likely to result from debris removal activities (NOAA MDP, 2013). Benefits would be direct, long-term, local, and negligible to minor.

4.6.2.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to public health and safety from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Eliminating coral restoration and intervention activities under Alternative 1 would also eliminate the potential for adverse impacts that may occur under the No Action Alternative, such as temporary water quality degradation or sediment disturbance. Under Alternative 1, adverse impacts to public health and safety would be expected due to the subsequent loss of coral reefs in the absence of restoration efforts. Adverse impacts would include increases wave energy reaching the coastline and subsequent shoreline damage and greater potential for flooding. Potential adverse impacts to public health and safety would be expected to be direct and indirect, short- to long-term, local, and negligible to moderate. No benefits to public health and safety under Alternative 1 are anticipated.

Watershed restoration and management. Potential adverse impacts and benefits to public health and safety would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Mooring buoys reduce the potential for anchor damage to coral reefs and other habitats and reduce the number of anchors on the sea bottom. Eliminating the installation of permanent mooring buoys under the No Action Alternative would result in further crowding and anchoring in areas most frequented or favored by boaters and would result in potential safety issues due to larger numbers of boats, anchors, and visitors in an area. Without mooring buoys, visitors may be unable to find safe anchoring locations, which could result in further safety issues related to vessel groundings or other boating accidents. Without moorings, in the potential interactions among anchors from different boats, and subsequent safety issues would persist. No benefits to public health and safety are anticipated as a result of eliminating installation of additional permanent mooring buoys. If the CRCP does not participate in debris removal, some debris removal may be delayed, but NOAA's Marine Debris Program and other organizations would continue to work to remove such debris. Therefore, if the CRCP were not to implement debris removal activities, the adverse effects would not be detectable.

Potential adverse impacts to public health and safety under Alternative 1 would be direct, short-term, and negligible to moderate. No benefits to public health and safety are anticipated as a result of eliminating these activities.

Monitoring, mapping, and research activities would continue to provide information for managing coastal and marine resources with respect to public health and safety. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water quality in coastal waters. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that directly address the potential impacts of mooring buoy installation, marine debris, and coral restoration to public health and safety. Therefore, overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.6.2.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP and may further reduce the potential for adverse impacts to public health and safety during proposed activities. Implementation of DCMMs alone would have no adverse impacts to public health and safety. Adverse impacts under Alternative 2 would be similar to the No Action Alternative but may have additional, negligible reductions in impacts as a result of DCMMs are anticipated.

DCMMs that may affect public health and safety include BMPs to control turbidity and sediment, management plans to ensure activities are completed and equipment removed when no longer in use, greater restrictions on instrument mooring, prioritizing the use of recreational mooring buoys or live boating, and additional training for vessel operators. These activities further enhance the public health and safety by reducing erosion and runoff in the watershed, improving water quality in coastal and marine waters, and reducing the potential impacts of accumulating marine debris on the seafloor.

4.6.3 Economic Environment

Healthy coral reefs and associated habitats in U.S. coral reef jurisdictions support tourism, recreation, and economic opportunities. In the U.S., approximately half of all federally managed fisheries, both commercial and recreational, depend on coral reefs and associated habitats for at least a portion of their life cycles (NOAA, 2018b). These fish are a significant food source for more than one billion people worldwide, and U.S. reef-related fisheries are valued at more than $100 million (NOAA Fisheries, 2019a), accounting for a large part of the overall commercial industry. Global reef fisheries are considered unsustainable based on several studies (McClanahan et al., 2011; Teh et al., 2013, Newton et al., 2007).

In 2010, more than 163 million people (approximately 52% of the U.S. population) lived in coastal counties, and this number is expected to increase to 178 million by the year 2020 (NOAA, 2013). Approximately eight million individuals participated in coastal recreational fishing along the Atlantic and Gulf of Mexico coasts each year between 2009 and 2014 (NOAA, 2019b). The most recent NOAA data indicate the commercial fishing industry employs around 1 million people (about 1,029,000 in 2009) and contributes $116 billion to the nation's economy. Recreational fishing industries supported about 327,000 full- and part-time jobs, contributing $50 billion to the nation's economy (NMFS, 2011). A recent study estimated that U.S. coral reefs provide more than $1.8 billion in shoreline protection (Storlazzi, 2019).

The CRCP funded and summarized coral reef valuation studies for each of the sevel U.S. coral jurisdictions. This summary (NOAA CRCP, 2013) presents a valuation of goods and services (e.g., tourism and recreation, fisheries, coastal protection, cultural resources, and biodiversity) provided by coral reefs under U.S. jurisdiction. In order to compare the studies across jurisdictions the annual values were converted to 2012 dollars and are presented in Table 4-2 (NOAA CRCP, 2013).

Table 4-2. Annual economic values of U.S. coral reefs based on the CRCP supported valuation studies.

Location	Study Year	2012 Value ($Million/year)
Florida	2001	324
Hawaii	2002	455
American Samoa	2004	11
CNMI	2006	68
Guam	2007	150
Puerto Rico	2008	1,161
USVI	2011	210

Source: NOAA Summary Report: The Economic Value of U.S. Coral Reefs (NOAA CRCP, 2013)

The values presented in Table 4-2 are lower than earlier citations ($8.5 billion) for economic activity linked to coral reefs because economic values (benefits) are inherently different from economic impacts (activity). Economic value resides in the contributions that ecosystem functions make to human well-being, while economic impact describes localized economic effects on local businesses and communities (sales, employment, income, and taxes). Economic impacts do not measure benefits to resource users. The table only highlights the mostly non-market economic values for coral reefs in these jurisdictions.

The impacts to coastal resources from human activities such as agriculture, transportation, port development, and urban development in general have been presented in previous sections (e.g., Section 4.3.4 and Chapter 3) and include degraded water quality and sediments and losses of coastal and marine habitats. Indirect adverse impacts could occur during construction through limits on recreational activities near the construction area to protect public safety, temporary increases in road traffic due to movement of construction vehicles, and adverse effects on aesthetics due to the presence of construction equipment, new breakwaters, or other changes to the surrounding environment (NOAA PDARP/PEIS, 2016).

4.6.3.1 No Action Alternative

Under the No Action Alternative, benefits to economies due to improved opportunities for recreation and tourism are expected due to improved health of coral reefs and associated habitats and subsequent increases in fisheries sustainability and other ecosystem services (e.g., coastal protection, biodiversity). Socioeconomic activities would also be affected by area closures that may occur due to logistics and safety reasons during some of the proposed CRCP activities under the No Action Alternative.

Monitoring, mapping, and research. Under the No Action Alternative, areas proposed for monitoring, mapping, and research would remain open to visitors during work to implement proposed activities. Boater safety practices and signs/markings to indicate work areas would reduce the risks of injury and/or vessel groundings. Adverse impacts of closures would be direct, short-term, local, and negligible. Benefits of mapping monitoring and research activities may include improved knowledge and management of coral ecosystems and their services and would be indirect, short-term to long-term, local, and negligible to moderate.

Coral reef restoration and interventions. Visitors are not required to be excluded from coral nursery areas during restoration and intervention. Because of the locations and small number of coral nursery sites around the globe, adverse impacts to tourism, recreation, or socioeconomics in general are not anticipated. Potential adverse impacts to socioeconomics would be direct and indirect, short- to long-term, local, and negligible to minor. Benefits to socioeconomics from coral reef restoration and intervention would be direct and indirect, long-term, local, and negligible to moderate.

Watershed restoration and management. Area closures to protect public safety during construction may result in short-term limitations on tourism and recreational uses. If these closures occur in areas where hunting, fishing, and tourist activities are high, users may choose to pursue these activities elsewhere or not at all. Potential adverse impacts to tourism and recreation resulting from potential closures would be expected to be direct, short-term, local, and negligible to moderate. Long-term benefits to the public are anticipated as a result of activities to reduce runoff, land loss, and restore native habitats. Implementation of watershed restoration and management activities that include upgrades or maintenance of infrastructure could result in minor, short- and long-term economic impacts related to funding of these efforts. Depending on the projects implemented, short-term benefits to the local economy could accrue through an increase in employment and associated spending in the project area during construction activities. Projects that are anticipated to enhance stormwater infrastructure would be expected to result in improved public health and safety as a result of improved runoff controls and reduced stormwater flooding that may otherwise flood streets and interfere with utilities, including storm sewers and wastewater facilities. Potential benefits would be direct and indirect, short- and long-term, local, and negligible to minor.

Reducing physical impacts to coral reef ecosystems. The installation of mooring buoys and removal of debris may require temporary closures in action areas for logistics and safety reasons in specific research areas, otherwise closures are not anticipated. No changes to fishing, boating, or other practices are anticipated as a result of these activities. Potential adverse impacts to socioeconomics would be the same as those for monitoring, mapping, and research. None of the alternatives and proposed activities are anticipated to adversely impact recreation opportunities. Benefits would include easier and safer anchoring, snorkeling, and SCUBA activities and would be direct, long-term, local, and negligible to moderate.

4.6.3.2 Alternative 1

Under Alternative 1, current CRCP activities that support coral restoration and intervention and reduce physical disturbance to corals would be eliminated.

Monitoring, mapping, and research. Potential adverse impacts and benefits to socioeconomics from monitoring, mapping, and research activities would be the same as described for the No Action Alternative.

Coral reef restoration and interventions. Potential adverse impacts to socioeconomics would be expected due to the continued decline and loss of coral reefs in the absence of restoration and intervention efforts. Adverse impacts would include associated loss of fish habitat, as well as increases wave energy reaching the coastline and subsequent shoreline damage and greater potential for flooding. Potential adverse impacts to socioeconomics would be expected to be direct and indirect, short- to long-term, local and large scale, and negligible to major. No benefits to socioeconomics under Alternative 1 during proposed activities would be expected.

Watershed restoration and management. Potential adverse impacts and benefits to socioeconomics would be the same as described for the No Action Alternative.

Reducing physical impacts to coral reef ecosystems. Eliminating the installation of permanent mooring buoys under the No Action Alternative may reduce water quality and benthic habitat damage due to continued multiple anchor deployments and anchors dragging along the seafloor in areas used by boaters. Without debris removal, derelict fishing gear, vessels, and other debris would continue to accumulate and/or move across the sea bottom with currents and waves, reducing the recreational, tourism, and socioeconomic opportunities associated with coastal and marine resources. Potential adverse impacts to socioeconomics under Alternative 1 would be direct, short- to long-term, local to large scale, and negligible to moderate. Benefits as a result of Alternative 1 would be direct, short-term, local, and negligible to minor.

Monitoring, mapping, and research activities would continue to provide information for managing coastal and marine resources with respect to socioeconomics. Watershed restoration and management activities would continue to reduce sediment and other pollutant loads and improve water clarity in coastal waters and socioeconomics. However, the overall benefits would be reduced due to the exclusion of the components of the CRCP that address the socioeconomic benefits of coastal and marine resources (i.e., tourism, recreation, coastal protection, fisheries sustainability, biodiversity). Overall potential benefits would be direct and indirect, short- to long-term, local, and negligible to minor.

4.6.3.3 Alternative 2

Under Alternative 2, DCMMs (Appendix B) would be implemented in addition to BMPs that are part of the current CRCP. Regarding DCMMs for projects that might negatively affect certain groups of people, efforts need to be made to educate user groups about the importance of and need for implementing the activities that support monitoring, mapping, and research; restore viable coral populations; restore and manage watersheds; and reduce physical impacts. Implementation of DCMMs alone would have no adverse impacts to socioeconomics. Adverse impacts under Alternative 2 would be similar to the No Action Alternative and may have additional, negligible reductions in impacts as a result of DCMMs. Additional DCMMs that may affect socioeconomics include BMPs that may further reduce adverse impacts to water quality and coastal marine habitats and, therefore, further improve the socioeconomic values for those who use these resources.

4.7 Cumulative Impacts

In accordance with NEPA and to the extent reasonable and practical, this DPEIS considers the combined incremental programmatic effects of the No Action Alternative, Alternative 1, and Alternative 2 with the effects of other past, present, and reasonably foreseeable actions to common resources identified, regardless of what agency (federal or nonfederal) undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant impacts from actions taking place over time. Cumulative impacts are an important consideration for programmatic analyses because of the potential for additive effects from individual projects that may result in a cumulative effect to a resource in the project area. Analyzing cumulative effects at a programmatic level is also challenging, primarily because of the large geographic extent of the CRCP programs, the long timeframes considered, and the future of program decisions.

The scope of the cumulative impact analysis for the CRCP proposed action and alternatives involves both the geographic extent of the effects and the timeframe in which the effects could be expected to occur, as well as the resources potentially cumulatively affected. When applying the concept of cumulative impacts to a programmatic analysis, additional consideration must be given to uncertainty associated with selection of specific future project locations. The design, construction, and operation of the CRCP activities would occur throughout U.S. coral reef jurisdictions and all specific project sites have not yet been identified. Furthermore, there is currently a wide range of existing, new, and developing technologies that NOAA and/or its partners may use to implement the CRCP. As such, it is not possible to quantify the cumulative effects of these projects when combined with other potential projects. Therefore, cumulative impacts are assessed qualitatively. Affected resources, program boundaries, and potential (past, present, and reasonably foreseeable) cumulative actions considered for this analysis are presented below. Cumulative impacts of individual projects conducted under the CRCP, as noted, will be conducted as necessary through project level review.

4.7.1 Resources Affected

Resources retained for analyses are considered here. None of the alternatives would result in potentially significant cumulative impacts at the programmatic level based on the impact significance criteria and analysis presented in this DPEIS. Impacts could occur as a result of other past and ongoing projects, but when combined with the potential impacts associated with the proposed action under any alternative, incremental impacts to the natural and human environment are not expected to be significant at the programmatic level. The project types that involve new construction and/or ground-disturbing activities would tend to be limited by their nature in the extent and duration of their effects, and these projects would include appropriate BMPs and/or mitigation measures to further reduce the already limited potential impacts. As reflected in previously prepared PEISs and PEAs and described in Section 4.2.3, no significant cumulative adverse impacts to resources are anticipated as a result of implementing the proposed activities.

Cumulatively, effects associated with project operations are not expected to be significant at the programmatic level. Taken together, these projects are not expected to result in significant adverse incremental cumulative impacts to either human health or the environment, because the long-term benefits essentially reflect increased sustainability and quality of coastal and marine habitats and fauna. The key factor to cumulative assessment is identifying any potential temporally and/or spatially overlapping or successive effects that may significantly affect resources occurring in the analysis areas (CEQ, 1997; EPA, 1999).

4.7.2 Geographic Boundaries and Timeframes

The spatial boundary includes those areas where CRCP activities described in each alternative are likely to occur, which is within U.S. coral reef jurisdictions and priority international areas. Although species such as highly migratory fish and wildlife may use areas beyond the jurisdictions, an analysis of potential cumulative impacts beyond these boundaries would be speculative and uninformative. Moreover, as explained, CRCP activities affect near-shore coastal resources and we anticipate little to no effect in the open ocean environment. Cumulative impact analyses in any subsequent tiered environmental reviews will address this potential at that more appropriate scale.

The duration of project implementation and useful project life, which can vary substantial depending on the specific details for each project, also contribute to an assessment of cumulative impacts. Although most CRCP projects last one to three years, over 75% of NOAA Restoration Center projects supported between 1992 and 2015 were short-term in duration and had design and construction durations less than five years (NOAA RC PEIS, 2015). Of those, many had an active construction window of only weeks or one to two seasons. Most (short-term) adverse impacts from restoration occur during the construction phase. NOAA has supported parts of longer-term, larger-scale projects that have taken longer than five years to design and implement or has continually supported the same restoration work in a given area for more than five years. These projects may have a higher likelihood of resulting in a cumulative impact from other construction activities happening at the same time or location. Similarly, the effects of one project may persist during implementation of another project, leading to a cumulative effect. This is usually, but not always, likely to occur in watersheds where large numbers of acres have been restored.

4.7.3 Past, Present, and Reasonably Foreseeable Future Actions

Actions or groups of actions within the established geographic and timeframe boundaries that are also programmatic in nature were considered. There may be additional small-scale activities not currently identified; however, these descriptions of actions provide the necessary information to fully understand the cumulative impacts to resources that may occur. The *CEQ Memorandum Guidance on Consideration of Past Actions in Cumulative Effects Analysis* (CEQ, 2005) states that consideration of past actions is only necessary insofar as it informs agency decision-making and that "[a]gencies are not required to list or analyze the effects of individual past actions unless such information is necessary to describe the cumulative effect of all past actions" (CEQ, 2005). Agencies may aggregate the effects of past actions without delving into the historical details of individual past actions. Chapter 3 presented a discussion of past activities that have influenced the current condition of many resources and identified impacts of those activities that are likely to persist (e.g., activities resulting in long-term climate change). In addition, to establish the context for the direct and indirect impacts analyses in Chapter 4 we included a brief description of past actions that have influenced the current condition of specific resources. Those discussions, while relevant, are not repeated here for efficiency.

Various impacts from other physical activities may occur at or near project sites, which may also have an additive effect on a proposed action. The present analysis considered the alternatives discussed in Chapter 2 and other programmatic-scale actions because analysis of specific actions for every potential project site or location neither practical nor informative. Cumulative effects analysis of individual projects and other past, present, and reasonably foreseeable future actions relevant at the local level can be addressed as part of future project-specific NEPA reviews, if needed. Project-specific analysis may be required depending on the site conditions, the type of deployment, or any other permits or permissions necessary to perform the work. Types of reasonably foreseeable future actions that may contribute negatively or positively to a cumulative effect to the natural or human environment in or proximate to a project site are briefly described below.

- **NOAA restoration projects.** The NOAA Restoration Center has restored 3,900 to 9,800 habitat acres per year since 2003. In 2016, the NOAA Restoration Center restored almost 200,000 acres (809 km^2) of habitat and expects to restore about 6,600 acres (27 km^2) per year in the future. A list of approved coral--reef--related projects based on the NOAA RC PEIS 2015 is provided in

Appendix D. The number of NOAA Restoration Center projects may decline as larger projects are given higher priority, resulting in less construction but no decline in total numbers of acres due to economy of scale. Nationwide, the NOAA Restoration Center implemented more than 85 coral restoration projects in waters of Florida, the Caribbean, and the Pacific Islands regions (NOAA RC PEIS, 2015).

- **Other activities conducted by NOAA and other agencies.** The proposed CRCP activities have been developed to address the impacts of land-based sources of pollution, fisheries sustainability, and climate change, and to support recovery of coral reefs. Proposed activities include watershed restoration, monitoring, mapping, research, coral reef restoration, and physical impacts reduction. Other agencies overlap with the CRCP in their focus on similar resources and restoration activities and include projects implemented by other federal, state, and local agencies or groups. Numerous agencies focus on habitat restoration to conserve native resources, protect fish and wildlife, and protect humans from storms and flooding. Cumulatively, these programs further benefit the coral reef ecosystems by implementing conservation and restoration activities that focus on habitats and resources that, while perhaps not the same habitats and resources, are ecologically connected and important to coral reef ecosystems.
    - NOAA's Marine Debris Program focuses on removal of marine debris and is a much larger program when compared to the CRCP. The goal is to remove debris that would otherwise degrade, reduce, or eliminate existing habitat. Similarly, the U.S. Coast Guard is responsible for removing derelict vessels, which cumulatively benefits CRCP resources. While removal of such vessels can result in incremental direct adverse effects to coral reefs and associated habitat, a long-term incremental benefit may occur through habitat restoration efforts occuring after removal of the vessels.
    - NMFS is charged with the conservation of many ESA-listed marine species, critical habitat, and EFH. Some such resources include coral reefs and associated habitat and species and NMFSs effort to conserve those resources would benefit coral reef ecosystems that the CRCP aims to conserve.
    - Similarly, the USFWS has authority under the ESA to protect some marine species and their designated critical habitat. Examples include sea turtle nesting beaches and manatees. Thus, the USFWS's efforts to conserve resources that use coral reef habitats would benefit coral reef ecosystems as well.
    - Coral reef conservation programs at State, Territorial, and local levels within the seven U.S. coral reef jurisdictions also conduct many activities, some similar to CRCP activities and others beyond the scope of CRCP, that benefit coral reef ecosystems.
    - The NOAA Habitat Focus Areas is a place-based initiative where NOAA is working across offices and program to maximize investments, apply science on the ground, and collaborate with communities in order to protect and restore valuable natural resources. NOAA selected ten Habitat Focus Areas nationwide; four of these areas are within the CRCP's action area: Biscayne Bay, FL; Northeast Reserve Marine Corridor & Culebra Island, Puerto Rico; West Hawaii, Hawaii; and Manell-Geus, Guam.
    - To address land-based sources of pollution, the USCRTF began working on watershed partnerships to leverage member resources and expertise. The USCRTF has identified priority watersheds in Puerto Rico (Guanica Bay/Rio Loco), Hawaii (West Hawaii), and American Samoa (Faga'alu).

