Programmatic Environmental Assessment (PEA)
Research Activities Conducted by the
Coral Reef Ecosystem Division
Pacific Islands Fisheries Science Center
National Marine Fisheries Service
Honolulu, Hawai`i

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List of Acronyms

ADCP	acoustic Doppler current profilers
AHI	R/V *Acoustic Habitat Investigator*
ARMS	autonomous reef monitoring structures
AUV	autonomous underwater vehicles
BE	Biological Evaluations
CAT	computerized axial tomography
CNMI	Commonwealth of the Northern Mariana Islands
CTD	conductivity, temperature, and depth
CRCP	Coral Reef Conservation Program
CRED	Coral Reef Ecosystem Division
CREWS	Coral Reef Early Warning System
DIC	dissolved inorganic carbon
EA	Environmental Assessment
EAR	ecological acoustic recorder
EFH	essential fish habitat
EPA	Environmental Protection Agency
ESA	*Endangered Species Act of 1973*
FAA	Federal Aviation Administration
FONSI	Finding of No Significant Impact
GPS	global positioning system
HAPC	habitat areas of particular concern
HIHWNMS	Hawaiian Islands Humpback Whale National Marine Sanctuary
ICES	International Council for the Exploration of the Sea
IHO	International Hydrographic Organization
IUCN	International Union for Conservation of Nature and Natural Resources
MHI	main Hawaiian Islands
NEPA	*National Environmental Policy Act of 1969*
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
nSPC	new stationary point count
NWHI	Northwestern Hawaiian Islands
ODP	ocean data platform
OMAO	Office of Marine and Aviation Operations
Pacific RAMP	Pacific Reef Assessment and Monitoring Program
PEA	Programmatic Environmental Assessment
PIFSC	Pacific Islands Fisheries Science Center
PIRO	Pacific Islands Regional Office
PRD	Protected Resources Division
PRIA	Pacific Remote Island Areas
PVC	polyvinyl chloride
RAS	remote automatic sampler
REA	Rapid Ecological Assessment
RPM	responsible program manager
ROV	remotely operated vehicle

SPA	special preservation area
SPC	stationary point count
SST	sea-surface temperature
STR	subsurface temperature recorder
TCBS	thiosulfate citrate bile salts sucrose
TOAD	towed optical assessment device
UAS	unmanned aerial systems
USCG	U.S. Coast Guard
WPRFMC	Western Pacific Regional Fishery Management Council
WTR	wave-and-tide recorder

Executive Summary

This Programmatic Environmental Assessment (PEA) considers the potential environmental effects of the program of activities conducted by the Coral Reef Ecosystem Division (CRED), Pacific Islands Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS). The CRED program includes a range of activities to improve our understanding of coral reef ecosystems, as mandated by the *Coral Reef Conservation Act of 2000*, which is currently under reauthorization.

The *Coral Reef Conservation Act* is intended to support a wide range of coral reef conservation activities, from developing sound science to enhancing compliance with management programs and increasing public knowledge of coral reefs. Enacted on December 14, 2000, this act has the following stated purposes:

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 non-governmental organizations
5. Provide financial resources for those programs and projects
6. Establish a formal mechanism for the collecting and allocating of monetary donations from the private sector to be used for coral reef conservation projects

Purposes 1–4 are intended to provide positive long-term environmental, social, and economic impacts to vulnerable coral reef environments and the users dependent on those ecosystems. Purposes 5 and 6 help provide the means for accomplishing those first 4 purposes.

Coral reefs are some of the most biologically rich and economically valuable ecosystems on Earth. They provide a wide variety of valuable products and services in the United States and in other countries, including the following contributions:

- Economic stability and food security for millions of people
- Chemicals and pharmaceuticals that contribute to improved human health
- Environmental services such as shoreline protection
- Areas of natural beauty and biodiversity
- Sources of revenue and employment through tourism and other industries

Coral reef ecosystems are in serious jeopardy, primarily due to the impacts of a variety of human activities. Coral reefs are threatened by overexploitation and destructive fishing practices; pollution and sedimentation associated with coastal development, deforestation, and agriculture; habitat loss from dredging and shoreline modification; vessel groundings and other direct physical impacts; invasive species; disease outbreaks; and other impacts associated with climate variability, such as coral bleaching, ocean acidification, increased storm frequency, and changing sea levels. By one estimate (Wilkinson 2008), 19% of the world's coral reefs have been destroyed, an additional 15%

of the world's coral reefs face impending destruction from human activities in the next 10–20 years and an additional 20% are under threat of being lost in the next 20–40 years. The rapid decline and loss of these valuable marine ecosystems have significant social, economic, and environmental consequences in the United States and around the world.

PURPOSE AND NEED

There is an overwhelming need to gather information about the state of coral reef ecosystems and the increasing threats, impacts, and damage to them worldwide. The purpose of the actions proposed in this PEA is to comply with governing U.S. statutory mandates by conducting authorized scientific activities, including mapping, assessment, monitoring, restoration, and research, to provide sound scientific information that enables informed and effective implementation of ecosystem-based management and conservation strategies for the coral reef ecosystems of the U.S.-affiliated Pacific Islands.

CURRENT PROGRAM

The current CRED program includes the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) component and the marine debris component. Pacific RAMP is an ecosystem-based research program that conducts mapping, monitoring, and assessment of coral reef ecosystems throughout the U.S.-affiliated waters of the central and western Pacific. The marine debris component is intended to protect coral reefs through a program of marine debris mitigation, primarily in the Hawaiian Archipelago.

The CRED Pacific RAMP component includes conducting ecological assessments of reef fishes, corals, other invertebrates, and marine algae to determine the status and trends of these coral reef ecosystems and the oceanographic processes that influence them. These investigations include standard diver surveys, towed-diver surveys, oceanographic moorings and buoys, and other in situ instrumentation. Much of this work is conducted from oceanographic research vessels. In addition to ecological assessments, habitat mapping and characterization is conducted by employing multibeam sonar, towed-camera systems, and underwater autonomous vehicles. As part of Pacific RAMP, the CRED also conducts biodiversity assessments by collecting baseline data on the biodiversity of marine life associated with coral reef habitats, including fishes, algae, macroinvertebrates, cryptic invertebrates, and corals, as well as characteristics of the physical environment.

The CRED marine debris component includes supporting activities that assess, monitor, and mitigate the adverse effects of derelict fishing gear that become ensnared within coral reef ecosystems and participating in the development of innovative technologies to recover marine debris that is still circulating at sea, before debris can reach reefs and damage coral reef ecosystems.

PROPOSED ACTIONS AND ALTERNATIVES

In order to fulfill statutory mandates and further conservation and management goals, the CRED has worked since its formal establishment in April 2001 to advance understanding of coral reef ecosystems of the U.S.-affiliated Pacific Islands and to improve support for science-based management of these ecosystems. An Environmental Assessment and associated Finding of No Significant Impact (FONSI) (June 2005) described and analyzed the activities conducted by the CRED during the period of 2005–2010. Building on the experience base of 9 years of work, this PEA describes and analyzes the current CRED program, along with proposed options for expansion. The following alternatives and options are considered in detail in this document:

- Continue the current program (the no-action alternative)
- Continue the current program as well as the inclusion of the following options for expansion:
    - Option A: incorporating expanded studies involving ocean acidification
    - Option B: incorporating studies that expand the biological sampling and collection of fishes for life history information needed to develop annual catch limits for reef fishes per the *Magnuson-Stevens Reauthorization Act of 2006*
    - Option C: incorporating both Option A and Option B (the preferred alternative)

AFFECTED ENVIRONMENT

A primary objective of the CRED program is to promote sound science to improve the understanding of coral reef ecosystems. The jurisdiction of the CRED program covers all areas in the U.S.-affiliated Pacific Islands with coral reef ecosystems. These ecosystems encompass coral reefs and their associated habitats, as well as the benthic invertebrates, algae, and fish species that utilize these habitats. The geographic extent is composed of the populated portions of Hawai`i, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI) and the more remote, unpopulated areas, including the Papahānaumokuākea Marine National Monument in the Northwestern Hawaiian Islands (NWHI), established in 2006, as well as the Marianas Trench Marine National Monument, Pacific Remote Islands Marine National Monument, and the Rose Atoll Marine National Monument, all established in 2009.

PROCEDURES, PERMITS, AND MITIGATION

The CRED program uses a set of standard operating procedures and protective measures for minimizing and avoiding adverse impacts to the environment and human health and safety. All field activities are conducted under standard special use permits or management permits as required by the relevant management agency for each area of operation. The guidance or restrictions of each permit is incorporated into the standard operating procedures of the CRED program to develop a consistent set of best practices that govern all CRED's field activities regardless of where they take place.

SUMMARY OF ENVIRONMENTAL IMPACTS

The positive environmental consequences of the implementation of the preferred alternative include increased understanding of the science of fragile coral reefs and their ecosystems that will aid in management of these important resources. 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 cumulative negative impacts are expected to be minimal and not significant. In all cases, activities conducted by the CRED program are noninvasive, do not involve manipulations of the environment, and only have temporary minor impacts while conducting the work (e.g., diver presence temporarily affects behavior of fishes) that disappear once divers leave the water.

The CRED program is intended to conduct assessment and ecological research that will support management actions by others to protect sensitive coral reef ecosystems from damage. The included activities have, at most, minor and temporary negative effects to the environment, and the data collected may be used by others to present conclusions and recommendations for management actions.

1 Introduction and Background

This Programmatic Environmental Assessment (PEA) considers the potential environmental impacts of activities conducted by the Coral Reef Ecosystem Division (CRED) at the Pacific Islands Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA). The PIFSC has taken a leading role in marine research on ecosystems in the central and western Pacific, both in insular and pelagic environments. The PIFSC implements an interdisciplinary research strategy including ecosystem observations and scientific analysis to support ecosystem approaches to management and restoration of living marine resources. Although the PIFSC has worked in Pacific coral reef ecosystems as part of its ongoing research since 1990, the CRED was formally organized in 2001 after issuance of Executive Order 13089 (1998), which established the U.S. Coral Reef Task Force and passage of the *Coral Reef Conservation Act of 2000*. The CRED's mission is to provide sound science to enable informed and effective implementation of ecosystem-based management and conservation strategies for coral reef ecosystems of the U.S.-affiliated Pacific Islands.

The CRED conducts interdisciplinary monitoring and research of coral reef ecosystems, primarily in the U.S.-affiliated Pacific Islands. Ecological assessments and monitoring are conducted throughout this region to document and quantify spatial and temporal changes in the health of coral reef living resources, including fishes, algae, corals, and other invertebrates, due to natural processes or human activities. Local and regional oceanographic and water-quality conditions that influence coral reef ecosystems are assessed and monitored through moored instruments and shipboard and nearshore surveys of hydrographic properties. Habitat mapping and characterization are carried out to define and understand the dynamics of habitat-ecosystem-resource linkages. Reef restoration is addressed through the assessment, monitoring, and removal of marine debris in coral reef ecosystems.