- USDA Joint Chiefs' Landscape Restoration Funding (2018) included mitigation of wildfire risk in Hawaii and improving water quality and restoring forest ecosystems in Puerto Rico. These projects could impact downstream co-occurring projects during construction activities or downstream resources affected by previous projects, resulting in a cumulative impact to downstream resources, but would be expected to improve the long-term ecological conditions and benefit resources.
- State programs such as fish stocking, invasive species removal, land acquisition, and stormwater management actions performed by state programs may enhance the benefits of a restoration project. Conversely, state programs may choose their area of activity based on NOAA proposed activities. State conservation programs would be expected to result in cumulative benefits to natural resources.

- **Non-governmental coral reef research and conservation.** Non-governmental organizations, academia, and the private sector all contribute to coral reef research and conservation. Projects include management capacity building efforts, research to enhance coral resilience, and prize competitions to design innovative conservation projects. These efforts benefit the same coral reef ecosystems that CRCP targets.

- **Land development.** The U.S. coastal counties along the Atlantic and Pacific oceans or Gulf of Mexico were home to about 29% of the total U.S. population in 2016 (U.S. Census Bureau, 2016) and are concentrations of economic and social activity. Coastal landscapes will continue to be altered by redevelopment for tourism-related, residential, commercial, industrial, recreational, agricultural, and forestry purposes. Degradation or development of natural areas, or disruption of natural processes through increased human activity, may adversely impact the affected area and specific project sites and resources during implementation of a proposed alternative or after restoration. Habitat restoration would reduce the adverse impacts of these activities.

- **Military operations.** Within the U.S. coral reef jurisdictions, Guam and Hawaii have U.S. military bases and associated uses. A Cooperative Security Location in the Caribbean (Aruba-Curacao) allows U.S. and partner nation aircraft the use of existing airfields to support the region's multinational efforts to combat transnational organized crime. Department of Defense lands may offer opportunities to connect otherwise fragmented landscapes and large areas of land to mitigation adverse impacts. However, restoration downstream of military bases may be adversely impacted by ground or surface water contaminated from ammunition, fire-retardants, and legacy pesticides and asbestos (Copp, 2018). Sound, vibration, and other effects of these activities will have cumulative effects on protected species, primarily fish, marine mammals, and sea turtles, as documented in the Department of Defense Record of Decision for proposed military testing and training activities under the Atlantic (DoD Atlantic ROD, 2018) and Hawaii and southern California (DoD HI-CA ROD, 2018). Likely to adversely affect determinations were made for several ESA-listed fish (e.g., Atlantic salmon (*Salmo salar*), oceanic whitetip shark, scalloped hammerhead shark, and smalltooth sawfish), although no impacts to EFH would be anticipated. A likely to adversely affect determination based on impacts of echosounder and transducers, explosives, and vessel strikes was also made for some ESA-listed marine mammals (e.g., North Atlantic right whale, sei whale, fin whale, blue whale, and sperm whale) (DoD Atlantic ROD, 2018; DoD HI-CA ROD, 2018). A determination of likely to adversely affect for ESA-listed green sea turtle, hawksbill sea turtle, Kemp's ridley, leatherback, and loggerhead sea turtle in response to military testing and training activities was also made, but not for corresponding critical habitat.

- **Marine transportation.** Marine transportation accounts for more than 90% (by weight) of global trade and is responsible for widespread coastal pollution, vessel strikes to marine mammals, seabird mortality, releases of invasive species from ballast water, oil and chemical spills, garbage, underwater sound pollution, and sediment contamination of ports during transshipment or ship breaking activities (Walker et al., 2019). In 2016, 1,806,650 principal marine vessels were registered, including: 778,890 bulk carriers, 75,258 general cargo, 503,343 oil tankers, 244,274 container ships, 44,347 chemical tankers, 5,950 ferry and passenger ships, and 1,800 liquefied natural gas tankers. These activities are expected to occur regardless of proposed activities. The Oil Pollution Act of 1990 (33 U.S.C. 2701-2761) created a comprehensive prevention, response, liability, and compensation regime to deal with vessel- and facility-caused oil pollution to U.S. navigable waters. The U.S. Coast Guard is responsible for removing fuel, oil, and other hazardous materials from grounded vessels in marine waters, reducing the need for vessel removal under the CRCP.

- **Energy activities.** Much of the south Pacific is reducing its reliance on oil and gas, and in 2017, the Department of the Interior announced nearly $3.5 million in funding to American Samoa, Guam, the CNMI, and the USVI for projects to address energy efficiencies and self-sufficiency. In 2016, the Bureau of Ocean Energy Management accepted bids for wind energy development areas in Hawaii. The major environmental concerns of offshore wind developments are increased sound levels, risk of collisions, changes to benthic and pelagic habitats, alterations to food webs, and pollution from increased vessel traffic or release of contaminants from seabed sediments. Primarily construction, but also operation, of offshore wind farms would result in cumulative impacts to fish, sea turtles, marine mammals, and sea birds. Benefits may include acting as artificial reefs and potential increases in shellfish and the animals that feed on them, including fish and marine mammals. A safety buffer zone surrounding the wind turbines may become a de-facto marine reserve, as the exclusion of boats within this zone would reduce disturbance from shipping (Bailey et al., 2014). U.S. jurisdictions in the Caribbean and Pacific are not sites of oil exploration; however, the Gulf of Mexico is a major site of oil and gas exploration in the U.S. and is expected to continue into the foreseeable future, along with increases in oil refining. Proposed activities would potentially reduce some of the adverse impacts of these activities by protecting shorelines, improving water and sediment quality, and restoring resources damaged by oil spills.

- **Marine mineral mining and sand and gravel extraction.** Sand and gravel are mined in the Gulf of Mexico and in Florida within U.S. jurisdictional waters. The number of requests to Bureau of Ocean Energy Management for sand from federal waters have increased because suitable resources in state waters are becoming depleted. Impacts from sand and gravel extraction activities may affect many benthic resources, including corals (Michel et al., 2013). No sand mining is planned for the Pacific Islands.

- **Fisheries and aquaculture.** NOAA and the Western Pacific Fishery Management Council intend to prepare a PEIS to analyze the potential environmental impacts of a federal aquaculture management program (NOI issued August 2016) to support an environmentally sound and economically sustainable aquaculture industry in federal waters of the Pacific Island region, including American Samoa, CNMI, Guam, and Hawaii. The Gulf of Mexico FMP (developed in 2009) for aquaculture was approved in 2016 and is intended to establish a regional permitting process to manage the development of an environmentally sound and economically sustainable aquaculture industry in federal waters of the Gulf of Mexico. That plan, however, remains ineffective as it was determined by one court not to be authorized by the MSA. Several smaller scale aquaculture projects in state waters currently exist and are likely to be authorized in the foreseeable future. Cumulative adverse impacts to natural resources from these activities would be expected due to potential degradation of water quality and/or habitat, impacts to wild fish stocks due to genetics from escapements (for example), exceedance of the carrying capacity of a site, and use of public resources for private profit.

- **Pollution.** Remaining point source discharges of domestic, municipal, and industrial wastewater into coastal waters of the U.S. and territories (see Chapter 3) would be expected to continue unless/until actions or programs outside the CRCP are undertaken to address these issues. For example, the U.S. Army Corps of Engineers funded planning and implementation of wastewater treatment projects in the FKNMS in 2006 to control the sources of wastewater into the FKNMS, including seepage of domestic wastewater from leaking and derelict septic tanks and open "cess pits" (unlined waste disposal pits located below land surface) into the porous limestone substrate of the Florida Keys and into FKNMS. The conversions were completed in Key Largo and Marathon in 2015, and conversions in Monroe County and other locations are underway. Projects to reduce the pollutant loading into the Florida Keys would improve the quality of water entering the FKNMS, although continued water quality issues due to legacy sources as well as continued nutrient loading from land-based non-point sources (e.g., higher nutrient levels from past 20 years [Briceno & Boyer, 2016]) persist.

- **Funding.** Public and private funding availability that is normally used to implement restoration may expand or contract and could affect whether a project is delayed, implemented, and/or completed. Funding is an inherent uncertainty.

- **Climate change.** The impacts of climate change, such as rising sea temperatures and sea level rise can fundamentally change ecosystem function by inundating habitat, altering tidal flow and sediment transport patterns, eroding shorelines, and causing species distribution shifts and population declines (Cahoon et al., 2006). Similarly, changes in precipitation and global meteorological patterns can impact project areas. Similarly, increasing frequency and intensity of storms, such as hurricanes, can damage or destroy coral reefs and the CRCP's restoration-related projects, such as in-water nurseries and erosion-control structures. Although predicting how climate-related impacts would translate at the local and regional level is difficult, global trends suggest that these impacts merit serious consideration in coastal management decisions and, more specifically, project planning and design and program prioritization (NMFS, 2011). Cumulative adverse impacts to coral reefs from climate change include coral bleaching and mortality, ocean acidification, disease transmission, direct destruction by storms, and other effects.
  Storms cause coastal erosion and other damage due to wind, waves, and water and can result in substantial damages to coastal communities and natural resources. Hurricanes Katrina (2005) and Maria (2017) (among the five deadliest hurricanes, in terms of human losses, to strike the U.S.) are recent examples of large-scale physical damage to the natural and human environment and how shifting priorities can also affect how/when projects may be implemented. Similarly,

changes in weather patterns or other meteorological shifts may impact project sites and ultimately change where and when the program is implemented. For example, watershed revegetation and in-stream habitat restoration projects may be delayed or canceled due to drought or flooding. Habitat restoration projects would be expected to buffer and reduce some of these impacts.

As described above, activities including energy and mining, coastal development and land use, military activities, and marine transportation would result in short- and long-term adverse impacts to habitats, including habitat degradation through reduced water and sediment quality, introduction of invasive species, habitat fragmentation, and habitat loss. Construction activities from habitat restoration and conservation and recovery efforts associated with other environmental stewardship and proposed activities would also contribute to short-term adverse impacts. However, the benefits of habitat restoration, conservation, and recovery efforts associated with other environmental stewardship and proposed activities would continue. These actions would likely create new habitats or restore degraded habitats, protect habitats from fragmentation, and preserve unaffected quality habitats, especially sensitive habitats.

4.7.4 Cumulative Impacts Analysis

This cumulative impacts analysis evaluates the impacts of the past, present, and reasonably foreseeable actions of Federal, state, local, and private entities (see Section 4.17.3) within the action area as well as the incremental contribution of CRCP's activities under each alternative. Continued activities such as construction and operation of energy and mining facilities (offshore and onshore); marine transportation facilities; commercial, industrial, and residential development in coastal habitats (hereinafter "ongoing activities") (see previous section) may alter, degrade, or eliminate physical resources due to water quality pollution, substrate disturbances, and conversion of habitats to developed uses or other human disturbances. Biological resources may be directly impacted by these ongoing activities through individual mortality and habitat loss or indirectly affected by degraded water quality, and/or sediment contamination. Socioeconomic resources would also be affected by these ongoing activities. Other activities, such as restoration projects, may also occur that would benefit physical, biological, and socioeconomic resources. Furthermore, the past and ongoing effects of global climate change contribute significantly to adverse impacts on coral reef ecosystems and associated physical, biological, and socioeconomic resources.

Overall, the adverse impacts from any CRCP proposed activities, as discussed in earlier sections of chapter 4, are likely to be short-term and negligible to moderate when they do occur. The CRCP proposed activities are intended to benefit coral reef ecosystems and contribute incrementally to long-term, negligible to minor cumulative benefits to physical, biological, and socioeconomic resources. Projects that do not perform as expected or desired would be modified through adaptive management based on data collected during monitoring activities. Because the CRCP project implementation periods (and the associated adverse effects) are short-term, and the beneficial impacts from a project are long-term, generally, the cumulative impact of the proposed program-wide activities would result in a net incremental benefit to physical, biological, and socioeconomic resources. When the CRCP activities are combined with the adverse effects from development, extractive activities, pollution, climate change, and others listed above, the cumulative impact on physical, biological, and socioeconomic resources may not result in a net benefit without a change in human behavioral patterns. When considering adverse and beneficial impacts from all actions identified above, for any of the three alternatives, the incremental contribution of the CRCP activities to the cumulative effects are not expected to contribute substantially to cumulative impacts to the physical, biological, or socioeconomic resources when analyzed in combination with other past, present, and reasonably foreseeable future actions.

No Action Alternative and Alternative 2. Many of the potential incremental impacts from the CRCP activities associated with the No Action Alternative and Alternative 2 would have net benefits and are expected to alleviate some of the adverse impacts imposed by past, present, and reasonably foreseeable activities. For example, watershed restoration would reduce the rate of accumulation of sediments and nutrients into coastal waters. Coral restoration would mitigate some impacts of climate change on corals and associated habitats. Installation of mooring buoys and removal of marine debris would reduce the physical damage and debris on the seafloor. Ongoing research activities (e.g., monitoring and mapping) would likely generate data that would inform coral reef ecosystem management.

Land development, military activities, and mining would likely be the biggest contributors to adverse impacts on physical resources because they involve disturbance of terrestrial and marine resources that would likely be permanent. Smaller-scale and shorter-term physical impacts include vessel groundings and damage from anchoring, which some CRCP activities focus on reducing under the No Action Alternative and Alternative 2. The incremental contribution of the CRCP activities under these alternatives would not be detectable for physical resources on land and would be detectable but not substantial for physical resources in the ocean.

Land development, military activities, pollution, extraction and energy-generating activities, marine transportation, and climate change all contribute adverse impacts to biological resources, both on land and in the ocean. Adverse impacts include habitat loss and fragmentation, habitat degradation, population declines, species distribution shifts, and loss of individuals. Research and conservation activities conducted by the CRCP, other government and non-governmental organizations, academia, and the private sector could have temporary minor effects on biological resources that would be outweighed by the long-term minor to moderate impacts on biological resources. The incremental contribution of the CRCP activities under these alternatives to cumulative impacts on biological resources would not be substantial.

Public health and safety, tourism, and socioeconomics can be complicated by large storm events such as tropical storms and hurricanes (and associated storm surges, winds, and battering waves) that may result in damage to the shoreline as well as infrastructure such as roadways, bridges, and buildings. In addition, construction activities and increased human uses of resources can also pose risks to public health and safety. Taken together, ongoing and likely future actions may benefit socioeconomic resources while adversely affecting resources such as commercial fisheries and recreation. Several of the past, present, and reasonably foreseeable activities, including the CRCP activities, would benefit socioeconomic resources. For example, development projects and extractive activities would likely contribute positively to the local economy. However, other activities, such as climate change effects and pollution, would negatively affect local socioeconomic resources as a result of damaged or lost infrastructure or water quality. The CRCP activities, such as providing information that supports more restrictive fishing regulations, could cause temporary adverse impacts to fisheries, but over the long-term, conservation activities such as fishing regulations would likely improve the health of wildlife and fish populations, which in turn leads to increased opportunities for recreation and fishing and the resulting regional economic benefits of increased tourism and recreation. In addition, watershed restoration activities would have short-term local economic benefits due to increased employment and spending. Many of the proposed activities would also have socioeconomic benefits as a result of the benefits of reduced risk of potential hazards such as storm surges and shoreline erosion, as well as increased public safety due to removal of marine debris and installation of mooring buoys. Overall, the cumulative effects on socioeconomic resources would be long-term, minor to moderate, and beneficial, and the CRCP's incremental contribution would be long-term, minor, and beneficial.

In the long-term, the CRCP's activities would support the conservation, restoration, and recovery of coral reef ecosystems and potentially ameliorate some of the adverse impacts of other past, present, and reasonably foreseeable actions. Based on information available for this analysis, the No Action Alternative and Alternative 2 are not expected to contribute substantially to cumulative impacts to the physical, biological, or socioeconomic resources when analyzed in combination with other past, present, and reasonably foreseeable future actions.

Alternative 1. Under Alternative 1, coral reef restoration and intervention activities and activities to reduce physical impacts to coral reefs (i.e., boat moorings and debris removal) that are part of the CRCP under the No Action Alternative and Alternative 2 would not occur. Consequently, the potential for restoration and recovery of coral reefs and associated habitats and biota would be reduced unless restoration activities conducted outside of the CRCP increase. Natural recovery of all coral reef ecosystems is not expected (see Section 4.4.3), and reliance on this approach could result in fewer restored coral reefs. Therefore, in combination with other past, present, and reasonably foreseeable future actions, cumulative impacts of this alternative would include less restoration and recovery than under the No Action Alternative and Alternative 2. Other restoration projects would also be ongoing and would help to reduce some of the adverse impacts of these ongoing activities; however, the lack of the CRCP activities focused on coral reef restoration and intervention and reducing physical impacts to corals would result in fewer restored coral reefs. Fewer restored or healthy coral reefs could adversely impact human health and safety due to, for example, reduced shoreline stabilization, and socioeconomics, due to degradation and/or loss of the reef fishery.

Other ongoing activities (e.g., coastal development, mining, fishing, and pollution) would continue, and the impacts of these activities on water quality, sediments, and natural resources, such as fish and wildlife, coral reefs, and other habitats, would continue. Alternative 1 would, therefore, likely result in fewer beneficial impacts and thus, a smaller incremental contribution to cumulative impacts to coral reefs and associated habitats and biota than discussed above for the No Action Alternative and Alternative 2.

4.8 Relationship of Short-Term Uses and Long-Term Productivity

Many of the proposed CRCP activities, such as monitoring, mapping, research, watershed restoration, stream, coral restoration and intervention, and preventing physical impacts are associated with short-term adverse impacts from construction or implementation of these activities. However, these impacts are expected to be temporary and the proposed activities are intended to enhance long-term coral reef ecosystem function and productivity. For example, restored coral habitat would provide food, shelter, and nursery habitat for many ecologically and economically important animals.

Under the No Action Alternative and Alternative 2, proposed public education programs, technical assistance activities, and debris removals would be expected to help reduce fishing pressure and restore ecosystem services provided by healthier coral reefs and associated habitats.s. Under all three alternatives, watershed restoration and monitoring, mapping, and research activities would continue and would help to alleviate stormwater runoff in areas where projects would be implemented and provide increased scientific data and information. However, Under Alternative 1 the continued loss of coral reefs and associated productivity would result in more overall losses of long-term productivity when compared with the No Action Alternative and Alternative 2.

4.9 Irreversible and Irretrievable Commitments of Resources

Implementation of any of the CRCP alternatives would require an irreversible and irretrievable commitment of resources due to staff time for project planning and development, funding necessary to go through the consultation, coordination, and the decision-making processes. Other resource uses that would be irreversible and irretrievable would be the use of energy through the combustion of fossil fuels and material resources for construction. However, the level of commitment would vary based on the activity, and some changes could be made to further reduce and avoid potential impacts to resources, such as ESA-listed species and designated critical habitat as part of programmatic and individual ESA Section 7 consultations and other statutory compliance efforts. For example, the reconstruction of a wetland would require more resources than revegetation.

The proposed activities outlined in the No Action Alternative and Alternative 2 generally would require the commitment of time, money, human effort, construction and restoration materials, and some use of fossil fuels. Such activities would be irreversible and irretrievable. However, the activities would also benefit most resources, and may result in a reversal of their present declining trends.Watershed restoration would involve the removal of specific types of vegetation (mostly invasive species) in favor of natural vegetation. Conversion to stormwater ponds and LID would change the long-term land use for some properties. This land use could be changed again in the future and is, therefore, not irreversible. In-water reef restoration could involve nursery structures or materials placed on reefs that would be irreversible and irretrievable commitments of such material resources. The potential destruction of cultural resources during watershed or in-water restoration implementation could occur and would, therefore, be irreversible. However, appropriate coordination with state or tribal agencies would take place on a project-by-project basis to avoid this scenario.

Under Alternative 1, the lack of coral reef restoration and intervention activities, such as outplanting and transplanting, may result in the irreversible and irretrievable commitments because materials and effort for restoration and intervention activities and mooring buoy installations would not be needed.

4.10 Unavoidable Adverse Impacts

Section 102(2)(c)(ii) of NEPA requires that an EIS include information on "any adverse environmental effects which cannot be avoided should the proposed action be implemented." Unavoidable adverse impacts are the effects on the human environment that would remain after mitigation measures and best practices have been applied. They do not include temporary or permanent impacts that would be mitigated. While these impacts do not have to be avoided by the planning agency, they must be disclosed, considered, and mitigated where possible (40 CFR § 1500.2[e]). The No Action Alternative and Alternative 2 would have the same unavoidable adverse impacts, and Alternative 1 would have fewer unavoidable adverse impacts because it would lack restoration and intervention activities. Unavoidable adverse impacts associated with the use of fossil fuels related to implementation of almost all of CRCP's activities are not expected to result in detectable adverse impacts to resources. In addition, future CRCP planning phases and associated NEPA analyses would consider the extent to which adverse impacts can be avoided, including consideration of appropriate mitigation, and would describe those adverse impacts that are unavoidable. The CRCP's current best practices are identified in Appendix A.

Best practices developed by the CRCP include guidance documents, lessons learned, and project design criteria for many restoration actions. Project proponents are expected to consider these, and any additional relevant best practices, in the development of subsequent CRCP projects and associated regulatory compliance. Trustees use appropriate best practices to avoid or minimize impacts to natural resources, including ESA-listed species and their designated critical habitats. During any environmental review process, additional project-specific BMPs or mitigation measures may be recommended or required as applicable to a specific project, such as endangered species presence or absence and resulting requirement to stay out of an area, or other factors. The final set of project-specific best practices and mitigation measures would be determined prior to implementation. Appendix A includes lists of BMPs is that would be included on a project-specific basis, as appropriate, to avoid, minimize, or reduce potential adverse effects on the resources. As new best practices are established, existing best practices are refined, or new techniques and information are informed by implementation, these measures will be added to or updated. Consequently, new projects will have available the current range of best practices to support project design and implementation.

4.11 Environmental Review and Consultation Requirements

The primary legal requirements that generally apply to CRCP activities are discussed in Section 3.4 and Section 1.10. The CRCP is conducting programmatic consultations pursuant to ESA and MSA, and correspondence for such consultations is included in Appendix H for the proposed action. As projects are proposed to implement the CRCP, additional environmental review and consultation may be required under statutes including the ESA, MMPA, MSA, NMSA, NHPA, and the Fish and Wildlife Coordination Act.

4.12 Summary and Comparison of Potential Impacts of Alternatives

This section presents a summary of potential adverse impacts to resources under the No Action Alternative, Alternative 1, and Alternative 2. A summary of general impacts expected from activities is outlined below.

- **Monitoring, mapping, and research activities**. No significant adverse impacts to resources are anticipated. Benefits of these activities would provide information critical to the conservation and management of resources such as water quality, fisheries, and coral reefs and associated habitats.
- **Coral restoration and intervention activities**. No significant adverse impacts to resources are anticipated. The potential risk to coral communities due to invasive species, disease, and corallivores would be avoided and minimized by implementation of BMPs and/or DCMMs. Overall benefits to coral reefs and associated habitats and biota be recovery and restoration of coral reefs in response to fishing impacts, climate change, and land-based sources of pollution.
- **Watershed restoration and management activities**. No significant adverse impacts to resources are anticipated. Potential impacts of implementing watershed restoration construction and

management activities would be avoided and minimized by implementation of BMPs. Benefits to resources would include improved coastal and marine water quality due to reduced land-based sources of pollution and subsequent benefits to coral reefs, seagrasses, and other habitats and biota.

- **Reduction in physical impacts to coral reefs**. No significant adverse impacts to resources are anticipated from activities such as permanent mooring buoys and debris removal. Benefits to resources would include restored habitats and reduced potential for physical destruction to coral reefs and associated habitats and biota and contamination of sediments and the water column.

A brief comparison of adverse impacts and benefits among alternatives is provided below and detailed for each resource in Table 4-3. The summary provides context and intensity of potential impacts using D for direct, I for indirect, S for short-term, L for long-term, etc., and combining these indicators of context, followed by the range of anticipated impact intensity (i.e., negligible to moderate). For example, an adverse impact that is expected to be direct, short- to long- term in duration, local, and negligible to minor, will appear in the table as D/S-L/L, negligible to minor, with further explanation of the potential impact(s).

The analysis summarized in Table 4-3 is supported by an impacts matrix that examined (and ranked) potential impacts to each of the 14 resources (e.g., fisheries) due to each of the 44 activities (e.g., lethal and nonlethal collection of fish, collection of coral gametes) in each of the four activity groups (e.g., mapping, monitoring, and research) for each of the three alternatives. The analysis used an Excel-based tool to generate a CRCP Impacts Matrix. The impacts matrix display is provided in Appendix G and presents a corresponding summary of the individual rankings for impacts analysis criteria of intensity, context, and duration, for each resource and alternative generated by the Excel-based tool.

No Action Alternative, Alternative 1, and Alternative 2. All three alternatives would have direct and indirect, short-term, negligible to moderate, local adverse impacts during the implementation of monitoring, mapping, and research activities. All three alternatives would also result in benefits from monitoring, mapping, and research activities that will support data collection and perform research critical to managing corals and associated coastal and marine resources. No differences in impacts from monitoring, mapping, and research activities are expected. All three alternatives would implement watershed restoration and management activities that would reduce erosion, stormwater runoff, and sediment and other pollutant loading into downstream and coastal waters. Adverse effects would be direct indirect, short-term, local to larger scale, negligible to moderate, and benefits would be direct and indirect, both short- and long-term, and local to the specific project location. Stabilized sediments (e.g., trails and roads) would restore natural hydrology and reduce sedimentation and erosion in terrestrial, aquatic, wetland, and floodplain habitats; restore flood storage capacity of wetlands and floodplains; and restore habitat for listed species. Reductions in sediments and pollutants in coastal waters would improve water quality and benefit coastal and marine habitats such as corals, seagrasses, mangroves, fish, and fisheries. No differences in impacts are expected.

No Action Alternative and Alternative 2. Only the No Action Alternative and Alternative 2 would implement activities to directly address the decline in coral reef health and benefit corals and associated habitats and biota. Both of these alternatives include transplanting and outplanting corals, development of coral nurseries, reducing invasive species, addressing coral diseases, and reducing physical impacts to corals from marine debris and vessel anchoring. Benefits would be direct and indirect, long-term, local to larger scale, and minor to major, depending on the project. Because coral reefs are not expected to recover without intervention, these alternatives are the only two that would support the recovery and restoration of coral reefs.

Alternative 2. Alternative 2 includes DCMMs that may be implemented to further reduce potential impacts of many of the proposed activities. DCMMs would be implemented in addition to BMPs that are implemented under the current CRCP (No Action Alternative) and would be expected to further benefit coral reefs and associated habitats and biota. Expected benefits to coral reefs would be the same as for the No Action Alternative, with potentially greater, albeit negligible, benefits.

Among the three alternatives, potential adverse impacts range from direct to indirect, short- to long-term, local to larger in scale, and from negligible to major. Benefits under the No Action Alternative, Alternative 1, and Alternative 2 are anticipated to be both direct and indirect, both short and long term, and potentially both local and large scale, depending on the project. The impacts summary table (Table 4-3) provides context and intensity of potential impacts using D for direct, I for indirect, S for short-term, L for long-term, etc., and combining these indicators of context, followed by the range of anticipated impact intensity (i.e., negligible to moderate). For example, an adverse impact that is expected to be direct, short- to long-term in duration, local, and negligible to minor, will appear in the table as D/S-L/L, negligible to minor, with further explanation of the potential impact(s).

Table 4-3. Summary of the impacts to resources anticipated under the alternatives. The CRCP's discretionary conservation and mitigation measures (DCMMs) are provided in Appendix B. Resources are analyzed for both terrestrial and coastal and marine environments where relevant. Context factors are abbreviated as: Direct and/or Indirect (D-I)/Short- to Long-term (S-L)/Local to Large Scale (L-LS), followed by intensity descriptions of negligible to major.

Resources	**No Action Alternative** *Continued Implementation of the Current CRCP*	**Alternative 1** *Current CRCP without Coral Reef Restoration/Intervention and Reducing Physical Impacts to Coral Reefs*	**Alternative 2** *Current CRCP with Addition of Required DCMMs*
Physical Environment			
Sediments and Soils	**Adverse Impacts.** <u>Terrestrial</u> - D/S/L, negligible to minor due to erosion, sedimentation, compaction, potential introduction of pollutants into soils during monitoring, construction, herbicide use, other watershed proposed activities. <u>Coastal waters</u>: D/S/L, negligible to minor due to sediment resuspension and deposition during vessel and other in-water activities.	**Adverse Impacts**. <u>Terrestrial</u> - same as for the No Action. <u>Coastal</u> - D/S-L/L, negligible to moderate. Combined adverse impacts to sediments under this alternative are due to continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor, due to	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible benefits due to DCMMs such as additional dive and vessel training, seafloor habitat avoidance, decontamination of equipment, use of mooring buoys or live boating, etc.

	Additional long-term, negligible to moderate impacts possible from large projects such as stormwater ponds, road stabilizations, and vessel removals. **Benefits.** D-I/S-L/L-LS, negligible to major due to reduced erosion and land loss, sediment and other pollutant loadings to coastal waters, improved soil and sediment quality, stabilized substrates, reduced debris and contamination, and acquisition of data critical to resource management.	elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	that reduce the amount of disturbance.
Terrestrial Habitats and Biota	**Adverse impacts.** D/S/L, negligible to minor displacement of fish, wildlife, and vegetation due to sound, runoff, altered hydrology, herbicide use, habitat loss due to construction and other watershed proposed activities; invasive species introduction and loss of native species. **Benefits.** D/S-L/L, negligible to moderate benefits due to potential increased quality of native habitat for foraging, nesting, and migratory stops for birds and other terrestrial wildlife; restored habitat due to reduced erosion and improved water quality for instream fish and wildlife.	**Adverse impacts.** D/S/L, negligible to minor, same as No Action, due to watershed proposed activities in terrestrial habitats. **Benefits.** D-I/S-L/L, negligible to moderate, due to continued mapping, monitoring, and research, and watershed restoration and management activities.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible water quality and habitat improvements due to DCMMs such as erosion and sediment controls and reduced herbicide concentrations.

Wetlands and Floodplains	**Adverse impacts.** D/S/L, negligible to minor impacts to wetlands and floodplains due to temporary construction activities and introduction of sediments, other pollutants, and invasive species. **Benefits.** D-I/S-L/L-LS, negligible to moderate due to potential for restored flood capacity, soil rehydration, and increase in native habitat due to reduced erosion and improved water quality.	**Adverse impacts.** D/S/L, negligible to minor same as No Action, negligible to minor due to watershed proposed activities in terrestrial habitats. **Benefits.** D-I/S-L/L-LS, same as No Action, negligible to moderate due to information available to support future conservation and management efforts.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible water quality and habitat improvements due to DCMMs such as erosion and sediment controls and reduced herbicide concentrations.
Water Resources	**Adverse Impacts.** Terrestrial: D/S/L, negligible to minor due to potential for erosion and transport of sediments/other pollutants generated from construction and other activities (see sediments and soils above) and conveyed into downstream and coastal waters. Coastal waters: same as terrestrial with additional impacts from land-based sediments and pollutants, resuspension of sediments due to vessels and other in-water activities associated with monitoring and coral transplanting, and potential contamination from debris. **Benefits**. D-I/S-L/L, negligible to major due to reduced sediments and other pollutant loadings to downstream waters, potential contamination from marine debris, and major benefits due	**Adverse impacts.** Terrestrial. D/S/L, negligible to minor impacts. Same as No Action. Coastal waters: D/S/L, negligible to minor impacts due to potential resuspension of sediment from anchoring and marine debris into the water column. **Benefits.** D-I/S-L/L, and negligible to moderate due to watershed restoration and management activities and continued monitoring, mapping, and research activities.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible, benefits due to DCMMs such as additional dive and vessel training, seafloor habitat avoidance, use of mooring buoys and live boating, and others that reduce the opportunity for resuspension of sediments into the water column.

	to acquisition of data critical to management.		
Biological Environment			
Seagrasses	**Adverse impacts.** D/S/L, negligible to minor due to temporary disturbance during monitoring/surveying, other in-water activities (esp. propeller scars), debris removal, installation of mooring buoys, and coral proposed activities. **Benefits.** D-I/L/L-LS, negligible to moderate due to reduced sediment and nutrient loading from watershed, reduced disturbance/damage from permanent moorings and debris/contamination, habitat stabilization due to potential coral reef recovery.	**Adverse Impacts.** D/S-L/L, negligible to moderate due to continued damage from anchoring and accumulation of marine debris, as well as potential loss of buffering effects of coral reefs. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible, benefits due to DCMMs such as additional dive and vessel training, seafloor habitat avoidance, use of mooring buoys and live boating, and others that reduce contact with resource.
Mangroves	**Adverse impacts.** D-I/S/L, negligible to minor, similar to disturbances described in sediment and soils. **Benefits**. D-I/S-L/L-LS, negligible to moderate to native mangroves due to reduced sediment and nutrient loadings from the watershed, reduced wave energy and sedimentation due to coral recovery, reduced disturbance and contamination due to permanent moorings and debris removal.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, but with additional, negligible benefits due to a reduction of indirect adverse impacts of sediment and pollutant loadings into coastal waters, potential impacts from anchors and marine debris, and erosion as a result of required DCMMs.
Corals and other associated invertebrates and algae	**Adverse impacts.** D-I/S-L/L, negligible to moderate from temporary disturbance during monitoring, surveying,	**Adverse impacts.** D-I/S-L/L-LS, negligible to major due to discontinued coral restoration efforts and	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs.

	research, mooring buoy, coral reef restoration, and debris removal activities; potential for disease, corallivores, and invasive species that may increase due to transplanting and outplanting activities. **Benefits.** D-I/S-L/L-LS, negligible to major due to reduced invasive species, acquisition of data available for recovery and management; reduced runoff from watershed, debris removal, reduced anchoring, and increased recovery due to transplanting and outplanting of corals, control of disease, corallivores, and invasive species, other activities that increase the potential for recovery of coral reefs.	continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Benefits.** Same as No Action, but with additional, negligible, benefits due to DCMMs such as additional restrictions on the amount of coral removed for transplants, additional decontamination protocols, and further reductions in physical contact with coral to reduce potential for physical damage, disease, corallivore, and invasive species impacts to corals.
Fish	**Adverse impacts.** D-I/S/L, negligible to minor impacts due to temporary disturbance and loss of habitat during monitoring, surveying, research, mooring buoy installation, debris removal, and coral reef restoration. **Benefits.** D-I/S-L/L-LS, negligible to major due to reduced watershed runoff, improved water quality and habitat; potential for restored reef habitat and increase in data for resource management.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to continued damage from coral reef habitat loss and anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional, negligible benefits due to DCMMs such as additional sediment and erosion control to improve water quality, reduced physical contact with habitats, and sound protocols to further reduce potential sound impacts.
Invasive Species	**Adverse impacts.** D-I/S-L/L-LS, negligible to moderate due to potential increases in invasive species due to disturbance and incidental	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to discontinued coral restoration efforts and continued disturbance from	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs.

	introductions via revegetation materials, transplants, vessels, equipment, trucks, etc. **Benefits.** Terrestrial: D-I/S-L/L-LS, negligible to major due to opportunities for native species to re-establish due to reduced erosion or revegetation. Coastal and marine waters: interventions to reduce invasive species would support recovery of corals and associated biota.	anchoring and accumulation of marine debris, resulting in continued introduction and establishment of invasive species. **Benefits.** D/S-L/L, negligible to minor due to the elimination of CRCP components that address invasive species.	**Benefits.** Same as No Action, with additional negligible benefits due to required DCMMs to reduce the concentration of herbicides used for vegetation management and to reduce the risk of introducing invasive species (as well as disease and corallivores) during coral restoration and intervention activities.
Regulatory Environment			
Essential Fish Habitat	**Adverse impacts.** D/S/L, negligible to minor disturbance and loss of habitat for fisheries during monitoring, surveying, research, mooring buoy installation, debris removal, and coral reef proposed activities. **Benefits.** D-I/S-L/L-LS, negligible to major due to restoration of reef and associated habitats (mangroves and seagrasses) due to reduced sediment loading, improved water quality, reduced derelict fishing gear and other debris, and additional data for EFH management.	**Adverse impacts.** D-I/S-L/L-LS, negligible to moderate due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D-I/S-L/L-LS, negligible to minor due to elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional, negligible benefits due to DCMMs such as additional sediment and erosion control to improve water quality, reduced physical contact with habitats, and sound protocols to further reduce potential sound impacts.
Protected Species	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to disturbance/displacement of organisms or habitat due to water quality, hydrologic alteration, or excavation during watershed proposed activities, temporary	**Adverse impacts.** D-I/S-L/L-LS, negligible to moderate due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts due to DCMMs. **Benefits.** Same as No Action, with additional negligible water quality benefits and reduced

	disturbance during surveying and research activities; potential use of herbicides; other potential impacts would require consultation. **Benefits.** D-I/L/L-LS, negligible to major due to proposed activities that reduce erosion and sedimentation; negligible to major due to invasive species control, road and trail stabilization, and habitat improvements for listed species.	**Benefits.** D/S/L, negligible to minor due to the elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	impacts to habitats from in-water activities due to DCMMs such as additional protocols to reduce physical contact with sea floor and potential sound/echosounder impacts, monitor vessel speeds, use of BMPs.
Socioeconomic Environment			
Cultural Resources	**Adverse impacts.** D-I/S-L/L, permanent, negligible to minor due to section 106 SHPO consultation to identify resources and subsequent unlikely disturbance except to remove or document an object or structure that is discovered. **Benefits.** D/L/L-LS, negligible to moderate due to the potential discovery and/or acquisition of data to support protection of these resources and protection from erosion and runoff.	**Adverse impacts.** D-I/S-L/L, negligible to minor due to the prior consultation with SHPO to avoid impacting these resources. **Benefits.** D-I/L/L, negligible to moderate due to potential documentation, recovery, and protection of cultural resources.	**Adverse impacts.** Same as No Action, but negligible reductions in adverse impacts, due to DCMMs. **Benefits.** Same as No Action, with additional negligible benefits due to required DCMMs protocols to reduce sedimentation into or physical contact with potential resources.
Public Health and Safety	**Adverse impacts.** D-I/S-L/L, negligible to minor due to closure of public and private areas for safety during periods of monitoring or research activities. **Benefits.** D-I/S-L/L-LS, negligible to moderate due to benefits to coastal storm surge and shoreline protection.	**Adverse impacts.** D-I/S-L/L, negligible to moderate due to continued accumulation of debris and the potential for adverse impacts to public health and safety. **Benefits.** D-I/S-L/L, negligible to minor, due to the elimination of CRCP components under this	**Adverse impacts.** Same as No Action alternative. **Benefits.** Same as No Action alternative.

		alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	
	Adverse impacts. D-I/S-L/L, negligible to minor due to potential interruptions in activities. **Benefits.** D-I/S-L/L, negligible to moderate include data acquisition and information to improve public health and safety.	**Adverse impacts.** D-I/S-L/L, negligible to major due to discontinued coral restoration efforts and continued damage from anchoring and accumulation of marine debris. **Benefits.** D/S-L/L, negligible to moderate, due to the elimination of CRCP components under this alternative; benefits of watershed restoration and mapping, monitoring, and research maintained.	**Adverse impacts.** Same as No Action alternative. **Benefits.** Same as No Action alternative.