Since 2001, the CRED has led a series of biennial or annual cruises to more than 50 islands, reefs, and atolls in the Hawaiian Archipelago, Mariana Archipelago, American Samoa, and Pacific Remote Island Areas (PRIA). Working with management agencies and scientists from all of these jurisdictions, the CRED has implemented a program to map, monitor, and assess coral reef ecosystems using a suite of uniform methods across this Pacific region. Primarily using NOAA vessels, CRED scientists lead or participate in 2–10 cruises per year. Many cruises have intensive small-boat operations with scuba-diving components to monitor the environment and deploy long-term instruments. Other cruises focus on mapping coral reef habitats and make extensive use of sonar and optical equipment. Funding for the CRED's mapping, monitoring, and assessment activities comes largely from NOAA's Coral Reef Conservation Program (CRCP), with additional funding from the U.S. Navy and complementary programs in NOAA and other government agencies. The CRED also conducts biodiversity assessments that include collecting baseline data on the biodiversity of marine life associated with coral reef habitats, including fishes, algae, macroinvertebrates, cryptic invertebrates, and corals, as well as characteristics of the physical environment.

Trawl nets, gill nets, and other fishing gear that is lost or discarded by North Pacific fishing fleets are damaging the coral reefs and beaches of the Hawaiian Archipelago, including the remote Northwestern Hawaiian Islands (NWHI) and the populated main Hawaiian Islands (MHI). The PIFSC has conducted marine debris cleanup efforts in the NWHI since 1996. Since 2001, the CRED has been responsible for these activities and has conducted annual operations using either charter vessels or NOAA ships. This work was extended to the MHI in 2006, using helicopters to support both survey and recovery efforts. The goals of the marine debris component of the CRED program include assessing the abundance and distribution of marine debris on coral reefs, nearshore areas, and beaches; removing debris that can be safely and practically recovered without further damage to the environment; evaluating rates and sources of debris accumulation; developing techniques for collecting marine debris at sea before it can damage coral reef environments; and increasing public awareness of marine debris issues. Funding for the CRED's marine debris activities come from the NOAA Marine Debris Program and the Papahānaumokuākea Marine National Monument as well as from the CRCP.

The first Environmental Assessment (EA) of CRED's work covered the period of 2005–2010 and was site specific. The CRED's program has expanded and matured since its inception in 2001, and the 2005 EA has been evaluated in a number of documents related to the *National Environmental Policy Act of 1969* (NEPA) and associated documents related to the *Endangered Species Act of 1973* (these documents are listed in Appendix C). The scientific methods and equipment used to map, monitor, and assess coral reef ecosystems have evolved in response to feedback from the scientific and management community. The CRED conducts every field activity under standard special use permits or management permits, and the guidance and restrictions of these permits have been incorporated into a single set of best practices that govern all of CRED's field activities wherever they take place. The data collected from a decade of research is now organized into an accessible database, and these data now represent a well-established baseline resource to study corals in the U.S.-affiliated Pacific Islands. In addition, some of the methods, techniques, and equipment developed by the CRED are now being used for study of coral reef ecosystems in other parts of the world, and CRED personnel are occasionally asked to support field work in areas outside of the Pacific, including U.S.-affiliated Caribbean waters and areas governed by other countries such as Indonesia. Because of the evolution of the CRED program, this document reflects the need for a programmatic EA.

2 Need, Purpose, and Scope

Coral reefs perform vital biological, ecological, and physical functions as one of the oldest and most diverse ecosystems on Earth and have become an essential part of the way of life for societies around the world. Coral reef ecosystems provide important economic and environmental benefits in the form of food, jobs, natural products, cultural traditions, medicine, and shoreline protection. A combination of stressors—including climate change, pollution, inadequate fishing practices, increased fishing pressure, incompatible coastal uses, invasive species, increased human expansion in coastal areas, extreme events like hurricanes and coastal flooding, and physical damage from actions such as ship groundings—has caused a rapid decline in the health of many coral reef ecosystems globally. This decline, if unimpeded, will lead to significant social, economic, and environmental consequences.

Coral reefs ecosystems support several million different species, more species per unit area than any other marine environment. Approximately half of all federally managed fish species depend on coral reefs and related habitats for a part of their life cycles. The value of commercial and recreational fisheries from coral reefs in the United States is estimated at more than $200 million, and tourism to reefs brings billions of dollars to local economies. Effective conservation, management, and restoration projects for coral reefs can help rebuild fisheries stocks and recover certain threatened and endangered species. In addition, conservation of coral reefs is necessary to ensure that these valuable resources are available to future generations that depend on these resources for their livelihood and cultural and social values.

The U.S. Department of Commerce through NOAA is responsible for preserving, sustaining, and restoring the condition of these coral reef ecosystems; promoting the wise management and sustainable use of coral reef ecosystems to benefit local communities and the nation; and developing sound scientific information on the condition of coral reef ecosystems and the threats to such ecosystems. The CRED, by means of the *Coral Reef Conservation Act* and the NOAA Coral Reef Conservation Program (CRCP), conducts habitat mapping, monitoring, assessment, restoration, and scientific research to advance the understanding, sustainable use, and long-term conservation of these coral reef ecosystems. These activities provide scientific data, analyses, and value-added products that enable informed and effective implementation of ecosystem-based conservation strategies by local and national resource management agencies, educational institutions, nongovernmental organizations, and community groups.