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List of Preparers

This document was prepared by a cross-NOAA Team* including staff from the Coral Reef Conservation Program, Office of General Council, the National Ocean Service, and the National Marine Fisheries Service with assistance from other NOAA staff. The Coral Reef Conservation Program contracted with Research Planning Inc. to conduct the impact assessment in Chapter 4.

NOAA Coral Reef Conservation Program

*Harriet Nash, Deputy Director (Federal)
*Elizabeth Fairey, Environmental Compliance Coordinator and Federal Program Officer (Federal)
*Kevin Staples, 2018 Sea Grant John A. Knauss Marine Policy Fellow (Fellow)
Lauren Swaddell, 2019 Sea Grant John A. Knauss Marine Policy Fellow (Fellow)
Eileen Alicea, Senior Program Analyst (CSS/Lynker Contractor)
Paulo Maurin, Hawaii Management Liaison (Lynker Contractor)
Marlon Hibbert, USVI Management Liaison (Lynker Contractor)
Hideyo Hittori, American Samoa Management Liaison (Lynker Contractor)
Robbie Green, CNMI Management Liaison (Lynker Contractor)
Adrienne Loerzel, Guam Management Liaison (Lynker Contrator)
Rob Ferguson, Land-based Sources of Pollution Coordinator (CSS Contractor)

NOAA Office of General Counsel

*Scott Farley, Environmental Review and Coordination Section (Federal)
*Lauren Bregman, Oceans and Coasts Section (Federal)
*Elizabeth Hook, Environmental Review and Coordination Section (Federal)
*Amanda Tun, Environmental Review and Coordination Section (ISS Contractor)

National Ocean Service

*Giannina DiMaio, NOS Environmental Compliance Coordinator (Federal)

National Marine Fisheries Service

*Kelli O'Donnell, Fisheries Biologist, Gulf of Mexico Branch (Federal)
Lisa Vandiver, Marine Habitat Restoration Specialist (Earth Resources Technology Contractor)

Research Planning Inc.

Jaqueline Michel, President
Pam Latham, Senior Scientist/Ecologist
Hal Farvel, Senior Scientist/Ecologist
Jennifer Weaver, Biologist

Appendices

Appendix A. Best Management Practices Implemented by CRCP

The following best management practices are used as mitigating measures to minimize the impact of some in-water research activities, watershed restoration activities, and vessel used. These practices don't reflect an exhaustive list of best practices used in NOAA programs, but are practices considered in the analysis of impacts.

1. Vessel Operations to Minimize or Avoid Impacts to Marine Mammals

In order to avoid causing injury or death to marine mammals and sea turtles, the following measures should be taken when consistent with safe navigation:

- Vessel operators and crews shall maintain a vigilant watch for marine mammals and sea turtles to avoid striking sighted protected species.
- Vessels should maintain speed a speed that is safe for the area in which it is moving through.
- When whales are sighted, maintain a distance of 100 yards or greater between the whale and the vessel.
- When sea turtles or small cetaceans are sighted, attempt to maintain a distance of 50 yards or greater between the animal and the vessel whenever possible.
- When small cetaceans are sighted while a vessel is underway (e.g., bow-riding), attempt to remain parallel to the animal's course. Avoid excessive speed or abrupt changes in direction until the cetacean has left the area.
- Reduce vessel speed to 10 knots or less when a North Atlantic right whale, mother/calf pairs, or large assemblages of cetaceans are observed near an underway vessel, when safety permits. A single cetacean at the surface may indicate the presence of submerged animals in the vicinity; therefore, prudent precautionary measures should always be exercised. The vessel shall attempt to route around the animals, maintaining a minimum distance of 100 yards whenever possible.
- Whales may surface in unpredictable locations or approach slowly moving vessels. When an animal is sighted in the vessel's path or in close proximity to a moving vessel and when safety permits, reduce speed and shift the engine to neutral. Do not engage the engines until the animals are clear of the area.
- Abide by the NMFS Southeast and Pacific Islands Regional Marine Mammal Viewing Guidelines.
- Abide by the Florida Fish and Wildlife Conservation Commission's Standard Manatee Conditions for In-water Work, if working in an area where manatees might be. https://www.fws.gov/northflorida/Manatee/Manate_Key_Programmatic/20130425_gd_Appendix%20B_2011_Standard%20Manatee%20Construction%20Conditions.pdf

2. Self-Contained Underwater Breathing Apparatus (SCUBA)/Snorkel:

- SCUBA divers that will be involved in in-water research and monitoring should have proper training in diving and be capable of exhibiting responsible dive practices (e.g., proper buoyancy) such that they minimize injure organisms or cause unnecessary habitat impacts. It is the responsibility of NOAA or a recipient organization to ensure that divers are trained to a level commensurate with the type and conditions of the diving activity being undertaken. The organization must have the capacity (appropriate insurance, safety policies, etc.) to oversee all proposed diving activities.

- To minimize disturbances, divers should use low-impact techniques which include having no more than four divers per group, the use of appropriate dive equipment and tools, expert boat anchoring, job-specific diver training, and diver awareness.
- When using a boat or platform to conduct in-water work, at least one person should maintain a visual watch for mobile protected species to ensure none are sighted within the working area. If a listed species moves into the area of work, cessation of operation of any moving equipment closer than 50 ft of animal and activities may resume once the species has departed the project area on its own volition.

3. Coral Fragmentation Collection

- Projects proposing the collection of coral fragments for use in laboratory/research studies shall take less than 20% of the colony unless the applicant/principle investigator demonstrates the removal of a larger amount will not negatively impact the survival of the coral or impact the local population of that species.
- Projects that remove cores from coral colonies will only be approved if the researcher has made provisions to fill the core hole with clay, cement, or epoxy unless permits do not allow for filling cores.
- To avoid transmission of possible disease agents, tools including collection bags, sampling gear, transect tapes, clipboards, underwater slates, weight belts and other equipment that comes in contact with the bottom should be decontaminated using diluted chlorine bleach. All tools should be soaked for 10 minutes in a 10% bleach solution (prepared within 12 hours of use and kept out of direct sunlight) before moving to new sites (following the field manual by Woodley et al., 2008[1] and Coral Disease Decontamination Protocol, 2018[2]).

4. Watershed Restoration Activities Best Management Practices

a. On-site Pollution Controls

- Properly confine, remove, and dispose of construction waste, including every type of debris, discharge water, concrete, cement, grout, washout facility, welding slag, petroleum product, or other hazardous materials generated, used, or stored on-site.
- All vehicles and other heavy equipment would be (a) operated in a safe manner; (b) stored, fueled, and maintained in a vehicle staging area set back from any natural waterbody or wetland; (c) inspected daily for fluid leaks before leaving the vehicle staging area.
- Generators, cranes, and any other stationary equipment operated within 150 feet of any natural waterway or wetland would be maintained as necessary to prevent leaks and spills from entering the water.
- Use procedures to contain and control a spill of any hazardous material generated, used or stored on-site, including notification of proper authorities. Heavy equipment can also leak oil and fluids. Equipment is always refueled away from stream corridors, and operators are required to have a spill response plan in place in case of a leak.

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[1] Woodley, C.M., A.W. Bruckner, A.L. McLenon, J.L. Higgins, S.B. Galloway and J.H. Nicholson. 2008. Field Manual for Investigating Coral Disease Outbreaks. NOAA Technical Memorandum NOS NCCOS 80 and CRCP 6. National Oceanic and Atmospheric Administration, Silver Spring, MD 85pp.

[2] https://nmsfloridakeys.blob.core.windows.net/floridakeys-prod/media/docs/coral-disease-decontamination-protocol.pdf

c. Invasive Species Spread Prevention

- Vehicles or equipment used to manage invasive plants should be cleaned of all debris before removing it from the treatment site to prevent the unintended spread of seeds, rhizomes or plant fragments to other areas. Biofouled debris bearing non-native species should be appropriately treated before moving to reduce the likelihood of introducing or spreading or invasive species.
- Implementation of prevention measures, such as application of Hazard Analysis and Critical Control Point planning, can be used to identify and minimize the risks introducing non-native organisms during restoration activities.

Activities that reduce disturbance to vegetation and soils

d. Erosion Control

- Temporary erosion controls would be in place before any significant alteration of the action site and would be monitored during construction to ensure proper function. Any number of erosion control structures or approaches may be used: turbidity curtains, hay bales, and erosion mats may be used where appropriate. When possible, stream flow would be diverted from work areas to prevent excess turbidity.
- Confine vegetation and soil disturbance to the minimum area, and minimum length of time, as necessary to complete the action, and otherwise prevent or minimize erosion associated with the action.
- Anticipate erosion and head cuts through grade control structures or bank recontouring.
- Cease work under high flows or seasonal conditions that threaten to disturb turbidity reduction measures, except for efforts to avoid or minimize resource damage.
- Exposed areas would be mulched and seeded after ground-disturbing activities are complete.
- Site restoration - Any woody debris, mature native vegetation, topsoil, and native channel material displaced by construction would be stockpiled for use during site restoration. When construction is finished, all streambanks, soils, and vegetation would be cleaned up and restored as necessary to renew ecosystem processes that form and maintain productive fish habitats.

e. Methods to Reduce Soil Compaction

- Existing access ways would be used whenever possible. Temporary access roads would not be built on slopes greater than 50%, where grade, soil, or other features suggest a likelihood of excessive erosion or failure. Soil disturbance and compaction would be minimized within 150 feet of a natural waterbody or wetland. All temporary access roads would be obliterated when the action is completed, the soil would be stabilized, and the site would be revegetated. Temporary roads in wet or flooded areas would be restored shortly after the work period is complete.
- Heavy equipment would be selected and operated in a manner that minimizes adverse effects to the environment (e.g., minimally-sized, low pressure tires, minimal hard turn paths for tracked vehicles, temporary mats or plates within wet areas or sensitive soils).
- To the extent feasible, heavy equipment would work from the top of the bank, unless work from another location would result in less habitat disturbance.

f. Planting or Installing Vegetation for Watershed Management

- Projects should use an appropriate assemblage of species native to the action area or region, including trees, shrubs, and herbaceous species should be planted.

- For all geographic areas, no more than 5% of the below ground biomass of an existing donor bed would be harvested for transplanting purposes. Plants harvested would be taken in a manner to thin an existing bed without leaving any noticeable bare areas. Harvesting of flowering shoots would occur only from widely separated plants.

g. Adequate training of volunteers

- Training should be provided to ensure minimal impact to the restoration site by volunteers. Volunteers shall be trained in the use of low-impact techniques for planting, equipment handling, and moving around the restoration site to avoid unnecessary impacts on native flora and fauna.

h. Activities that avoid disturbing sensitive areas and species

- Sensitive resource areas adjacent to the action area, such as buffers, archeological sites, and wetlands would be flagged to avoid accidental impacts.
- All applicable work windows for species listed under the Endangered Species Act would be followed.
- Training should be provided to ensure minimal impact to the restoration site by volunteers. Volunteers shall be trained in the use of low-impact techniques for planting, equipment handling, and moving around the restoration site to avoid unnecessary impacts on native flora and fauna.

5. In-water restoration activities

- When barges and other boats must moor on site to accomplish restoration work, mooring locations would be chosen to minimize damage to existing coral reefs or adjacent submerged aquatic vegetation beds.

6. Other

- Vessels used in implementing activities must meet all EPA Vessel General Permits and Coast Guard requirements.
- Projects involving laboratory studies will follow the laboratory's environmental compliance guidelines and ensure that chemicals are disposed of in a proper manner, and comply with the ethical treatment of animals.

Appendix B. CRCP Discretionary Mitigation Measures

The following practices are used as discretionary mitigation measures to avoid or minimize potentially adverse impacts during the implementation of activities under the CRCP. Where appropriate, these practices will be incorporated into all CRCP funded activities. These practices are not an exhaustive list of best practices used in NOAA programs, but are practices considered in the analysis of impacts. Additional discretionary measures in the form of conservation recommendations may be developed through consultation with NMFS pursuant to Section 7 of the Endangered Species Act (ESA) and the Essential Fish Habitat provisions of the Magnuson Stevens Act.

1. Vessels Operations -
    a. To reduce the risk of vessel impacts to coral reefs, colonized hard bottom, and seagrass areas, vessel operator must carry and consult appropriate NOAA nautical charts, NOAA benthic habitat maps and aerial photographs and/or use real-time data (e.g., GPS with nautical chart and depth finder on boat) will be continuously observed to verify water depths and vessel location.

2. Vessel Anchoring for all in-water boat use:
    a. Vessel operators should use recreational mooring buoys or live boating (boat operator keeps engine on to keep boat on station without anchoring) when possible. If anchoring, only used designated anchoring area or in mud or sand.
    b. If anchoring is necessary, vessels should be anchored preferentially on sandy bottom whenever possible. If anchoring on sandy bottom is not possible, vessels may be anchored on vegetated bottom that consists of seagrass and/or algae (seaweed). Vessels should not be anchored on hard bottom that contains hard and/or soft coral, regardless of the percentage of coral cover present. The type of bottom present will be confirmed by divers, onboard using a glass-bottom bucket, or by other appropriate means, prior to anchoring.
    c. If the vessel is anchored on vegetated bottom (seagrass/algae), the anchor will be removed from the seafloor in a manner that minimizes disturbance to the vegetation, for example, by attaching a secondary anchor line to the rear of any plow-type anchor and pulling the anchor free from the seafloor before lifting to the surface.

3. Remotely Operated Vehicles (ROV)
    a. ROV operators should have the training necessary to maintain and operate these vehicles at a depth above the seafloor and coral relief in order to avoid contact.
    b. Use stiffer line materials for towing and keep lines taut during operations to reduce potential for entanglement.

4. Acoustics/Echo Sounder Restrictions:
    a. Operate all active acoustic systems at or above 180 kHz when practicable.
    b. If echosounder frequencies less than 180 must be employed, operate at the lowest possible power (to reduce source level) and ping-rate (to reduce accumulated energy).
    c. Use directional echosounders with the smallest beam width practicable to concentrate noise directly under vessel to maximum extent practicable.
    d. Minimize use of all active acoustic systems (e.g., turn off all non-navigational echosounder when not actively mapping)

    e. Power down or turn off mapping echosounder if a marine mammal is observed closely approaching or within 100m of the vessel.

5. Self-Contained Underwater Breathing Apparatus (SCUBA)/Snorkel:
    a. The dive team lead will make sure that underwater conditions (e.g., visibility, current speeds) and weather are suitable for diving to ensure the safety of divers and for ability to avoid damaging sensitive underwater habitats.
    b. The point of entry and exit will be carefully selected to avoid damaging coral.
    c. Divers should stay off the bottom and should never stand or rest on corals or other sessile benthic invertebrates.
    d. During all in-water activities, participants in education programs and other activities should avoid stepping on/standing on corals, kicking coral colonies while swimming, and placing equipment on top of sensitive benthic resources.

6. Instruments Moored to the Seafloor:
    a. The installation and removal of in-water structures for research equipment should be performed by divers; all equipment must be removed once the study is complete.
    b. Moored instruments should be securely placed on/anchored into uncolonized hard bottom areas of rubble or sand.
    c. Any lines associated with moored instruments should be taught to reduce the possibility of entanglement of protected species.
    d. Heavy instruments should lowered and retrieved using air lift bags.

7. Coral Nursery

    a. When determining new nursery sites the following factors should be considered: 1) Proximity to natural live bottom, 2) hydrological and geological factors, and 3) traditional uses of the proposed site.
    b. Nursery maintenance and monitoring plan should be developed. The plan should include method(s) to be used to remove structures that are no longer needed, functional, or of a design that has become obsolete. The plan should also include a timeframe for the removal of structures and restoration of the area to pre-construction conditions to commence no later than 30 days after the structures are no longer in use.
    c. Structures must be constructed in a manner that ensures the structures will not move or flip during storm events or due to human impacts such as anchor drag:
        i. Stabilization of structures can be achieved with the use of weights and/or penetrating anchor systems such as Duckbill® or Helix® anchors or rebar driven to sufficient depth to prevent movement or lifting of the structures.
        ii. Structures must be placed a minimum of 50 ft from live stony corals and seagrass beds to avoid potential impacts from movement of structures.
    d. Floating structures that use lines as part of the support system or for attaching corals must be constructed in a manner to eliminate or minimize the chances of entanglement of sea turtles and marine mammals:
        i. Line nurseries must have, at a minimum, either horizontal or vertical components that are rigid (e.g., PVC pipe) to prevent the structures from collapsing and potentially causing entanglement of animals.
        ii. Vertical lines for anchoring structures to the seafloor must have sufficient tension created by buoys on the line to avoid slack.

        iii. Buoys should be tied to the rigid component of the structure with the minimum use of line such that less than 50 cm (20 in) of line is exposed between each buoy and the structure.
        iv. Line used to attach corals vertically to the nursery structures must be no longer than 20 cm (8 in).
        v. Horizontal lines must be at least 20 cm (8 in) apart and must be kept taut and supported by a rigid frame structure (PVC or similar) in order to avoid slack in the horizontal lines.
    e. The use of monofilament lines instead of steel cables to reduce the need to replace cables regularly is acceptable as long as the lines for floating structures are kept taut and follow the recommendations above for new floating structures to minimize entanglement of marine organisms.
    f. All applicable permits for the installation of coral nursery structures shall be obtained prior to installation.

8. Coral Restoration/Transplantation/Relocation:
    a. Unless part of scientifically vetted study with risks analyzed and appropriate approval such as an ESA consultation, if applicable, outplants/transplants must be from a 'genetically connected' population (e.g., corals are not transplanted from Puerto Rico to Florida).
    b. Restoration projects should include a scientific hypothesis, experimental design and follow-up monitoring, such as monitoring of the control sites where corals were collected from, to ensure the project does not have significant cumulative impacts, and to ensure that lessons learned from the project can be applied to future efforts thereby mitigating their potential for causing significant adverse impacts.
    c. Projects involving the collecting corals for transplantation should only collect a minimal portion of the wild colony, based on best practices that have been recommended by the international community (e.g., no more than 20% of a colony is removed and colonies are removed from areas where there are competitive interactions and are likely to die or be overgrown).
    d. When relocating, avoid placing the transplanted corals/grid and any required equipment (e.g., tools, sensors, weights, etc.) on live bottom substrate.
    e. Transporting live coral either from collection site to nursery or nursery to outplanting site:
        i. Each coral may be carried by hand or in a bucket to the relocation site.
        ii. In order to reduce stress to the coral from transport and to increase the likelihood of success, the coral colonies should remain submerged in seawater at all times.
        iii. Corals should be handled as little as possible.
        iv. Detached coral colonies should not be in contact with each other to prevent additional harm to their structures and tissue.
        v. If a bucket or container is used for transportation and transportation will be above water (such as on a vessel to get from the removal site to the transplant site), the seawater should be routinely changed to avoid prolonged exposure to increased water temperatures.
        vi. Corals should be reattached the same day they are removed; they should not be stored overnight in transport containers.

9. Coral Fragment Collection:

a. Monitor, if possible, the parent coral colonies from which samples have been taken to track and record that tissue regeneration across the lesions has been effective.

10. Invasive Species:
    a. In areas where there is an identified risk of spreading invasive species or if particular activity can increase the chance of spreading invasive species, grantees/principle investigators should ensure invasive species are not introduced to non-native areas through means such as: 1) cleaning instruments or tools according to scientific protocols to ensure no biofouling is present (e.g., scraping, treating surface with a mild bleach solution, storing removed species in a safe location to decompose, etc.); 2) rinsing dive gear in a bleach solution at the end of each day in the field; 3) sanitizing vessels and all gear at each departure from port; 4) disinfecting equipment and gear between use/sites; and 5) decontamination of clothing and soft gear to be taken ashore from a vessel by freezing materials for 48 hours or by the use of new clothing or soft gear.
    b. Laboratory studies involving the use of live plants, animals, bacteria, and virus must ensure proper steps are taken so that non-native species or pathogens are not introduced or spread as a result of the work.

11. Reduce Impacts to Essential Fish Habitat and Designated Critical Habitat:
    a. Projects involving the use of traps, nets, or other types of fishing gear used to sample fish populations must include measures to ensure the use of these gear types is in a way that minimizes impacts to benthic habitats.
    b. Nets must be monitored at all times to insure ESA-listed sea turtles and other non-target species do not become entangled. If entanglement does occur, the animals will be freed immediately in accordance with any existing guidelines.
    c. Fishing gear will not be deployed in areas with ESA-listed corals if there is a likelihood that gear could become entangled in coral.

12. Bottom Sediment Sample Collection:
    a. Avoid collecting bottom samples in seagrass ESA critical habitat.

13. For project that may temporarily increase sedimentation:
    a. Due to the high risk of sedimentation or suspended material, operations should be halted during peak stony coral spawning periods. To allow for recruitment sediment generating activities should be limited for a three-week period after the primary spawning event.
    b. Avoid sediment-generating activities during soft coral spawning periods if soft corals are observed at or near the site. Sediment generating activities should be restricted for three weeks beginning one week after the full moon of each month to protect the spawning season for soft corals if they are present.

14. Buoy Installation:
    a. Buoys should only be installed at locations with no or low vertical relief and no coral colonization within 1-meter radius from the buoy anchor location to avoid breakage or abrasion of sessile benthic organism from the movement of buoy and tackle. All buoy mooring systems must have floats on the lines to prevent any tackle from dragging on the bottom.
    b. The attachment of a 11.5-inch buoy to the buoy chain approximately 2 feet above the chain attachment point to the bottom anchor in order to prevent the anchor chain from dragging on the seafloor should the chain become detached from the anchor.

c. The use of a helical screw anchor or drill and epoxied pin anchor, depending on substrate type, to minimize the footprint of the anchor in the marine bottom.
d. Anchors will only be installed in sandy bottom areas free of submerged aquatic vegetation (SAV), coral, or hard bottom.
e. The use of an oversight vessel to ensure no marine mammals or sea turtles are in the area during buoy installation. If marine mammals or sea turtles are observed, operations will cease until the animal has left the area.
f. GPS locations of the buoys will be collected once installation is complete and once a month for 3 months to determine whether the buoys are moving. If the buoys have not moved during the first 3 months after installation, quarterly monitoring will be done from the surface and once every 6 months using divers.

15. Watershed Restoration Activities:
    a. Use only native or naturalized plants in vegetative plantings.
    b. Avoid using products with large concentrations of pesticides.
    c. Avoid planting vegetation when a storm is approaching.

16. Terrestrial Work Restrictions:
    a. Do not collect birds (live or dead) or their eggs, nests, or parts (e.g., feathers).
    b. Take all necessary precautions to prevent wounding any birds or disturbing any bird nests.

17. Other
    a. Projects involving implementation of management measures that may have negative socioeconomic implications (e.g., activities that affect the livelihood of user groups such as fishing regulations), should include efforts to educate the user groups regarding the need for these measures and assist user groups in identifying alternatives they could pursue to minimize economic burdens.

Appendix C. EFH- HAPC's under the Four Fishery Management Councils: South Atlantic, Caribbean, Gulf of Mexico, and Western Pacific Regional

South Atlantic Fishery Management Council

Essential Fish Habitat	Fisheries/Species	HAPC's
Wetlands		
Estuarine and marine emergent wetlands	Shrimp, Snapper-Grouper	Shrimp: state designated nursery habitats and mangrove wetlands
Tidal palustrine forested wetlands	Shrimp	
Submerged Aquatic Vegetation		
Estuarine and marine submerged aquatic vegetation	Shrimp, Snapper-Grouper, Spiny Lobster	Snapper-Grouper, Shrimp
Shell bottom		
Oyster reefs and shell banks	Snapper-Grouper	Snapper-Grouper
Coral and Hardbottom		
Coral reefs, live/hardbottom, medium to high rock outcroppings from shore to at least 183 meters.	Snapper-Grouper, Spiny Lobster, Coral, Coral Reefs and Live Hard/bottom Habitat	The Point, Ten Fathom Ledge, and Big Rock, marine protected areas; worm reefs off central east coast of Florida and nearshore hardbottom; coral and hardbottom habitat from Jupiter through the Dry Tortugas, FL; Deepwater Coral HAPCs
Rock overhangs, rock outcrops, manganesephosphorite rock slab formations, and rocky reefs		Blueline Tilefish (in Snapper- Grouper)
Artificial reefs	Snapper-Grouper	Special Management Zones
Soft bottom		
Subtidal, intertidal non-vegetated flats	Shrimp	
Offshore marine habitats used for spawning and growth to maturity	Shrimp	
Sandy shoals of capes and offshore bars	Coastal Migratory Pelagics	Sandy shoals; Cape Lookout; Cape Fear; Cape Hatteras and Hurl Rocks
Troughs and terraces intermingled with sand, mud, or shell hash at depths of 150 to 300 meters		Golden Tilefish (in Snapper-Grouper)

Water Column		
Ocean-side waters, from the surf to the shelf break zone, including Sargassum	Coastal Migratory Pelagics	
All coastal inlets	Coastal Migratory Pelagics	Shrimp, Snapper-Grouper
All state-designated nursery habitats of particular importance	Coastal Migratory Pelagics	Shrimp, Snapper-Grouper
High salinity bays, estuaries	Cobia (in Coastal Migratory Pelagics)	Spanish mackerel: Bogue Sound, New River, NC; Broad River, SC
Pelagic Sargassum	Dolphin	
Gulf Stream	Shrimp, Snapper-Grouper, Coastal Migratory Pelagics, Spiny Lobster, Dolphin-Wahoo	
Spawning area in the water column above the adult habitat and the additional pelagic environment	Snapper-Grouper	

For additional information, go to: http://safmc.net/download/SAFMCEFHUsersGuideFinalNov16.pdf

Caribbean Fishery Management Council

Coral - Ecologically Important Habitats

Puerto Rico

- Luis Peña Channel, Culebra
- Mona/Monito
- La Parguera, Lajas
- Caja de Muertos, Ponce
- Tourmaline Reef
- Guánica State Forest
- Punta Petrona, Santa Isabel
- Ceiba State Forest
- La Cordillera, Fajardo
- Guayama Reefs
- Steps and Tres Palmas, Rincon
- Los Corchos Reef, Culebra
- Desecheo Reefs, Desecheo

St. Croix

- St. Croix Coral Reef Area of Particular Concern, including the East End Marine Park
- Buck Island Reef National Monument
- South Shore Industrial Area Patch Reef and Deep Reef System
- Frederiksted Reef System
- Cane Bay
- Green Cay Wildlife Refuge

Reef Fish - Spawning Habitats

Puerto Rico

- Tourmaline Bank/Buoy 8
- Abrir La Sierra Bank/Buoy 6
- Bajo de Sico
- Vieques, El Seco

St. Croix

- Mutton snapper spawning aggregation area
- East of St. Croix (Lang Bank)
- St. Thomas
- Hind Bank Marine Conservation District
- Grammanik Bank

Reef Fish - Ecologically Important Habitats

Puerto Rico

- Hacienda la Esperanza, Manití
- Bajuras and Tiberones, Isabela
- Cabezas de San Juan, Fajardo
- JOBANNERR, Jobos Bay
- Bioluminescent Bays, Vieques
- Boquerón State Forest
- Pantano Cibuco, Vega Baja

- Piñones State Forest
- Río Espiritu Santo, Río Grande
- Seagrass beds of Culebra Island (nine sites designated as Resource Category 1 and two additional sites)
- Northwest Vieques seagrass west of Mosquito Pier, Vieques

St. Thomas

- Southeastern St. Thomas, including Cas Key and the mangrove lagoon in Great St. James Bay
- Saba Island/Perseverance Bay, including Flat Key and Black Point Reef

St. Croix

- Salt River Bay National Historical Park and Ecological Preserve and Marine Reserve and Wildlife Sanctuary
- Altona Lagoon
- Great Pond South Shore Industrial Area
- Sandy Point National Wildlife Refuge

Gulf of Mexico Fishery Management Council

Florida

- Madison-Swanson Marine Reserve
- Tortugas North
- Tortugas South
- Florida Middle Grounds
- Pulley Ridge

Texas/Louisiana Topographic Features (Reefs and Banks)

- West Flower Garden Banks
- East Flower Garden Banks
- Stetson Bank
- 29 Fathom Bank
- MacNeil Bank
- Rezak Sidner Bank
- Rankin Bright Bank
- Geyer Bank
- McGrail Bank
- Bouma Bank
- Sonnier Bank
- Alderdice Bank
- Jakkula Bank

Western Pacific Regional Fishery Management Council

Combined foot print for all Management Unit Species:	
American Samoa	All bottom habitat from the shoreline to a depth of 400 m (1312 ft); the water column from the shoreline to EEZ, and from the surface to 1000 m (3281 (ft).
Hawaii	All bottom habitat from the shoreline to a depth of 400 m (1312 ft), and the outer reef slopes at depths between 400 m to 700 m (1312 ft and 2297 ft); the water column from the shoreline to EEZ, and from the surface to 1000 m (3281 (ft).
Guam and CNMI	All bottom habitat from the shoreline to a depth of 400 m (1312 ft); the water column from the shoreline to EEZ, and from the surface to 1000 m (3281 (ft).

Appendix D. NOAA Restoration Center PEIS Project List, March 2019

Project Name	State	Project Type	Date Signed
Restoring Abundance to Hawaiian Fisheries and Coastal Communities through Restoration of Fishpond Estuaries - Phase III	HI	Invasive Species Control	2/11/2019
Building Community Capacity for Habitat Restoration and Conservation in the Manell-Geus HFA	GU	Freshwater Stream Bank Restoration and Erosion Reduction	7/2/2018
FEMA USVI post-hurricane coral assessment and restoration	VI	Reef Restoration- Coral	4/5/2018
FEMA Puerto Rico post-hurricane coral assessment and restoration	PR	Reef Restoration- Coral	4/5/2018
M/V Vogetrader Grounding	HI	Reef Restoration- Coral	1/17/2018
Building Community Capacity for Habitat Restoration and Conservation in the Manell-Geus HFA	GU	Planning, Feasibility Studies, Design Engineering, and Permitting	7/5/2017
Community and Coral Restoration and Resilience in the West Hawaii HFA	HI	Environmental Education Programs, Partnerships; Training Programs	7/5/2017
NE Puerto Rico Wave Attenuation Modeling	PR	Planning, Feasibility Studies, Design Engineering, and Permitting	6/30/2017
Expanding Efforts on Building Resiliency in the Puerto Rico Northeast Reserves	PR	Planning, Feasibility Studies, Design Engineering, and Permitting	6/29/2017
Kawaihae Watershed Stabilization and Restoration in Hawaii	HI	Reef Restoration- Coral	6/27/2017
Restoring Abundance to Hawaiian Fisheries and Coastal Communities through Restoration of Fishpond Estuaries - Phase II	HI	Invasive Species Control	6/15/2017
Building Resiliency in the Puerto Rico Northeast Reserves by Addressing Land-based Sources of Pollution (LBSPs), Restoring Coral Reef Habitat	PR	Road Upgrading/Decommissioning; Trail Restoration	5/2/2017
Wetland and Stream Restoration in He'eia, O'ahu (Hawaii)	HI	Invasive Species Control	12/7/2016

Project Name	State	Project Type	Date Signed
Restoring Streams in Wahikuli Watershed, Hawaii	HI	Freshwater Stream Bank Restoration and Erosion Reduction	12/5/2016
Unpaved Road Stabilization - Culebra, Puerto Rico	PR	Road Upgrading/Decommissioning; Trail Restoration	11/25/2016
Kawaihae Watershed Stabilization and Restoration in Hawaii	HI	Reef Restoration- Coral	6/27/2017
Restoring Abundance to Hawaiian Fisheries and Coastal Communities through Restoration of Fishpond Estuaries	HI	Invasive Species Control	6/24/2016
Unpaved Road Stabilization - Culebra, Puerto Rico	PR	Road Upgrading/Decommissioning; Trail Restoration	6/16/2016
Active Coral Propagation - FL	FL	Reef Restoration- Coral	6/16/2016
Coral active propagation - USVI and PR	PR	Species Enhancement	6/6/2016
Culebra Unpaved Road Stabilization - Coronel	PR	Road Upgrading/Decommissioning; Trail Restoration	6/6/2016
Seeding reefs with Diadema antillarum - Puerto Rico	PR	Species Enhancement	6/3/2016
Building Resiliency in the PR Northeast Reserves by Addressing LBSP, Restoring Coral Reef Habitat	PR	Road Upgrading/Decommissioning; Trail Restoration	5/23/2016
Grounding Response - PR and USVI	PR	Reef Restoration- Coral	5/18/2016
Building Resiliency in the Puerto Rico Northeast Reserves	PR	Reef Restoration- Coral	4/27/2016

Appendix E. USFWS Listed ESA Species

Listed status	Species	Jurisdiction
Animals		
T	Knot, red Wherever found (Calidris canutus rufa)	Florida
T	Manatee, West Indian Wherever found (Trichechus manatus)	Florida, Puerto Rico
T	Snake, eastern indigo Wherever found (Drymarchon corais couperi)	Florida
T	Stork, wood AL, FL, GA, MS, NC, SC (Mycteria americana)	Florida
T	Plover, piping [Atlantic Coast and Northern Great Plains populations] - Wherever found, except those areas where listed as endangered. (Charadrius melodus)	Florida
T	Sea turtle, green North Atlantic DPS (Chelonia mydas)	Florida, Hawaii, Guam, CNMI, and American Samoa
E	Sea turtle, hawksbill Wherever found (Eretmochelys imbricata)	Florida, Puerto Rico, Virgin Islands, Hawaii,
E	Sea turtle, leatherback Wherever found (Dermochelys coriacea)	Florida, Puerto Rico, Virgin Islands, Hawaii
E	Woodpecker, red-cockaded Wherever found (Picoides borealis)	Florida
E	Tiger beetle, Miami Wherever found (Cicindelidia floridana)	Florida
E	Mouse, Key Largo cotton Wherever found (Peromyscus gossypinus allapaticola)	Florida
T	scrub-jay, Florida Wherever found (Aphelocoma coerulescens)	Florida
T	Snail, Stock Island tree Wherever found (Orthalicus reses (not incl. nesodryas))	Florida
E	Sparrow, Cape Sable seaside Wherever found (Ammodramus maritimus mirabilis)	Florida
E	Warbler, Kirtland's Wherever found (Setophaga kirtlandii (= Dendroica kirtlandii))	Florida
E	Warbler (=wood), Bachman's Wherever found (Vermivora bachmanii)	Florida
E	Woodrat, Key Largo Wherever found (Neotoma floridana smalli)	Florida
E	Panther, Florida Wherever found (Puma (=Felis) concolor coryi)	Florida
E	Rabbit, Lower Keys marsh Wherever found (Sylvilagus palustris hefneri)	Florida
E	Rice rat lower FL Keys (Oryzomys palustris natator)	Florida
T	Tern, roseate Western Hemisphere except NE U.S. (Sterna dougallii dougallii)	Florida, Puerto Rico, Virgin Islands
T	Crocodile, American U.S.A. (FL) (Crocodylus acutus)	Florida
E	Mouse, Anastasia Island beach Wherever found (Peromyscus polionotus phasma)	Florida

Listed status	Species	Jurisdiction
T	Mouse, southeastern beach wherever found (Peromyscus polionotus niveiventris)	Florida
E	Bat, gray Wherever found (Myotis grisescens)	Florida
E	Kite, Everglade snail Wherever found (Rostrhamus sociabilis plumbeus)	Florida
E	bat, Florida bonneted Wherever found (Eumops floridanus)	Florida
E	Butterfly, Bartram's hairstreak Wherever found (Strymon acis bartrami)	Florida
E	Butterfly, Miami Blue Wherever found (Cyclargus (=Hemiargus) thomasi bethunebakeri)	Florida
T	Caracara, Audubon's crested FL pop. (Polyborus plancus audubonii)	Florida
E	Deer, key Wherever found (Odocoileus virginianus clavium)	Florida
E	Butterfly, Florida leafwing Wherever found (Anaea troglodyta floridalis)	Florida
E	Butterfly, Schaus swallowtail Wherever found (Heraclides aristodemus ponceanus)	Florida
E	Anole, Culebra Island giant Wherever found (Anolis roosevelti)	Puerto Rico
E	Blackbird, yellow-shouldered Wherever found (Agelaius xanthomus)	Puerto Rico
T	Boa, Mona Wherever found (Epicrates monensis monensis)	Puerto Rico
E	Boa, Puerto Rican Wherever found (Epicrates inornatus)	Puerto Rico
E	Boa, Virgin Islands tree Wherever found (Epicrates monensis granti)	Puerto Rico, Virgin Islands
T	Coqui, golden Wherever found (Eleutherodactylus jasperi)	Puerto Rico
E	Coqui, Llanero Wherever found (Eleutherodactylus juanariveroi)	Puerto Rico
E	Gecko, Monito Wherever found (Sphaerodactylus micropithecus)	Puerto Rico
T	Guajon Wherever found (Eleutherodactylus cooki)	Puerto Rico
E	Hawk, Puerto Rican broad-winged Wherever found (Buteo platypterus brunnescens)	Puerto Rico
E	Hawk, Puerto Rican sharp-shinned Wherever found (Accipiter striatus venator)	Puerto Rico
T	Iguana, Mona ground Wherever found (Cyclura stejnegeri)	Puerto Rico
E	Nightjar, Puerto Rican Wherever found (Caprimulgus noctitherus)	Puerto Rico
E	Parrot, Puerto Rican Wherever found (Amazona vittata)	Puerto Rico
E	Pigeon, Puerto Rican plain Wherever found (Columba inornata wetmorei)	Puerto Rico
T	Toad, Puerto Rican crested Wherever found (Peltophryne lemur)	Puerto Rico
T	Warbler, elfin-woods Wherever found (Setophaga angelae)	Puerto Rico
E	Lizard, St. Croix ground Wherever found (Ameiva polops)	Virgin Islands
E	Akekee Wherever found (Loxops caeruleirostris)	Hawaii
E	akepa, Hawaii Wherever found (Loxops coccineus)	Hawaii
E	akepa, Maui Wherever found (Loxops ochraceus)	Hawaii
E	akialoa, Kauai (honeycreeper) Wherever found (Akialoa stejnegeri)	Hawaii
E	akiapolaau Wherever found (Hemignathus wilsoni)	Hawaii
E	Akikiki Wherever found (Oreomystis bairdi)	Hawaii