2.1 The Need to Conserve Coral Reefs

The following information regarding the importance of coral reef ecosystems and the primary threats to their survival and health is taken from the testimony of Katherine Andrews, manager of the CRCP, at a hearing before the House Subcommittee on Insular Affairs, Oceans, and Wildlife on February 25, 2009 (U.S. House Committee 2009), on the reauthorization of the *Coral Reef Conservation Act* and from more recent events, including a petition that was filed in October 2009 to list 83 species of coral under the *Endangered Species Act* (ESA).

2.1.1 WHY CORAL REEFS ARE IMPORTANT

Coral reefs, often called the "rainforests of the sea," are among the oldest and most diverse ecosystems on the planet and have become an integral part of the culture, heritage, and economies of societies around the world. These ecosystems provide important economic and environmental benefits in the form of food, jobs, natural products, pharmaceuticals, and shoreline protection.

Coral reef ecosystems provide resources worth billions of dollars each year to the United States economy and other economies of the world. Coral reefs, according to estimates, support several million different species. They house more than one third of all described marine species—more species per unit area than any other marine environment—including about 4000 known species of fishes and 800 species of hard corals. Approximately half of all federally managed fish species depend on coral reefs and related habitats for a portion of their life cycles. The NMFS estimates that the annual dockside commercial value to U.S. fisheries from coral reefs is over $100 million, while the annual value of reef-dependent recreational fisheries exceeds $100 million. Local economies also receive billions of dollars from visitors to reefs through diving tours, recreational fishing trips, hotels, restaurants, and other businesses associated with reef ecosystems. In the Florida Keys, for example, coral reefs attract more than $1.2 billion annually from tourism. In addition, coral reef structures buffer shorelines against waves, storms, and floods, helping to prevent loss of life, property damage, and erosion. Numerical modeling performed by NOAA's Geophysical Fluid Dynamics Laboratory and Princeton University suggests healthy reefs can also provide protection and reduce damage from tsunamis.

2.1.2 INCREASING THREATS TO CORAL REEFS, LOCAL AND GLOBAL

A combination of stressors has caused a rapid decline in the health of many coral reef ecosystems globally, and this decline, if left unchecked, will lead to significant social, economic, and environmental consequences. Staghorn and elkhorn corals (*Acropora cervicornis* and *A. palmata*), for example, once the dominant shallow-water corals in Florida and the Caribbean, declined in population an estimated 97% during the 1980s and 1990s. This observed decline led NOAA to make these species the first coral species listed under the ESA when they were listed as endangered in May 2006. The Global Coral Reef Monitoring Network estimated in the 2008 edition of its *Status of Coral Reefs of the Worlds* report that 19% of the world's coral reefs have been destroyed (Wilkinson 2008). This report predicts that an additional 15% of the world's coral reefs face impending destruction from human activities in the next 10–20 years and that an additional 20% are under threat of being lost in the next 20–40 years.

Globally, coral reefs are under stress from many different sources, including increased sea-surface temperatures, pollution, increased fishing pressure, harmful fishing practices, incompatible coastal uses, invasive species, extreme events like hurricanes and coastal flooding, and physical damage from actions such as ship groundings. Expanded human populations in coastal areas exacerbate many of these factors. Climate change—in particular, rises in global air and ocean temperatures—threatens coral reef ecosystems through increased occurrence and severity of coral bleaching and disease events, sea-level rise, and storm activity. Increased absorption of atmospheric carbon dioxide (CO_2) into oceans also leads to ocean acidification, which reduces and reverses calcification rates and, therefore, growth rates in reef-building organisms, outcomes that affect a reef's ability to maintain itself.

In October 2009, the NMFS received a petition from the Center for Biological Diversity proposing that 83 species of coral be listed as endangered under the ESA. Among the primary threats, global climate change was cited as a major stressor in this petition. On February 10, 2010, the NMFS produced a positive finding for 82 of 83 species in the petition, and an NMFS Status Review is currently underway with results mandated by the ESA one year after receipt of a petition.

2.1.2.1 Impacts from Global Fishing Pressures

The CRCP considers global fishing pressures to be one of the most significant threats to coral reefs worldwide. Rapidly increasing growth rates of human populations, the use of more efficient fishery gear in industrial fishing fleets, destructive fishing techniques, and inadequate management and enforcement of habitats have led to the depletion of key functional groups of reef species in many locations, with cascading impacts on coral reef habitats and associated species and ecosystems. Some successes in limiting these pressures have been achieved in the United States and other countries by banning certain gear types and protecting vulnerable fish habitat.

2.1.2.2 Land-based Sources of Pollution

Healthy coral reefs require good water quality to grow, remain viable, and provide ecosystem benefits. Land-based sources of pollution can threaten reef resources by harming sensitive species, altering species composition, disrupting critical ecological functions (e.g., photosynthesis), and impeding normal growth and settlement of stony corals and other benthic invertebrates. Reef systems are impacted by a variety of pollutants, including sediments, nutrients, and chemical contaminants. Pollution enters coral reef ecosystems in many ways, ranging from point-source discharges, such as sewage pipes and vessels, to more diffuse sources such as runoff associated with agriculture, coastal development, and road construction. Reef degradation is increased in areas where the loss of wetlands or other associated habitats has reduced a system's natural ability to filter nutrients and other pollutants before reaching nearby reefs.