Listed status	Species	Jurisdiction
E	Albatross, short-tailed Wherever found (Phoebastria (=Diomedea) albatrus)	Hawaii
E	Amphipod, Kauai cave Wherever found (Spelaeorchestia koloana)	Hawaii
E	Bat, Hawaiian hoary Wherever found (Lasiurus cinereus semotus)	Hawaii
E	Coot, Hawaiian Wherever found (Fulica americana alai)	Hawaii
E	Creeper, Hawaii Wherever found (Oreomystis mana)	Hawaii
E	Creeper, Molokai Wherever found (Paroreomyza flammea)	Hawaii
E	Creeper, Oahu Wherever found (Paroreomyza maculata)	Hawaii
E	Crow, Hawaiian (='alala) Wherever found (Corvus hawaiiensis)	Hawaii
E	Damselfly, blackline Hawaiian Wherever found (Megalagrion nigrohamatum nigrolineatum)	Hawaii
E	Damselfly, crimson Hawaiian Wherever found (Megalagrion leptodemas)	Hawaii
E	Damselfly, flying earwig Hawaiian Wherever found (Megalagrion nesiotes)	Hawaii
E	Damselfly, oceanic Hawaiian Wherever found (Megalagrion oceanicum)	Hawaii
E	Damselfly, orangeblack Hawaiian Wherever found (Megalagrion xanthomelas)	Hawaii
E	Damselfly, Pacific Hawaiian Wherever found (Megalagrion pacificum)	Hawaii
E	Duck, Hawaiian (=koloa) Wherever found (Anas wyvilliana)	Hawaii
E	Duck, Laysan Wherever found (Anas laysanensis)	Hawaii
E	elepaio, Oahu Wherever found (Chasiempis ibidis)	Hawaii
E	Finch, Laysan (honeycreeper) Wherever found (Telespyza cantans)	Hawaii
E	Finch, Nihoa (honeycreeper) Wherever found (Telespyza ultima)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila aglaia)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila differens)	Hawaii
E	Fly, Hawaiian picture-wing Wherever found (Drosophila digressa)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila hemipeza)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila heteroneura)	Hawaii
T	fly, Hawaiian picture-wing Wherever found (Drosophila mulli)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila musaphilia)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila obatai)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila ochrobasis)	Hawaii
E	Fly, Hawaiian picture-wing Wherever found (Drosophila sharpi)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila substenoptera)	Hawaii
E	fly, Hawaiian picture-wing Wherever found (Drosophila tarphytrichia)	Hawaii
E	gallinule, Hawaiian common Wherever found (Gallinula galeata sandvicensis)	Hawaii
E	Goose, Hawaiian Wherever found (Branta (=Nesochen) sandvicensis)	Hawaii
E	Hawk, Hawaiian (='lo) Wherever found (Buteo solitarius)	Hawaii
E	honeycreeper, (Akohekohe) crested Wherever found (Palmeria dolei)	Hawaii
T	\`I\`iwi Wherever found (Drepanis coccinea)	Hawaii
E	Millerbird, Nihoa (old world warbler) Wherever found (Acrocephalus familiaris kingi)	Hawaii
E	Moth, Blackburn's sphinx Wherever found (Manduca blackburni)	Hawaii
E	nukupuu, Kauai Wherever found (Hemignathus hanapepe)	Hawaii
E	nukupuu, Maui Wherever found (Hemignathus affinis)	Hawaii
E	\`O\`o, Kauai (honeyeater) Wherever found (Moho braccatus)	Hawaii
E	\`O\`u (honeycreeper) Wherever found (Psittirostra psittacea)	Hawaii
E	Palila (honeycreeper) Wherever found (Loxioides bailleui)	Hawaii
E	parrotbill, Maui (Kiwikiu) Wherever found (Pseudonestor xanthophrys)	Hawaii

Listed status	Species	Jurisdiction
E	petrel, Hawaiian Wherever found (Pterodroma sandwichensis)	Hawaii
E	picture-wing fly, Hawaiian Wherever found (Drosophila montgomeryi)	Hawaii
E	picture-wing fly, Hawaiian Wherever found (Drosophila neoclavisetae)	Hawaii
E	Po`ouli (honeycreeper) Wherever found (Melamprosops phaeosoma)	Hawaii
T	Sea turtle, green Central North Pacific DPS (Chelonia mydas)	Hawaii, Guam, CNMI, American Samoa
T	Sea turtle, olive ridley Wherever found, except when listed as endangered under 50 CFR 224.101 (Lepidochelys olivacea)	Hawaii
T	Shearwater, Newell's Townsend's Wherever found (Puffinus auricularis newelli)	Hawaii
E	Shrimp, anchialine pool Wherever found (Procaris hawaiana)	Hawaii
E	Shrimp, anchialine pool Wherever found (Vetericaris chaceorum)	Hawaii
E	Snail, Lanai tree Wherever found (Partulina semicarinata)	Hawaii
E	Snail, Lanai tree Wherever found (Partulina variabilis)	Hawaii
T	Snail, Newcomb's Wherever found (Erinna newcombi)	Hawaii
E	Snails, Oahu tree Wherever found (Achatinella spp.)	Hawaii
E	Spider, Kauai cave wolf or pe'e pe'e maka 'ole Wherever found (Adelocosa anops)	Hawaii
E	Stilt, Hawaiian Wherever found (Himantopus mexicanus knudseni)	Hawaii
E	Storm-petrel, band-rumped USA (HI) (Oceanodroma castro)	Hawaii
E	Thrush, large Kauai (=kamao) Wherever found (Myadestes myadestinus)	Hawaii
E	Thrush, Molokai Wherever found (Myadestes lanaiensis rutha)	Hawaii
E	Thrush, small Kauai (=puaiohi) Wherever found (Myadestes palmeri)	Hawaii
E	Tree snail, Newcomb's Wherever found (Newcombia cumingi)	Hawaii
E	Yellow-faced bee, anthricinan Wherever found (Hylaeus anthracinus)	Hawaii
E	Yellow-faced bee, assimulans Wherever found (Hylaeus assimulans)	Hawaii
E	Yellow-faced bee, easy Wherever found (Hylaeus facilis)	Hawaii
E	yellow-faced bee, Hawaiian Wherever found (Hylaeus kuakea)	Hawaii
E	yellow-faced bee, Hawaiian Wherever found (Hylaeus longiceps)	Hawaii
E	yellow-faced bee, Hawaiian Wherever found (Hylaeus mana)	Hawaii
E	Yellow-faced bee, hilaris Wherever found (Hylaeus hilaris)	Hawaii
E	Bat, little Mariana fruit Wherever found (Pteropus tokudae)	Guam
T	Bat, Mariana fruit (=Mariana flying fox) Wherever found (Pteropus mariannus mariannus)	Guam, CNMI
E	Butterfly, Mariana eight-spot Wherever found (Hypolimnas octocula marianensis)	Guam
E	Butterfly, Mariana wandering Wherever found (Vagrans egistina)	Guam, CNMI
E	Crow, Mariana (=aga) Wherever found (Corvus kubaryi)	Guam, CNMI
E	Kingfisher, Guam Micronesian Wherever found (Halcyon cinnamomina cinnamomina)	Guam
E	Megapode, Micronesian Wherever found (Megapodius laperouse)	Guam, CNMI
E	Moorhen, Mariana common Wherever found (Gallinula chloropus guami)	Guam, CNMI
E	Rail, Guam Wherever found, except where listed as an experimental population (Rallus owstoni)	Guam

Listed status	Species	Jurisdiction
E	skink, Slevin's Wherever found (Emoia slevini)	Guam, CNMI
E	Snail, fragile tree Wherever found (Samoana fragilis)	Guam, CNMI
E	Snail, Guam tree Wherever found (Partula radiolata)	Guam
E	Snail, Humped tree Wherever found (Partula gibba)	Guam
E	Swiftlet, Mariana gray Wherever found (Aerodramus vanikorensis bartschi)	Guam, CNMI
E	Warbler, nightingale reed (old world warbler) Wherever found (Acrocephalus luscinia)	Guam, CNMI
E	White-eye, bridled Wherever found (Zosterops conspicillatus conspicillatus)	Guam
E	Bat, Pacific sheath-tailed Wherever found (Emballonura semicaudata rotensis)	CNMI
E	damselfly, Rota blue Wherever found (Ischnura luta)	CNMI
E	damselfly, Rota blue Wherever found (Ischnura luta)	CNMI
E	Snail, Langford's tree Wherever found (Partula langfordi)	CNMI
E	White-eye, Rota bridled Wherever found (Zosterops rotensis)	CNMI
E	Bat, Pacific sheath-tailed American Samoa (Emballonura semicaudata semicaudata)	American Samoa
E	Ground-Dove, Friendly American Samoa DPS (Gallicolumba stairi)	American Samoa
E	[no common name] Snail Wherever found (Eua zebrina)	American Samoa
E	[no common name] Snail Wherever found (Ostodes strigatus)	American Samoa
Plants		
E	Chaffseed, American (Schwalbea americana)	Florida
T	Butterwort, Godfrey's (Pinguicula ionantha)	Florida
T	Crabgrass, Florida pineland (Digitaria pauciflora)	Florida
E	fern, Florida bristle (Trichomanes punctatum ssp. floridanum)	Florida
E	Flax, Carter's small-flowered (Linum carteri carteri)	Florida
E	Flax, sand (Linum arenicola)	Florida
E	Lead-plant, Crenulate (Amorpha crenulata)	Florida
E	Milkpea, Small's (Galactia smallii)	Florida
E	Pea, Big Pine partridge (Chamaecrista lineata keyensis)	Florida
E	Prairie-clover, Florida (Dalea carthagenensis floridana)	Florida
T	Sandmat, pineland (Chamaesyce deltoidea pinetorum)	Florida
T	silverbush, Blodgett's (Argythamnia blodgettii)	Florida
E	Spurge, deltoid (Chamaesyce deltoidea ssp. deltoidea)	Florida
E	Spurge, wedge (Chamaesyce deltoidea serpyllum)	Florida
E	Thoroughwort, Cape Sable (Chromolaena frustrata)	Florida
T	Bonamia, Florida (Bonamia grandiflora)	Florida
T	Buckwheat, scrub (Eriogonum longifolium var. gnaphalifolium)	Florida
E	Cactus, Florida semaphore (Consolea corallicola)	Florida
T	Spurge, Garber's (Chamaesyce garberi)	Florida
E	Prickly-apple, fragrant (Cereus eriophorus var. fragrans)	Florida

Listed status	Species	Jurisdiction
E	Campion, fringed (Silene polypetala)	Florida
E	Jacquemontia, beach (Jacquemontia reclinata)	Florida
E	Polygala, tiny (Polygala smallii)	Florida
E	Pawpaw, four-petal (Asimina tetramera)	Florida
E	Gourd, Okeechobee (Cucurbita okeechobeensis ssp. okeechobeensis)	Florida
E	Bariaco (Trichilia triacantha)	Puerto Rico
E	Boxwood, Vahl's (Buxus vahlii)	Puerto Rico, Virgin Islands
E	Capa rosa (Callicarpa ampla)	Puerto Rico
T	Chumbo, Higo (Harrisia portoricensis)	Puerto Rico
E	Chupacallos (Pleodendron macranthum)	Puerto Rico
T	Cobana negra (Stahlia monosperma)	Puerto Rico
E	Erubia (Solanum drymophilum)	Puerto Rico
E	Fern, Elfin tree (Cyathea dryopteroides)	Puerto Rico
E	Goetzea, beautiful (Goetzea elegans)	Puerto Rico
E	Higuero de sierra (Crescentia portoricensis)	Puerto Rico
E	Holly, Cook's (Ilex cookii)	Puerto Rico
T	Manaca, palma de (Calyptronoma rivalis)	Puerto Rico
E	No common name (Adiantum vivesii)	Puerto Rico
E	No common name (Aristida chaseae)	Puerto Rico
E	No common name (Auerodendron pauciflorum)	Puerto Rico
E	No common name (Catesbaea melanocarpa)	Puerto Rico, Virgin Islands
E	No common name (Chamaecrista glandulosa var. mirabilis)	Puerto Rico
E	No common name (Cordia bellonis)	Puerto Rico
E	No common name (Cranichis ricartii)	Puerto Rico
E	No common name (Daphnopsis hellerana)	Puerto Rico
E	No common name (Elaphoglossum serpens)	Puerto Rico
E	No common name (Eugenia woodburyana)	Puerto Rico
T	No common name (Gesneria pauciflora)	Puerto Rico
E	No common name (Gonocalyx concolor)	Puerto Rico
E	No common name (Ilex sintenisii)	Puerto Rico
E	No common name (Lepanthes eltoroensis)	Puerto Rico
E	No common name (Leptocereus grantianus)	Puerto Rico
E	No common name (Lyonia truncata var. proctorii)	Puerto Rico
E	No common name (Mitracarpus maxwelliae)	Puerto Rico

Listed status	Species	Jurisdiction
E	No common name (Mitracarpus polycladus)	Puerto Rico
E	No common name (Myrcia paganii)	Puerto Rico
E	No common name (Polystichum calderonense)	Puerto Rico
T	No common name (Schoepfia arenaria)	Puerto Rico
E	No common name (Tectaria estremerana)	Puerto Rico
E	No common name (Ternstroemia subsessilis)	Puerto Rico
E	No common name (Thelypteris inabonensis)	Puerto Rico
E	No common name (Thelypteris verecunda)	Puerto Rico
E	No common name (Thelypteris yaucoensis)	Puerto Rico
T	No common name (Varronia rupicola)	Puerto Rico
E	No common name (Vernonia proctorii)	Puerto Rico
E	Palo colorado (Ternstroemia luquillensis)	Puerto Rico
E	Palo de jazmin (Styrax portoricensis)	Puerto Rico
E	Palo de nigua (Cornutia obovata)	Puerto Rico
E	Palo de ramon (Banara vanderbiltii)	Puerto Rico
E	Palo de rosa (Ottoschulzia rhodoxylon)	Puerto Rico
E	Pelos del diablo (Aristida portoricensis)	Puerto Rico
E	Peperomia, Wheeler's (Peperomia wheeleri)	Puerto Rico
E	Prickly-ash, St. Thomas (Zanthoxylum thomasianum)	Puerto Rico, Virgin Islands
E	Uvillo (Eugenia haematocarpa)	Puerto Rico
E	Walnut (=Nogal), West Indian (Juglans jamaicensis)	Puerto Rico
E	No common name (Agave eggersiana)	Virgin Islands
E	No common name (Calyptranthes thomasiana)	Virgin Islands
E	A`e (Zanthoxylum dipetalum var. tomentosum)	Hawaii
E	A`e (Zanthoxylum hawaiiense)	Hawaii
E	A`e (Zanthoxylum oahuense)	Hawaii
T	`Ahinahina (Argyroxiphium sandwicense ssp. macrocephalum)	Hawaii
E	`Ahinahina (Argyroxiphium sandwicense ssp. sandwicense)	Hawaii
E	`Aiakeakua, popolo (Solanum sandwicense)	Hawaii
E	`Aiea (Nothocestrum breviflorum)	Hawaii
E	`Aiea (Nothocestrum latifolium)	Hawaii
E	`Aiea (Nothocestrum peltatum)	Hawaii
E	`Akoko (Euphorbia celastroides var. kaenana)	Hawaii
E	`Akoko (Euphorbia deppeana)	Hawaii
E	`Akoko (Euphorbia eleanoriae)	Hawaii

Listed status	Species	Jurisdiction
E	`Akoko (Euphorbia haeleeleana)	Hawaii
E	`Akoko (Euphorbia herbstii)	Hawaii
E	`Akoko (Euphorbia kuwaleana)	Hawaii
E	`Akoko (Euphorbia remyi var. kauaiensis)	Hawaii
E	`Akoko (Euphorbia remyi var. remyi)	Hawaii
E	`Akoko (Euphorbia rockii)	Hawaii
E	"Akoko (Euphorbia halemanui)	Hawaii
E	`Akoko, Ewa Plains (Euphorbia skottsbergii var. skottsbergii)	Hawaii
E	`aku (Cyanea tritomantha)	Hawaii
E	`aku`aku (Cyanea platyphylla)	Hawaii
E	`Ala `ala wai nui (Peperomia subpetiolata)	Hawaii
E	Alani (Melicope adscendens)	Hawaii
E	Alani (Melicope balloui)	Hawaii
E	Alani (Melicope christophersenii)	Hawaii
E	Alani (Melicope degeneri)	Hawaii
E	Alani (Melicope haupuensis)	Hawaii
E	Alani (Melicope hiiakae)	Hawaii
E	Alani (Melicope knudsenii)	Hawaii
E	Alani (Melicope lydgatei)	Hawaii
E	Alani (Melicope makahae)	Hawaii
E	Alani (Melicope mucronulata)	Hawaii
E	Alani (Melicope munroi)	Hawaii
E	Alani (Melicope ovalis)	Hawaii
E	Alani (Melicope pallida)	Hawaii
E	Alani (Melicope paniculata)	Hawaii
E	Alani (Melicope puberula)	Hawaii
E	Alani (Melicope quadrangularis)	Hawaii
E	Alani (Melicope reflexa)	Hawaii
E	Alani (Melicope saint-johnii)	Hawaii
E	Alani (Melicope zahlbruckneri)	Hawaii
E	`Anaunau (Lepidium arbuscula)	Hawaii
E	`Anunu (Sicyos albus)	Hawaii
E	`Anunu (Sicyos macrophyllus)	Hawaii
E	aumakua, Palapalai (Dryopteris crinalis var. podosorus)	Hawaii
E	Aupaka (Isodendrion hosakae)	Hawaii
E	Aupaka (Isodendrion laurifolium)	Hawaii
T	Aupaka (Isodendrion longifolium)	Hawaii

Listed status	Species	Jurisdiction
E	`Awikiwiki (Canavalia molokaiensis)	Hawaii
E	`Awikiwiki (Canavalia napaliensis)	Hawaii
E	`Awikiwiki (Canavalia pubescens)	Hawaii
E	Awiwi (Schenkia sebaeoides)	Hawaii
E	'Awiwi (Kadua cookiana)	Hawaii
E	bean, sea (Mucuna sloanei var. persericea)	Hawaii
E	Bluegrass, Hawaiian (Poa sandvicensis)	Hawaii
E	Bluegrass, Mann's (Poa mannii)	Hawaii
E	Chaff-flower, round-leaved (Achyranthes splendens var. rotundata)	Hawaii
E	diellia, Asplenium-leaved (Asplenium dielerectum)	Hawaii
E	`Ena`ena (Pseudognaphalium sandwicensium var. molokaiense)	Hawaii
E	Fern, pendant kihi (Adenophorus periens)	Hawaii
E	Gardenia (=Na`u), Hawaiian (Gardenia brighamii)	Hawaii
E	Geranium, Hawaiian red-flowered (Geranium arboreum)	Hawaii
E	Haha (Cyanea acuminata)	Hawaii
E	Haha (Cyanea asarifolia)	Hawaii
E	Haha (Cyanea asplenifolia)	Hawaii
E	Haha (Cyanea calycina)	Hawaii
E	Haha (Cyanea copelandii ssp. copelandii)	Hawaii
E	Haha (Cyanea copelandii ssp. haleakalaensis)	Hawaii
E	haha (Cyanea crispa)	Hawaii
E	Haha (Cyanea dolichopoda)	Hawaii
E	haha (Cyanea dunbariae)	Hawaii
E	haha (Cyanea duvalliorum)	Hawaii
E	Haha (Cyanea eleeleensis)	Hawaii
E	haha (Cyanea gibsonii)	Hawaii
E	Haha (Cyanea glabra)	Hawaii
E	Haha (Cyanea grimesiana ssp. grimesiana)	Hawaii
E	Haha (Cyanea grimesiana ssp. obatae)	Hawaii
E	Haha (Cyanea hamatiflora ssp. carlsonii)	Hawaii
E	Haha (Cyanea hamatiflora ssp. hamatiflora)	Hawaii
E	Haha (Cyanea humboldtiana)	Hawaii
E	Haha (Cyanea kolekoleensis)	Hawaii
E	Haha (Cyanea koolauensis)	Hawaii
E	Haha (Cyanea kuhihewa)	Hawaii
E	Haha (Cyanea kunthiana)	Hawaii
E	Haha (Cyanea lanceolata)	Hawaii
E	Haha (Cyanea lobata)	Hawaii

Listed status	Species	Jurisdiction
E	Haha (Cyanea longiflora)	Hawaii
E	haha (Cyanea magnicalyx)	Hawaii
E	Haha (Cyanea mannii)	Hawaii
E	haha (Cyanea maritae)	Hawaii
E	Haha (Cyanea marksii)	Hawaii
E	haha (Cyanea mauiensis)	Hawaii
E	Haha (Cyanea mceldowneyi)	Hawaii
E	haha (Cyanea munroi)	Hawaii
E	Haha (Cyanea obtusa)	Hawaii
E	Haha (Cyanea pinnatifida)	Hawaii
E	Haha (Cyanea procera)	Hawaii
E	Haha (Cyanea profuga)	Hawaii
E	Haha (Cyanea purpurellifolia)	Hawaii
T	Haha (Cyanea recta)	Hawaii
E	Haha (Cyanea remyi)	Hawaii
E	Haha (Cyanea rivularis)	Hawaii
E	Haha (Cyanea shipmanii)	Hawaii
E	Haha (Cyanea stictophylla)	Hawaii
E	Haha (Cyanea st.-johnii)	Hawaii
E	Haha (Cyanea superba)	Hawaii
E	Haha (Cyanea truncata)	Hawaii
E	Haha (Cyanea undulata)	Hawaii
E	haiwale (Cyrtandra ferripilosa)	Hawaii
E	Haiwale (Cyrtandra gracilis)	Hawaii
E	Haiwale (Cyrtandra paliku)	Hawaii
E	Haiwale (Cyrtandra waiolani)	Hawaii
E	Ha`iwale (Cyrtandra crenata)	Hawaii
E	Ha`iwale (Cyrtandra dentata)	Hawaii
E	Ha`iwale (Cyrtandra filipes)	Hawaii
E	Ha`iwale (Cyrtandra giffardii)	Hawaii
E	Ha`iwale (Cyrtandra hematos)	Hawaii
E	Ha`iwale (Cyrtandra kaulantha)	Hawaii
T	Ha`iwale (Cyrtandra limahuliensis)	Hawaii
E	Ha`iwale (Cyrtandra munroi)	Hawaii
E	Ha`iwale (Cyrtandra oenobarba)	Hawaii
E	Ha`iwale (Cyrtandra oxybapha)	Hawaii
E	Ha`iwale (Cyrtandra polyantha)	Hawaii

Listed status	Species	Jurisdiction
E	Ha`iwale (Cyrtandra sessilis)	Hawaii
E	Ha`iwale (Cyrtandra subumbellata)	Hawaii
E	Ha`iwale (Cyrtandra tintinnabula)	Hawaii
E	Ha`iwale (Cyrtandra viridiflora)	Hawaii
E	Hala pepe (Pleomele fernaldii)	Hawaii
E	Hala pepe (Pleomele forbesii)	Hawaii
E	Hala pepe (Pleomele hawaiiensis)	Hawaii
E	Hau kuahiwi (Hibiscadelphus giffardianus)	Hawaii
E	Hau kuahiwi (Hibiscadelphus hualalaiensis)	Hawaii
E	Hau kuahiwi (Hibiscadelphus woodii)	Hawaii
E	Heau (Exocarpos luteolus)	Hawaii
E	Heau (Exocarpos menziesii)	Hawaii
E	Hibiscus, Clay's (Hibiscus clayi)	Hawaii
E	Hoawa (Pittosporum halophilum)	Hawaii
E	Hoawa (Pittosporum hawaiiense)	Hawaii
E	Ho`awa (Pittosporum napaliense)	Hawaii
E	Hohiu (Dryopteris glabra var. pusilla)	Hawaii
E	Holei (Ochrosia haleakalae)	Hawaii
E	Holei (Ochrosia kilaueaensis)	Hawaii
E	Honohono (Haplostachys haplostachya)	Hawaii
E	Hulumoa (Korthalsella degeneri)	Hawaii
E	Ihi (Portulaca villosa)	Hawaii
E	Ihi`ihi (Marsilea villosa)	Hawaii
E	Iliau, dwarf (Wilkesia hobdyi)	Hawaii
E	Ischaemum, Hilo (Ischaemum byrone)	Hawaii
E	Kamakahala (Labordia cyrtandrae)	Hawaii
E	Kamakahala (Labordia helleri)	Hawaii
E	Kamakahala (Labordia lydgatei)	Hawaii
E	Kamakahala (Labordia pumila)	Hawaii
E	Kamakahala (Labordia tinifolia var. lanaiensis)	Hawaii
E	Kamakahala (Labordia tinifolia var. wahiawaensis)	Hawaii
E	Kamakahala (Labordia triflora)	Hawaii
E	Kamanomano (Cenchrus agrimonioides)	Hawaii
E	Kamapua`a (Kadua fluviatilis)	Hawaii
E	Kauai hau kuahiwi (Hibiscadelphus distans)	Hawaii
E	Kauila (Colubrina oppositifolia)	Hawaii
E	Kaulu (Pteralyxia kauaiensis)	Hawaii

Listed status	Species	Jurisdiction
E	Kaulu (Pteralyxia macrocarpa)	Hawaii
E	Kio`ele (Kadua coriacea)	Hawaii
E	Kiponapona (Phyllostegia racemosa)	Hawaii
E	Kohe malama malama o kanaloa (Kanaloa kahoolawensis)	Hawaii
E	Koholapehu (Dubautia latifolia)	Hawaii
E	Koki`o (Kokia drynarioides)	Hawaii
E	Koki`o (Kokia kauaiensis)	Hawaii
E	Koki`o, Cooke's (Kokia cookei)	Hawaii
E	Koki`o ke`oke`o (Hibiscus arnottianus ssp. immaculatus)	Hawaii
E	Koki`o ke`oke`o (Hibiscus waimeae ssp. hannerae)	Hawaii
E	Kolea (Myrsine fosbergii)	Hawaii
E	Kolea (Myrsine juddii)	Hawaii
E	Kolea (Myrsine knudsenii)	Hawaii
T	Kolea (Myrsine linearifolia)	Hawaii
E	Kolea (Myrsine mezii)	Hawaii
E	Kolea (Myrsine vaccinioides)	Hawaii
E	Ko`oko`olau (Bidens amplectens)	Hawaii
E	Ko`oko`olau (Bidens campylotheca ssp. pentamera)	Hawaii
E	Ko`oko`olau (Bidens campylotheca ssp. waihoiensis)	Hawaii
E	Ko`oko`olau (Bidens conjuncta)	Hawaii
E	Ko`oko`olau (Bidens micrantha ssp. ctenophylla)	Hawaii
E	Ko`oko`olau (Bidens micrantha ssp. kalealaha)	Hawaii
E	Ko`oko`olau (Bidens wiebkei)	Hawaii
E	Ko`oloa`ula (Abutilon menziesii)	Hawaii
E	kopa (Kadua cordata remyi)	Hawaii
E	Kopiko (Psychotria grandiflora)	Hawaii
E	Kopiko (Psychotria hexandra ssp. oahuensis)	Hawaii
E	Kopiko (Psychotria hobdyi)	Hawaii
E	Kuahiwi laukahi (Plantago hawaiensis)	Hawaii
E	Kuahiwi laukahi (Plantago princeps)	Hawaii
E	Kuawawaenohu (Schiedea lychnoides)	Hawaii
E	Kula wahine noho (Isodendrion pyrifolium)	Hawaii
E	Kulu`i (Nototrichium humile)	Hawaii
E	Kupukupu makalii (Cyclosorus boydiae)	Hawaii
E	Lau `ehu (Panicum niihauense)	Hawaii
E	Laulihilihi (Schiedea stellarioides)	Hawaii
E	lehua makanoe (Lysimachia daphnoides)	Hawaii

Listed status	Species	Jurisdiction
E	Liliwai (Acaena exigua)	Hawaii
E	Lo`ulu (Pritchardia hardyi)	Hawaii
E	Lo`ulu (Pritchardia kaalae)	Hawaii
E	Lo`ulu (Pritchardia lanigera)	Hawaii
E	Lo`ulu (Pritchardia maideniana)	Hawaii
E	Lo`ulu (Pritchardia munroi)	Hawaii
E	Lo`ulu (Pritchardia napaliensis)	Hawaii
E	Lo`ulu (Pritchardia remota)	Hawaii
E	Lo`ulu (Pritchardia schattaueri)	Hawaii
E	Lo`ulu (Pritchardia viscosa)	Hawaii
E	Loulu, Baker"s (Pritchardia bakeri)	Hawaii
E	Love grass, Fosberg's (Eragrostis fosbergii)	Hawaii
E	Mahoe (Alectryon macrococcus)	Hawaii
T	Makou (Peucedanum sandwicense)	Hawaii
E	Makou (Ranunculus hawaiensis)	Hawaii
E	Makou (Ranunculus mauiensis)	Hawaii
E	Ma`o hau hele, (=native yellow hibiscus) (Hibiscus brackenridgei)	Hawaii
E	Ma`oli`oli (Schiedea apokremnos)	Hawaii
E	Ma`oli`oli (Schiedea hawaiiensis)	Hawaii
E	Ma`oli`oli (Schiedea kealiae)	Hawaii
E	Ma`oli`oli (Schiedea pubescens)	Hawaii
E	Mapele (Cyrtandra cyaneoides)	Hawaii
E	Mehamehame (Flueggea neowawraea)	Hawaii
E	Naenae (Dubautia kalalauensis)	Hawaii
E	Naenae (Dubautia kenwoodii)	Hawaii
E	Na`ena`e (Dubautia herbstobatae)	Hawaii
E	Na`ena`e (Dubautia imbricata ssp. imbricata)	Hawaii
E	Na`ena`e (Dubautia pauciflorula)	Hawaii
E	Na`ena`e (Dubautia plantaginea ssp. humilis)	Hawaii
E	Na`ena`e (Dubautia plantaginea ssp. magnifolia)	Hawaii
E	Na`ena`e (Dubautia waialealae)	Hawaii
E	Nani wai`ale`ale (Viola kauaiensis var. wahiawaensis)	Hawaii
E	Nanu (Gardenia mannii)	Hawaii
E	Nanu (Gardenia remyi)	Hawaii
E	Naupaka, dwarf (Scaevola coriacea)	Hawaii
E	Nehe (Lipochaeta fauriei)	Hawaii
E	Nehe (Lipochaeta lobata var. leptophylla)	Hawaii

Listed status	Species	Jurisdiction
E	Nehe (Lipochaeta micrantha)	Hawaii
E	Nehe (Lipochaeta waimeaensis)	Hawaii
E	nehe (Melanthera kamolensis)	Hawaii
E	Nehe (Melanthera tenuifolia)	Hawaii
E	Nioi (Eugenia koolauensis)	Hawaii
E	No common name (Abutilon eremitopetalum)	Hawaii
E	No common name (Abutilon sandwicense)	Hawaii
E	No common name (Achyranthes mutica)	Hawaii
E	No common name (Amaranthus brownii)	Hawaii
E	No common name (Asplenium dielfalcatum)	Hawaii
E	No common name (Asplenium diellaciniatum)	Hawaii
E	No common name (Asplenium dielmannii)	Hawaii
E	No common name (Asplenium dielpallidum)	Hawaii
E	No common name (Asplenium peruvianum var. insulare)	Hawaii
E	No common name (Asplenium unisorum)	Hawaii
E	No common name (Bidens hillebrandiana ssp. hillebrandiana)	Hawaii
E	No common name (Bonamia menziesii)	Hawaii
E	No common name (Cyanea kauaulaensis)	Hawaii
E	No common name (Cyperus fauriei)	Hawaii
E	No common name (Cyperus neokunthianus)	Hawaii
E	No common name (Cyperus pennatiformis)	Hawaii
E	No common name (Cyrtandra nanawaleensis)	Hawaii
E	No common name (Cyrtandra wagneri)	Hawaii
E	No common name (Delissea rhytidosperma)	Hawaii
E	No common name (Delissea undulata)	Hawaii
E	No common name (Deparia kaalaana)	Hawaii
E	No common name (Diplazium molokaiense)	Hawaii
E	No common name (Doryopteris angelica)	Hawaii
E	No common name (Doryopteris takeuchii)	Hawaii
E	No common name (Festuca hawaiiensis)	Hawaii
E	No common name (Festuca molokaiensis)	Hawaii
E	No common name (Gouania hillebrandii)	Hawaii
E	No common name (Gouania meyenii)	Hawaii
E	No common name (Gouania vitifolia)	Hawaii
E	No common name (Hesperomannia arborescens)	Hawaii
E	No common name (Hesperomannia arbuscula)	Hawaii

Listed status	Species	Jurisdiction
E	No common name (Hesperomannia lydgatei)	Hawaii
E	No common name (Huperzia stemmermanniae)	Hawaii
E	No common name (Kadua degeneri)	Hawaii
E	No common name (Kadua haupuensis)	Hawaii
E	No common name (Kadua parvula)	Hawaii
E	No common name (Kadua st.-johnii)	Hawaii
E	No common name (Keysseria (=Lagenifera) erici)	Hawaii
E	No common name (Keysseria (=Lagenifera) helenae)	Hawaii
E	No common name (Labordia lorenciana)	Hawaii
E	No common name (Lepidium orbiculare)	Hawaii
E	No common name (Lipochaeta venosa)	Hawaii
E	No common name (Lobelia koolauensis)	Hawaii
E	No common name (Lobelia monostachya)	Hawaii
E	No common name (Lobelia niihauensis)	Hawaii
E	No common name (Lobelia oahuensis)	Hawaii
E	No common name (Lysimachia filifolia)	Hawaii
E	No common name (Lysimachia iniki)	Hawaii
E	No common name (Lysimachia lydgatei)	Hawaii
E	No common name (Lysimachia maxima)	Hawaii
E	No common name (Lysimachia pendens)	Hawaii
E	No common name (Lysimachia scopulensis)	Hawaii
E	No common name (Lysimachia venosa)	Hawaii
E	No common name (Microlepia strigosa var. mauiensis)	Hawaii
E	No common name (Neraudia angulata)	Hawaii
E	No common name (Neraudia ovata)	Hawaii
E	No common name (Neraudia sericea)	Hawaii
E	No common name (Phyllostegia bracteata)	Hawaii
E	No common name (Phyllostegia brevidens)	Hawaii
E	No common name (Phyllostegia floribunda)	Hawaii
E	No common name (Phyllostegia glabra var. lanaiensis)	Hawaii
E	No common name (Phyllostegia haliakalae)	Hawaii
E	No common name (Phyllostegia helleri)	Hawaii
E	No common name (Phyllostegia hirsuta)	Hawaii
E	No common name (Phyllostegia hispida)	Hawaii
E	No common name (Phyllostegia kaalaensis)	Hawaii
E	No common name (Phyllostegia knudsenii)	Hawaii
E	No common name (Phyllostegia mannii)	Hawaii

Listed status	Species	Jurisdiction
E	No common name (Phyllostegia mollis)	Hawaii
E	No common name (Phyllostegia parviflora)	Hawaii
E	No common name (Phyllostegia pilosa)	Hawaii
E	No common name (Phyllostegia renovans)	Hawaii
E	No common name (Phyllostegia stachyoides)	Hawaii
E	No common name (Phyllostegia velutina)	Hawaii
E	No common name (Phyllostegia waimeae)	Hawaii
E	No common name (Phyllostegia warshaueri)	Hawaii
E	No common name (Phyllostegia wawrana)	Hawaii
E	No common name (Platanthera holochila)	Hawaii
E	No common name (Platydesma cornuta var. cornuta)	Hawaii
E	No common name (Platydesma cornuta var. decurrens)	Hawaii
E	No common name (Platydesma remyi)	Hawaii
E	No common name (Poa siphonoglossa)	Hawaii
E	No common name (Polyscias bisattenuata)	Hawaii
E	No common name (Polyscias flynnii)	Hawaii
E	No common name (Polyscias lydgatei)	Hawaii
E	No common name (Polyscias racemosa)	Hawaii
E	No common name (Pteris lidgatei)	Hawaii
E	No common name (Remya kauaiensis)	Hawaii
E	No common name (Remya montgomeryi)	Hawaii
E	No common name (Sanicula mariversa)	Hawaii
E	No common name (Sanicula purpurea)	Hawaii
E	No common name (Sanicula sandwicensis)	Hawaii
E	No common name (Santalum involutum)	Hawaii
E	No common name (Schiedea attenuata)	Hawaii
E	No common name (Schiedea diffusa ssp. macraei)	Hawaii
E	No common name (Schiedea diffusa subsp. diffusa)	Hawaii
E	No common name (Schiedea haleakalensis)	Hawaii
E	No common name (Schiedea helleri)	Hawaii
E	No common name (Schiedea hookeri)	Hawaii
E	No common name (Schiedea jacobii)	Hawaii
E	No common name (Schiedea kaalae)	Hawaii
E	No common name (Schiedea kauaiensis)	Hawaii
E	No common name (Schiedea laui)	Hawaii
E	No common name (Schiedea lydgatei)	Hawaii
E	No common name (Schiedea membranacea)	Hawaii
E	No common name (Schiedea nuttallii)	Hawaii
E	No common name (Schiedea obovata)	Hawaii

Listed status	Species	Jurisdiction
E	No common name (Schiedea salicaria)	Hawaii
E	No common name (Schiedea sarmentosa)	Hawaii
E	No common name (Schiedea spergulina var. leiopoda)	Hawaii
T	No common name (Schiedea spergulina var. spergulina)	Hawaii
E	No common name (Schiedea trinervis)	Hawaii
E	No common name (Schiedea viscosa)	Hawaii
E	No common name (Sicyos lanceoloideus)	Hawaii
E	No common name (Silene alexandri)	Hawaii
T	No common name (Silene hawaiiensis)	Hawaii
E	No common name (Silene lanceolata)	Hawaii
E	No common name (Silene perlmanii)	Hawaii
E	No common name (Spermolepis hawaiiensis)	Hawaii
E	No common name (Stenogyne angustifolia var. angustifolia)	Hawaii
E	No common name (Stenogyne bifida)	Hawaii
E	No common name (Stenogyne campanulata)	Hawaii
E	No common name (Stenogyne cranwelliae)	Hawaii
E	No common name (Stenogyne kaalae ssp. sherffii)	Hawaii
E	No common name (Stenogyne kanehoana)	Hawaii
E	No common name (Stenogyne kauaulaensis)	Hawaii
E	No common name (Stenogyne kealiae)	Hawaii
E	No common name (Tetramolopium arenarium)	Hawaii
E	No common name (Tetramolopium filiforme)	Hawaii
E	No common name (Tetramolopium lepidotum ssp. lepidotum)	Hawaii
E	No common name (Tetramolopium remyi)	Hawaii
T	No common name (Tetramolopium rockii)	Hawaii
E	No common name (Trematolobelia singularis)	Hawaii
E	No common name (Vigna o-wahuensis)	Hawaii
E	No common name (Viola helenae)	Hawaii
E	No common name (Viola lanaiensis)	Hawaii
E	No common name (Viola oahuensis)	Hawaii
E	No common name (Wikstroemia skottsbergiana)	Hawaii
E	No common name (Wikstroemia villosa)	Hawaii
E	No common name (Xylosma crenatum)	Hawaii
E	Nohoanu (Geranium hanaense)	Hawaii
E	Nohoanu (Geranium hillebrandii)	Hawaii
E	Nohoanu (Geranium kauaiense)	Hawaii
E	Nohoanu (Geranium multiflorum)	Hawaii
E	nui, haha (Cyanea horrida)	Hawaii
E	Oha (Delissea subcordata)	Hawaii