2.1.2.3 Physical Damage to Reefs

Every year, many boats run aground on coral reefs, causing significant damage to these fragile ecosystems. These vessel groundings are not well documented in all regions, but the numbers, where recorded, are astounding. For example, 7 incidents of coral damage have either been confirmed or are highly likely to have occurred in the U.S. Virgin Islands and Puerto Rico in January 2009. Emergency restoration, involving coral stabilization and reattachment, following these incidents is critical because very large colonies often are damaged or broken free during groundings. Coral colonies impacted by groundings are often hundreds of years old. Given their age, these corals play a key part in the reproductive strategy of reefs because they likely are resilient enough to have survived bleaching and disease events in the past.

2.1.2.4 Climate Change and Ocean Acidification

The rapid increase in atmospheric CO_2 over the past 2 centuries and the trajectories currently expected over the coming decades pose a unique and daunting challenge to coral reef ecosystems through both rising ocean temperatures and changing ocean chemistry. As global air temperatures have risen over the past 30 years, there has been a corresponding increase in the frequency of extremely high sea-surface temperatures and coral bleaching events in many tropical regions. Coral bleaching is a response of corals to unusual levels of stress primarily thought to be associated with high solar radiation and unusually high sea-surface temperatures. Bleaching occurs when a coral expels the symbiotic algae that live in its tissues and, thus, loses the photosynthetic function of these algae. Symbiotic algae provide a coral with essential nutrients and give a coral its coloration. Corals often recover from mild bleaching; however, if stress is prolonged or intense, corals may weaken and become more susceptible to disease and other stressors, or they may die from direct thermal stress.

A growing number of studies now demonstrate that ocean acidification, as a direct consequence of rising concentrations of CO_2 absorbed by the oceans, may have important consequence for coral reefs. Recent studies have shown that ocean acidification has already reduced the ability of corals to build their skeletons at reefs across the Great Barrier Reef and Arabian Gulf. Other work has shown that changing ocean chemistry may make corals susceptible to bleaching at temperatures lower than the levels at which bleaching has typically been observed in the past.

We still do not know much about the effects of mass mortality of corals associated with bleaching and of ocean acidification on the functioning of coral reef ecosystems and associated ecosystem uses and benefits, such as fisheries, coastal protection, recreation, and tourism industries. However, we do know that rising temperatures and ocean acidification act in concert with local threats, such as land-based sources of pollution and overfishing. These local factors can make reefs less resilient to climate change and, conversely, climate change reduces the ability of coral reefs to cope with local stress.

2.1.3 LEGAL BASIS FOR MANAGEMENT OF CORAL REEFS

In June 1998, Executive Order 13089 on coral reef protection established the Coral Reef Task Force and directed federal agencies to improve their stewardship and conservation of the nation’s coral reefs. In March 2000, this task force approved the first ever National Action Plan to Conserve Coral Reefs (National Action Plan), which outlined a series of specific, high-priority actions focused on ensuring the long-term viability of coral reef ecosystems in the United States and around the world. In May 2000, Executive Order 13158 was issued to establish and strengthen marine protected areas in U.S. waters. The *Coral Reef Conservation Act of 2000*, currently under the process of reauthorization by

Congress, was passed to preserve, sustain, and restore the condition of coral reef ecosystems.

The U.S. Department of Commerce through NOAA is responsible for implementation of the *Coral Reef Conservation Act*. The primary goals of this act are to preserve, sustain, and restore the condition of coral reef ecosystems; promote the wise management and sustainable use of coral reef ecosystems to benefit local communities and the nation; and develop sound scientific information on the condition of coral reef ecosystems and the threats to such ecosystems. This legislation also authorizes the creation of a national program to conserve coral reef ecosystems, consistent with this act and other legislation, such as the *Endangered Species Act of 1973* (ESA), *Magnuson-Stevens Reauthorization Act of 2006* (*Magnuson-Stevens Act*), and the *Marine Mammal Protection Act of 1972*. This national program, known as the NOAA Coral Reef Conservation Program (CRCP), is authorized to conduct the following activities:

- Mapping, monitoring, assessment, restoration, and scientific research that benefit the understanding, sustainable use, and long-term conservation of coral reefs and coral reef ecosystems
- Enhancing public awareness, education, understanding, and appreciation of coral reefs and coral reef ecosystems
- Providing assistance to states in removing abandoned fishing gear and vessels and marine debris from coral reefs
- Conducting cooperative conservation and management of coral reefs and coral reef ecosystems with local, regional, or international programs and partners

These activities provide scientific information that support local and national resource management agencies, educational institutions, nongovernmental organizations, and community groups through which coral reef conservation actions are realized.

Executive Orders 13178 and 13196 in 2000 and 2001 established the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve and set forth management principles to "support, promote, and coordinate appropriate scientific research and assessment, and long-term monitoring of reserve resources, and the impacts or threats thereto from human and other activities, to help better understand, protect, and conserve these resources and species for future generations." These executive orders also call for the cleanup and prevention of marine debris in this reserve.

In 2006, additional protections were added to the coral reef ecosystems in this area with the creation of the Northwestern Hawaiian Islands Marine National Monument, which was then the largest marine protected area in the world. Later renamed the Papahānaumokuākea Marine National Monument, this monument comes under the joint jurisdiction of the state of Hawai`i, U.S. Fish and Wildlife Service, and NOAA. Any actions conducted within this marine national monument require a permit, including actions conducted by the CRED program.

Coral reef ecosystems in other areas of the Pacific received federal protection in January 2009, when 3 national marine monuments were established through presidential proclamation: Marianas Trench Marine National Monument, Pacific Remote Islands Marine National Monument, and Rose Atoll Marine National Monument (see Figure 1 in Section 5: "Affected Environment" for the locations of these monuments). Details of the administration of these monuments are jointly determined by the Departments of Interior and Commerce and in some cases in consultation with the Department of Defense, which continues to manage Wake Island (President 2009a, 2009b, 2009c).

The *Marine Debris Research, Prevention, and Reduction Act of 2006* (*Marine Debris Act*) gives NOAA authority to map, assess, and remove marine debris that poses a threat to living marine resources, and this act establishes and funds NOAA's Marine Debris Prevention and Removal Program (Marine Debris Program). This legislation has 3 main purposes:

- Help identify, determine sources of, assess, reduce, and prevent marine debris and its adverse impacts on the marine environment and navigation safety
- Reactivate the Interagency Marine Debris Coordinating Committee
- Develop a federal clearinghouse for marine debris information

NOAA and the U.S. Coast Guard (USCG) define marine debris as "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or Great Lakes." The CRED is responsible for meeting the mandates of the *Marine Debris Act*.

2.2 Purpose of Action

The purpose of the action proposed by this PEA is continuation of the PIFSC CRED program to map, monitor, assess, and restore coral reef ecosystems primarily in the U.S.-affiliated Pacific Islands. The multidisciplinary regional research conducted by CRED is critical to understanding and protection of corals reefs not only in the Pacific region, but also worldwide.

Marine resource management is undergoing a fundamental transformation from the management of individual species to ecosystem-based management. This transition has challenged policymakers, resource managers, and scientists as they struggle to define and implement ecosystem-based management.

In response to the National Action Plan developed in compliance with the *Coral Reef Conservation Act*, biologists and oceanographers at the PIFSC and the NOAA Fisheries Office of Habitat Conservation initiated the development of an interdisciplinary, multi-agency, and multiplatform program to assess, monitor, protect, and conduct applied research on the coral reef ecosystems of the U.S. Pacific Islands. The U.S. Pacific Islands support a large proportion of the nation's coral reefs. After thorough program design and development with partners from other NOAA offices, federal, state, and territorial government agencies, and nongovernmental organizations, the CRED was formally established in April 2001 to improve scientific understanding of and support for science-based management of the coral reef ecosystems of the U.S. Pacific Islands.

In support of the *Coral Reef Conservation Act* and the *Marine Debris Act*, the CRED has developed and implemented a 3-pronged interdisciplinary program for assessment and protection of coral reef ecosystems in the central and western Pacific under the jurisdiction of the United States and U.S.-affiliated governments:

- Monitoring and Mapping: monitoring coral reef ecosystems and their components, including baseline assessments and interdisciplinary spatial and temporal monitoring, and locating, characterizing, and mapping of benthic communities associated with coral reefs

- Biodiversity Assessment: collecting baseline data on the biodiversity of marine life associated with coral reef habitats, including fishes, algae, macroinvertebrates, cryptic invertebrates, and corals, as well as characteristics of the physical environment
- Marine Debris Assessment and Removal: locating, assessing, collecting, and removing terrestrial and submerged marine debris with a focus on derelict fishing gear

Funding to support CRED activities has primarily been provided by NOAA's CRCP, and marine debris removal efforts since 2005 have been funded by the NOAA Marine Debris Program. Additional funds to support the development of the CRED's biodiversity program have been provided by the Sloan Foundation through grants to the University of Hawai`i. Results of the CRED's activities are provided to the agencies responsible for managing the coral reef ecosystems throughout the U.S.-affilated waters in the central and western Pacific. A complete list of CRED partners can be found in Appendix B.

The CRED has conducted mapping and monitoring and marine-debris-cleanup activities since it was established in 2001. CRED's biodiversity activities began in 2005, when the Census of Marine Life initiated its Census of Coral Reef Ecosystems project as a collaboration between the CRED, Australian Institute of Marine Science, and Scripps Institution of Oceanography at the University of California, San Diego.

The CRED's research and monitoring component provides high-quality, unbiased scientific information about fragile coral reef ecosystems so that others may better identify, recommend, and implement management actions that will effectively protect and enhance coral reef ecosystems. The marine debris removal component directly protects sensitive coral reefs by removing nets and other marine debris that are damaging coral reefs.

NOAA established its Marine Debris Program to reduce and prevent the occurrence of marine debris and its associated adverse effects on the marine environment and navigation safety. This program includes the following activities:

- Cataloging and maintaining an inventory of marine debris, including location, size, age, and origin, and its impacts on habitat, living marine resources, human health, and navigation safety
- Developing measures to identify the origin, location, and projected movement of marine debris, including the use of oceanographic, atmospheric, satellite, and remote-sensing data
- Developing, documenting, and implementing strategies, methods, and priorities for preventing and removing marine debris

2.3 Temporal and Spatial Scope

This PEA is intended to provide the basis for long-term continuation and potential expansion of existing activities, including monitoring, mapping, assessment, and marine-debris collection. As long as individual projects are conducted as described in Section 4, "Description of Alternatives," and Section 6, "Procedures, Permits, and Mitigation to Protect Personnel and Natural Resources," and the actual impacts associated with implementation remain within the range of impacts as identified in Section 7, "Evaluation of Environmental Consequences," this PEA remains current but will be reviewed on a periodic basis. In accordance with NOAA policy, any decision based on this analysis will be reviewed for consistency and appropriateness at least every 5 years.

This PEA provides detailed descriptions of and evaluates existing and proposed CRED programs to assess, monitor, map, and prevent damage to coral reef ecosystems primarily in the U.S.-affiliated Pacific Islands (for a detailed description of the spatial scope of this program, see Section 5: "Affected Environment"). Although the CRED program focuses primarily on the U.S.-affiliated Pacific Islands, techniques and equipment developed by the CRED have already been applied in other areas such as Australia and the Coral Triangle, and CRED personnel may occasionally be asked to participate in field activities in areas other than the Pacific.