Listed status	Species	Jurisdiction
E	Ohai (Sesbania tomentosa)	Hawaii
E	`Oha wai (Clermontia drepanomorpha)	Hawaii
E	`Oha wai (Clermontia lindseyana)	Hawaii
E	`Oha wai (Clermontia oblongifolia ssp. brevipes)	Hawaii
E	`Oha wai (Clermontia oblongifolia ssp. mauiensis)	Hawaii
E	`Oha wai (Clermontia peleana)	Hawaii
E	`Oha wai (Clermontia pyrularia)	Hawaii
E	`Oha wai (Clermontia samuelii)	Hawaii
E	`Ohe (Joinvillea ascendens ascendens)	Hawaii
E	`Ohe`ohe (Polyscias gymnocarpa)	Hawaii
E	olua (Hypolepis hawaiiensis var. mauiensis)	Hawaii
E	Olulu (Brighamia insignis)	Hawaii
E	Opuhe (Urera kaalae)	Hawaii
E	Pa`iniu (Astelia waialealae)	Hawaii
E	Pamakani (Tetramolopium capillare)	Hawaii
E	Pamakani (Viola chamissoniana ssp. chamissoniana)	Hawaii
E	Panicgrass, Carter's (Panicum fauriei var. carteri)	Hawaii
E	Papala (Charpentiera densiflora)	Hawaii
E	Pauoa (Ctenitis squamigera)	Hawaii
E	pilo (Kadua laxiflora)	Hawaii
E	Pilo kea lau li`i (Platydesma rostrata)	Hawaii
E	Po`e (Portulaca sclerocarpa)	Hawaii
E	Popolo (Cyanea solanacea)	Hawaii
E	Popolo (Solanum nelsonii)	Hawaii
E	Popolo ku mai (Solanum incompletum)	Hawaii
E	Pua `ala (Brighamia rockii)	Hawaii
E	Pu`uka`a (Cyperus trachysanthos)	Hawaii
E	Reedgrass, Hillegrand's (Calamagrostis hillebrandii)	Hawaii
E	Reedgrass, Maui (Calamagrostis expansa)	Hawaii
E	Remya, Maui (Remya mauiensis)	Hawaii
E	Sandalwood, Lanai (=`iliahi) (Santalum haleakalae var. lanaiense)	Hawaii
E	Schiedea, Diamond Head (Schiedea adamantis)	Hawaii
E	Silversword, Mauna Loa (=Ka'u) (Argyroxiphium kauense)	Hawaii
E	Uhi uhi (Mezoneuron kavaiense)	Hawaii
E	Vetch, Hawaiian (Vicia menziesii)	Hawaii
E	Wahane (Pritchardia aylmer-robinsonii)	Hawaii
E	Wawae`iole (Huperzia mannii)	Hawaii

Listed status	Species	Jurisdiction
E	Wawae`iole (Huperzia nutans)	Hawaii
E	Aplokating-palaoan (Psychotria malaspinae)	Guam
T	Fadang (Cycas micronesica)	Guam, CNMI
E	halomtano, Berenghenas (Solanum guamense)	Guam
T	halumtano, Cebello (Bulbophyllum guamense)	Guam, CNMI
E	Iagu, Hayun (=(Guam), Tronkon guafi (Rota)) (Serianthes nelsonii)	Guam, CNMI
T	No common name (Dendrobium guamense)	Guam, CNMI
E	No common name (Eugenia bryanii)	Guam, CNMI
T	No common name (Maesa walkeri)	Guam, CNMI
T	No common name (Nervilia jacksoniae)	Guam, CNMI
E	No common name (Phyllanthus saffordii)	Guam
T	No common name (Tabernaemontana rotensis)	Guam
E	No common name (Tinospora homosepala)	Guam
T	No common name (Tuberolabium guamense)	Guam, CNMI
E	Paudedo (Hedyotis megalantha)	Guam
E	Ufa-halomtano (Heritiera longipetiolata)	Guam, CNMI
E	No common name (Nesogenes rotensis)	CNMI
E	No common name (Osmoxylon mariannense)	CNMI
T	No common name (Tabernaemontana rotensis)	CNMI

Appendix F. List of marine mammals found within the U.S. regions where CRPC works

Common Name	Scientific Name	Pacific	Southeast	Gulf	Caribbean
Atlantic Spotten dolphin	*Stenella frontalis*		X	X	X
Blainville's Beaked Whale	*Mesoplodon densirostris*	X		X	
Blue Whale	*Balaenoptera musculus*	X			
Bottlenose Dolphin	*Tursiops truncatus*	X	X	X	X
Bryde's Whale	*Balaenoptera edeni*	X		X	
Clymene Dolphin				X	X
Common Dolphin	*Delphinus delphis*	X			
Cuvier's Beaked Whale	*Ziphius cavirostris*	X		X	X
Dense Beaked Whale	*Mesoplodon densirostris*			X	
Dugong*	*Dugong dugon*	X			
Dwarf Sperm Whale	*Kogia simus*	X		X	
False Killer Whale — Hawaiian Pelagic	*Pseudorca crassidens*	X		X	
Fin Whale	*Balaenoptera physalus*	X	X	X	X
Florida manatee	*Trichechus manatus latirostris*		X	X	
Fraser's Dolphin	*Lagenodelphis hosei*	X		X	
Gervais Beaked Whale	*Mesoplodon europaeus*		X	X	
Hawaiian Monk Seal	*Neomonachus schauinslandi*				
Humpback Whale	*Megaptera novaeangliae*	X	X		
Killer Whale	*Orcinus orca*	X		X	
Long-finned Pilot Whale	*Globicephala melaena*	X			
Longman's Beaked Whale	*Indopacetus pacificus*	X			
Melon-Headed Whale	*Peponocephala electra*	X	X	X	
Minke Whale	*Balaenoptera acutorostrata*	X	X	X	X
North Pacific Right Whale	*Eubalaena japonica*	X			
Pantropical Spotted Dolphin	*Stenella attenuata*	X		X	
Pilot whale, Short finned	*Globicephala macrorhynchus*				X
Pygmy killer whale	*Feresa attenuata*	X		X	
Pygmy Sperm Whale	*Kogia breviceps*	X		X	
Risso's Dolphin	*Grampus griseus*	X	X	X	
Rough-toothed Dolphin	*Steno bredanensis*	X	X	X	
Sei Whale	*Balaenoptera borealis*	X	X	X	X
Short-Finned Pilot Whale	*Globicephala macrorhynchus*		X	X	
Sperm Whale	*Physeter macrocephalus*	X		X	
Spinner Dolphin	*Stenella longirostris*	X		X	X
Striped Dolphin	*Stenella coeruleoalba*	X		X	
West Indian manatee	*Trichechus manatus manatus*				X

Appendix G. The CRCP Impacts Matrix

CRCP Impacts Matrix: Comparison for Coral Reef Restoration/Interventions and Reductions in Physical Impacts to Coral Reefs

I = Intensity, C = Context, D = Duration

- 3 = Major (-), -2 = Moderate (-), -1 = Minor (-), 0 = Neglible, 1 = Minor (+), 2 = Moderate (+), 3 = Major (+)

A = Adverse, B = Benefit

Resource		No Action Alterative			Alternative 1			Alternative 2		
		A	B		A	B		A	B	
Soils and Seidments	I	-1	3	Minor (-) to Major (+)	-1	1	Moderate (-) to Minor (+)	-1	3	Minor (-) to Major (+)
	C	-1	2		-1	0		-1	2	
	D	-1	2		-2	0		-1	2	
Terrestrial Habitat and Biota	I	-1	2	Minor (-) to Moderate (+)	-1	2	Minor (-) to Moderate (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		-1	2		-1	2	
	D	-1	2		-1	2		-1	2	
Wetlands and Floodplains	I	-1	2	Minor (-) to Moderate (+)	-1	2	Minor (-) to Moderate (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		-1	1		-1	2	
	D	-1	2		-1	1		-1	2	
Water Resources	I	-1	3	Minor (-) to Major (+)	-1	1	Minor (-) to Moderate (+)	-1	3	Minor (-) to Major (+)
	C	-1	2		-1	2		-1	2	
	D	-1	2		-1	2		-1	2	
Seagrasses	I	-1	2	Minor (-) to Moderate (+)	-1	1	Moderate (-) to Minor (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		-1	0		-1	2	
	D	-1	2		-2	0		-1	2	
Mangroves	I	-1	2	Minor (-) to Moderate (+)	-1	1	Moderate (-) to Minor (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		-1	0		-1	2	
	D	-1	2		-2	0		-1	2	
Corals, Other Assocaited Invertebrates, and Algae	I	-1	3	Moderate (-) to Major (+)	-3	1	Major (-) to Minor (+)	-1	3	Moderate (-) to Major (+)
	C	-2	2		-3	1		-2	2	
	D	-1	2		-2	0		-1	2	
Fish	I	-1	3	Minor (-) to Major (+)	-2	1	Moderate (-) to Minor (+)	-1	2	Minor (-) to Major (+)
	C	-1	2		-1	1		-1	2	
	D	-1	2		-2	0		-1	2	
Invasive Species	I	-2	3	Moderate (-) to Major (+)	-2	0	Moderate (-) to Minor (+)	-2	3	Moderate (-) to Major (+)
	C	-2	2		-1	1		-2	2	
	D	-2	2		-2	0		-2	2	
Essential Fish Habitat	I	-1	3	Minor (-) to Major (+)	-2	1	Moderate (-) to Minor (+)	-1	3	Minor (-) to Major (+)
	C	-1	2		-2	1		-1	2	
	D	-1	2		-2	1		-1	2	
Protected Species (Sea Turtles, Whales, and Birds)	I	-2	3	Moderate (-) to Major (+)	-2	1	Moderate (-) to Minor (+)	-2	3	Moderate (-) to Major (+)
	C	-1	2		-1	0		-1	2	
	D	-1	2		-2	0		-1	2	
Cultural Resources	I	-1	2	Minor (-) to Moderate (+)	0	2	Minor (-) to Moderate (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		-1	2		-1	2	
	D	-1	2		0	2		-1	2	
Public Health and Safety	I	-1	2	Minor (-) to Moderate (+)	0	1	Moderate (-) to Minor (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		0	1		-1	2	
	D	-1	2		-2	0		-1	2	
Economic Environment	I	-1	2	Minor (-) to Moderate (+)	0	1	Moderate (-) to Minor (+)	-1	2	Minor (-) to Moderate (+)
	C	-1	2		0	1		-1	2	
	D	-1	2		-2	1		-1	2	

Appendix H. Consultation and Coordination Letters

1. NMFS ESA Consultation Request and Response
2. NMFS EFH Early Coordination Request
3. USFWS ESA Consultation Transmittal Letter (Informal Consultation Underway)
4. Coastal Zone Management Coordination Transmittal Letters
5. SHPO Coordination Transmittal Letters

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office for Coastal Management
Silver Spring Metro Center, Building 4
1305 East-West Highway
Silver Spring, Maryland 20910

Cathy Tortorici
Division Chief, ESA interagency Cooperation Division
Office of Protected Resources
1315 East West Hwy
Silver Spring, MD 20910

Subject: Request for Initiation of Programmatic Consultation under Section 7 of the Endangered Species Act for Activities to Implement the Coral Reef Conservation Program

Dear Ms. Tortorici,

The purpose of this letter is to formally initiate the programmatic consultation process related to implementation of activities under the National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Program (CRCP) to ensure compliance with the Endangered Species Act (ESA) Section 7, including authorization for anticipated and unanticipated incidental takes. This initiation letter does not include the programmatic Biological Assessment (BA), which is under development and will be completed using information in the CRCP's Draft Programmatic Environmental Impact Statement, also under development. The CRCP is also initiating early coordination with NOAA's Office of Habitat Conservation regarding Essential Fish Habitat (EFH), and when the BA is ready for the Section 7 consultation, CRCP would like to conduct a joint consultation to meet EFH and ESA Section 7 requirements in a streamlined process.

The CRCP's activities are based on carrying out the policies and purposes of the Coral Reef Conservation Act, 16 U.S.C. § 6401, et seq., which are to protect, conserve, and restore the nation's coral reefs by maintaining healthy ecosystem function. The CRCP brings together expertise from across NOAA for a multidisciplinary approach to studying and effectively managing these complex ecosystems. The CRCP also works with a variety of partners that include other federal agencies, state and territorial agencies, research and academic institutions, non-governmental organizations, and community groups in both the Pacific (Pacific Islands Region) and Atlantic Oceans (Gulf of Mexico, South Atlantic, and Caribbean Sea) to conserve shallow-water coral reef ecosystems across multiple states and territories using a targeted approach focused on local issues. Additionally, the CRCP supports capacity building in other nations (e.g., those in the wider Caribbean, the Coral Triangle, the South Pacific, and Micronesia) that have coral reefs with ecological connectivity to U.S. coral reef resources.

The CRCP's current strategic plan focuses efforts on four areas of work, which are also supported through cross-cutting functions. These four areas are improving fisheries sustainability, reducing land-based sources of pollution, increasing resilience to climate change impacts, and restoring viable coral populations. The cross-cutting functions include research and monitoring, mapping, social science, communications, and capacity building. Domestically, the CRCP supports on-the-ground and in-the-water actions to conserve coral reef ecosystems through resilience-based management in the seven U.S. coral reef jurisdictions. Internationally, the CRCP supports capacity-building efforts to strengthen local frameworks and policies to build marine protected area networks; to improve and maintain resilience of coral reef ecosystems; to observe, predict, communicate, and manage the effects of climate change; to reduce impacts of fishing on coral reef ecosystems; and to reduce impacts from land-based pollution.

After reviewing the status of the ESA-listed species and designated critical habitat in the action area, the CRCP has determined that planned activities may adversely affect some ESA-listed species and designated critical habitat. Considering the existing CRCP mitigation measures that are designed to avoid or minimize impacts to these species and/or their habitats during implementation of activities, the CRCP expects effects to be negligible or minor. Attached is a brief description of the action area, the activities the CRCP intends to implement within the action area, ESA-listed species and designated critical habitat within the action area, and mitigation measures to reduce potential impacts of CRCP's activities.

Prior to issuance of a Biological Opinion from the NMFS, the CRCP will notify NMFS of any proposed activities that are underway via memos written in compliance with ESA Section 7(a)(2) (describing the proposed action during the consultation period, and effects of the proposed action) and ESA Section 7(d) (describing time limitations regarding the proposed action).

If you have any questions, please contact Liz Fairey, the CRCP Environmental Compliance Coordinator, at liz.fairey@noaa.gov or 301-427-8632.

Sincerely,

Jennifer Koss

Director, Coral Reef Conservation Program

Attachment 1

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

JUN 2 1 2019

Refer to NMFS No: OPR-2019-01044

Ms. Jennifer Koss
Director
Coral Reef Conservation Program
Office for Coastal Management
Building 4
1305 East-West Highway
Silver Spring, MD 20910

RE: Request for Programmatic Consultation Pursuant to Section 7 of the Endangered Species Act on the Implementation of Activities under the Coral Reef Conservation Program

Dear ~~Ms. Koss~~: Jen

On May 16, 2019, the National Marine Fisheries Service (NMFS) received your request for programmatic formal consultation under section 7 of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.) for the implementation of activities under the Coral Reef Conservation Program (CRCP). Activities would take place in coral jurisdictions throughout the U.S. The CRCP also supports capacity building in other nations in the Caribbean and Pacific that have coral reef ecosystems with ecological connectivity to U.S. coral resources. This response to your request was prepared by NMFS pursuant to section 7(a)(2) of the ESA, implementing regulations at (50 CFR Part 402), and agency guidance.

Enclosed with your request was an overview document describing: the action area, the activities CRCP intends to implement within the action area, ESA-listed species and designated critical habitat within the action area, and avoidance and minimization measures CRCP intends to implement as part of program activities in the action area in order to reduce the potential effects of the action on ESA resources. I also understand that the CRCP is developing a programmatic Biological Assessment (BA) for this consultation. My staff have been providing technical assistance to you and your staff on the CRCP, including refining the avoidance and minimization measures for program activities, reviewing the content of the draft Programmatic Environmental Impact Statement, and providing comments regarding the contents of the BA.

You also noted that the CRCP will inform NMFS of any proposed program activities in the action area, which will require the implementation of the avoidance and minimization measures as described in the information accompanying your letter, via memoranda written in compliance with ESA section 7(a)(2), 7(d). Any reports or other documentation generated as part of the completion of the activities should be provided to NMFS as part of the programmatic consultation for implementation of activities under the CRCP.

We will respond as to whether or not we agree with the analysis in the memoranda regarding particular activities within 15 working days of receipt of a memorandum. To comply with ESA section 7 regulations (50 CFR 402.14(c)), the initiation package submitted with the request for consultation must apply the best scientific and commercial data available. Until we receive you BA and determine that it has enough information, we cannot initiate formal consultation. In the meantime, we will continue to provide technical assistance and work with you and your staff regarding information to be included in the BA.

The ESA requires that after initiation of formal consultation, the action agency may not make any irreversible or irretrievable commitment of resources that would preclude the formulation or implementation of any reasonable and prudent alternatives that would avoid violating section 7(a)(2) (50 CFR §402.09). This prohibition is in force during the consultation process and continues until the requirements of section 7(a)(2) are satisfied.

I look forward to our continued work with you and your staff on this project. If you have any questions, please contact Dr. Lisamarie Carrubba, Consultation Biologist, at (301) 427-8493, or by e-mail at lisamarie.carrubba@noaa.gov or me at (301) 427-8495 or by e-mail at cathy.tortorici@noaa.gov.

Sincerely,

Cathryn E. Tortorici
Chief, ESA Interagency Cooperation Division
Office of Protected Resources

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office for Coastal Management
Silver Spring Metro Center, Building 4
1305 East-West Highway
Silver Spring, Maryland 20910

May 17, 2019

Kara Meckley
Chief, Habitat Protection Division
Office of Habitat Conservation
1315 East West Hwy
Silver Spring, MD 20910

Subject: Request for Early Coordination of Programmatic Consultation on Essential Fish Habitat for Activities to Implement the Coral Reef Conservation Program

Dear Ms. Meckley,

The National Oceanic Atmospheric Administration (NOAA), Coral Reef Conservation Program (CRCP) is requesting early coordination on a programmatic consultation for impacts to Essential Fish Habitat (EFH). Currently, the CRCP is drafting a Programmatic Environmental Impact Statement, and we intend to use the information in the draft document to support the early coordination.

This letter is in reference to the CRCP's action to carry out the policies and purposes of the Coral Reef Conservation Act, 16 U.S.C. § 6401, et seq., which are to protect, conserve, and restore the nation's coral reefs by maintaining healthy ecosystem function. The CRCP brings together expertise from across NOAA for a multidisciplinary approach to studying and effectively managing these complex ecosystems. The CRCP also works with a variety of partners that include other federal agencies, state and territorial governments and agencies, research and academic institutions, non-governmental organizations, and community groups in both the Pacific (Pacific Islands Region) and Atlantic Oceans (Gulf of Mexico, South Atlantic, and Caribbean Sea) to conserve shallow-water coral reef ecosystems across multiple states and territories using a targeted approach focused on local issues. Additionally, the CRCP supports capacity building in other nations (e.g., those in the wider Caribbean, the Coral Triangle, the South Pacific, and Micronesia) that have coral reefs with ecological connectivity to the coral reef ecosystems in the U.S.

The CRCP's current strategic plan focuses efforts on four areas of work, which are also supported through cross-cutting functions. These four areas are improving fisheries sustainability, reducing land-based sources of pollution, increasing resilience to climate change impacts, and restoring viable coral populations. The cross-cutting functions of the CRCP include research and monitoring, mapping, social science, communications, and capacity building. Domestically, the CRCP supports on-the-ground and in-the-water actions to conserve coral reef ecosystems through resilience-based management in the seven U.S. coral reef jurisdictions. Internationally, the CRCP supports capacity-building efforts to strengthen local frameworks and policies to build marine protected area networks; to improve and maintain resilience of coral reef ecosystems; to observe, predict, communicate, and manage the effects of climate change on coral reefs; to reduce impacts of fishing on coral reef ecosystems; and to reduce impacts from land-based pollution.

The CRCP has also initiated formal consultation with National Marine Fisheries Service's Office of Protected Resources (OPR) pursuant to Section 7 of the Endangered Species Act and is working with OPR to develop a biological assessment (BA). Once the BA is ready for the Section 7 consultation, the CRCP intends to conduct a joint consultation to meet EFH and ESA Section 7 requirements in a streamlined process. Attached is a description of the action area, the activities the CRCP intends to implement within the action area, a general EFH characterization, and CRCP mitigation measures to reduce potential impacts to EFH.

After reviewing the status of the EFH in the action area, it is likely that some of the planned activities would have adverse effects on EFH. Considering the existing CRCP mitigation measures that are designed to avoid or minimize impacts to habitats during implementation of activities, the CRCP expects the proposed action would have negligible to minor adverse impacts to EFH.

If you have any questions, please contact Liz Fairey, the CRCP Environmental Compliance Coordinator, at liz.fairey@noaa.gov or 301-427-8632.

Sincerely,

Jennifer L. Koss

Jennifer Koss
Director, Coral Reef Conservation Program

Attachment 1