This document outlines CRED actions that are funded from multiple sources and ongoing under existing permits and authorizations granted by various federal, state, and local agencies and (Appendix C provides a listing of 17 NEPA- or ESA-related documents that have been prepared by the CRED since 2001).

3 Alternatives and Issues

This section discusses the alternatives that are under consideration, alternatives that are not and issues that will not be considered for the PEA.

3.1 Alternatives to Be Considered

The responsible program manager (RPM, the director of the PIFSC) will use this PEA to make decisions about current and proposed CRED activities as described in Section 4, "Description of Alternatives," within the geographic scope identified in Section 5, "Affected Environment."

The following alternatives and options are considered in detail in this report:

- **Alternative 1.** Continuation of the current program (the no action alternative).
- **Alternative 2.** Continuation of the current program as well as inclusion of the following options for expansion:
  - **Option A.** Incorporating expanded studies involving ocean acidification
  - **Option B.** Incorporating studies that expand the biological sampling and collection of fishes for life history information that contributes to the development of scientifically based annual catch limits for reef fishes per the *Magnuson-Stevens Act*
  - **Option C.** Incorporating both Option A and Option B (preferred alternative)

This PEA, therefore, will be used to comply with NEPA and inform PIFSC decisions regarding activities within the scope of this PEA conducted by the CRED. As this PEA evaluates in detail the impacts of all in-scope activities currently conducted and proposed, the RPM may select any combination of options within Alternative 2, including deferring and later selecting some of them.

3.2 Alternatives Not Considered in Detail

Because they fail to meet the purpose and need for the proposed actions, 2 alternatives for actions will not be considered in detail: (1) discontinuing CRED activities and (2) tagging and releasing ghost nets for research purposes.

3.2.1 DISCONTINUING CRED ACTIVITIES

This alternative will not be considered in detail because the CRED's current activities are ongoing and provide valuable information and data to scientists, oceanographers, educational institutions, and marine and fisheries managers worldwide. These activities are in compliance with the *Coral Reef Conservation Act*, Executive Order 13089, *Magnuson-Stevens Act*, *Marine Debris Act*, and other laws and executive orders. The services of the CRED are needed, requested, and funded both within the geographic scope of this PEA as well as, increasingly, outside this scope, so it is not reasonable to evaluate in detail any alternatives that discontinue CRED activities.

3.2.2 TAGGING AND RELEASING GHOST NETS FOR RESEARCHING DEBRIS MOVEMENT AND OCEAN CIRCULATION PATTERNS

The term "ghost net" refers to lost or abandoned fishing gear that drifts in the ocean and may continue to catch fish and entangle marine mammals, turtles, and seabirds. The synthetic materials currently used in fishing nets decay extremely slowly, so these nets can continue to drift for years. Many of these end up trapped on coral reefs, and, given the magnitude of this problem and the hazards associated with cleaning reefs, a multiagency effort is under way to locate ghost nets in the open ocean and collect them before they reach reefs (Pichel 2007). The CRED is among the agencies participating in this collection effort.

One method of learning more about the distribution and behavior of these hazards includes locating a number of ghost nets, tagging them with sensors to report their location and then releasing them back into the environment to determine how they move within oceanic currents and to learn whether any ocean areas are subject to collecting large numbers of these nets. This PEA does not consider this activity of tagging and releasing ghost nets because it is possible that such nets would capture or continue to capture marine fishes, birds, and mammals after they are released. No purposeful tagging for research purposes will be conducted. The potential for incidental take incurred solely for the purpose of tracking net movements in the ocean is not acceptable to the CRED; therefore, this activity will not be considered in detail.

This document does consider instances when CRED may tag a ghost net for safe recovery at a later time as identified in Section 4.1.3.1.

3.3 Issues Not Considered in Detail

There are a number of issues that are covered by existing regulations, acts, laws or well established, long-standing procedures; because compliance with these measures is required for all CRED activities, the following issues will not be considered in this PEA.

3.3.1 CRED ACTIVITIES INVOLVING TAKE OF FISHES AND CORALS REGULATED BY STATE AND TERRITORIAL GOVERNMENTS

The ESA and similar state statutes provide special protections for species identified as being in danger of extinction or being threatened with extinction. The ESA prohibits “take” of such species, defined as “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.” State and territorial agencies regulate take of a number of fish species through fishing regulations. In general, CRED activities do not involve any take of commercial species. Should such take be necessary, it will be identified in permit applications filed with the appropriate governing agency, and these activities would be limited by the guidelines within the resulting permit.

In the state of Hawai`i, it is unlawful to take live rock; to break or damage it with a crowbar, chisel, or any other implement; or to take any rock or coral to which marine life is visibly attached or affixed. All CRED interactions with live rock are specifically identified in permit applications filed with the Hawai`i Department of Land and Natural Resources, and these activities are limited by the guidelines within the resulting permits.

Therefore, this issue will not be further evaluated in this PEA.

3.3.2 ESSENTIAL FISH HABITAT AND HABITAT AREAS OF PARTICULAR CONCERN

The *Magnuson-Stevens Act* identifies essential fish habitat (EFH) as those waters and substrates necessary to fishes for spawning, breeding, feeding, and growth to maturity. Habitat areas of particular concern (HAPC) are defined as areas where the ecological function of a habitat is important, habitat is sensitive to anthropogenic degradation, development activities that are or will stress a habitat, or a habitat type is rare. Marine organisms managed per the *Magnuson-Stevens Act* in fisheries management plans involving the water column include highly migratory and pelagic fish species. Marine organisms managed per the *Magnuson-Stevens Act* on the ocean bottom include bottomfish and seamount groundfish, precious corals and coral reef ecosystems, and crustaceans.

The methods used by the CRED are designed to limit impact to all aspects of EFH and HAPC, including benthic habitats and the water column. The CRED carefully selects equipment that has the potential for fewest impacts, places this equipment in carefully selected sites to avoid impacts to sensitive ecosystem components, and does not leave any equipment in place any longer than necessary for data collection. All interactions with the benthos are conducted carefully and guided by visual observations and protocols to minimize any impacts (Section 6, “Procedures, Permits, and Mitigation to Protect Personnel and Natural Resources”). All activities are conducted within the laws and regulations of the applicable federal, state, or territorial regulatory agency. Therefore, no adverse impacts would occur to EFH and or associated HAPC, and this issue will not be considered further in this PEA.

3.3.3 POTENTIAL FOR INTRODUCTION OF INVASIVE SPECIES

Based on the standard operating procedures carefully practiced by the CRED and required by permits (Section 6), the potential for any CRED activities to contribute to the introduction of invasive species is negligible. Therefore, this issue will not be considered further in this PEA.

3.3.4 POTENTIAL FOR ADVERSE SOCIOECONOMIC IMPACTS

The CRED's mission is to monitor and assess sensitive coral reef ecosystems to provide the foundation for science-based management by other agencies and organizations. Coral reef ecosystems provide many economic benefits to local communities and countries in the Pacific, and are a part of cultural practices and lifestyles. By supporting more effective management of reefs and their associated biota, including the identification of the appropriate levels of fishing for reef fishes, the CRED provides indirect yet beneficial assistance to local communities. Therefore, since CRED activities make positive contributions, this issue will not be considered further in this PEA.

3.3.5 POTENTIAL FOR ADVERSE EFFECTS ON SAMPLED POPULATIONS

CRED protocols for sampling live organisms are very clear: no samples are collected if any adverse impact on populations would occur. Sampling is limited to only that which is absolutely necessary for assessing the conditions and biodiversity of coral reefs, including identification of new species (Section 4, "Description of Alternatives," and Appendix A). Species that are protected by the ESA, *Marine Mammal Protection Act*, and *Migratory Bird Treaty Act of 1918* are carefully avoided based on appropriate consultation and standard operating procedures. Therefore, this issue will not be considered further in this PEA.

4 Description of Alternatives

Detailed descriptions of the actions related to the alternatives discussed in this report can be found in Appendix A.

4.1 Alternative 1: Description of the Current Program (No Action Alternative)

4.1.1 ACTIVITIES, METHODS, AND PROTOCOLS INVOLVED IN MONITORING AND MAPPING CORAL REEF ECOSYSTEMS

All monitoring research cruises are conducted in collaboration with colleagues and partners from other NOAA offices, federal, state, and territorial government agencies, academia, industry, and nongovernmental organizations to describe, map, and monitor coral reef ecosystems (for a complete list of CRED partners, see Appendix B.) For the Pacific Reef Assessment and Monitoring Program (Pacific RAMP), the CRED uses a suite of standardized methods, including ecological assessments, oceanographic and water-quality measurements, and benthic habitat mapping to improve understanding of the spatial and temporal processes influencing the health of coral reef ecosystems throughout the region.

Monitoring teams include a Rapid Ecological Assessment (REA) team of 5 to 8 divers that from one small vessel conduct surveys at long-term REA sites and deploy or recover autonomous reef monitoring structures (ARMS). Two other REA survey teams operating on their own small vessels, and each consisting of 2 fish-survey divers, work independently of the primary REA team to survey coral reef fishes using a stratified random design covering hard-bottom habitats at depths of 0–30 m. A towboard team of 4 divers operates out of another small vessel that is used to conduct towed-diver surveys around designated regions. The oceanographic instrumentation team operates out of another small vessel with 3 to 6 divers maintaining monitoring devices and collecting water samples. The NOAA survey launch R/V *Acoustic Habitat Investigator* (*AHI*) is also deployed in conjunction with Pacific RAMP cruises or independently with a crew of at least 2 people; no dive operations are conducted from its platform. At times, a separate dive-support vessel may be used to aid in the transport of tanks, gear, and personnel.

Typical NOAA monitoring cruises are ~ 90 days in length, typically consisting of several cruise legs of varying duration (with a maximum 35 days of consecutive field operations). There are currently 2–3 cruise legs scheduled for each monitoring cruise, although future cruises may be split into 4 or more legs depending on funding and allocation of NOAA vessel time.

The following actions continue to be incorporated into the current monitoring and mapping protocols conducted by the CRED:

- Examine algal species presence, diversity, and abundance in each island ecosystem, and evaluate the relationships of trends in quantities of individuals and population changes over time to reef health, involving limited collections of species

- Monitor the abundance, diversity, density, percentage of cover, and size-class distribution of shallow-water (< 20 m) scleractinian (hard) corals
- Assess and monitor the abundance and geographical distribution of shallow-water coral diseases and diseased corals
- Procure samples of diseased and healthy (control) coral tissues for histological studies pertaining to disease etiology
- Verify range extensions of described species of corals, and procure type specimens, if needed, for the description of new species
- Establish new permanent transect markers at previously established long-term monitoring sites
- Collect both quantitative and qualitative information for non-coral macroinvertebrate species present at all sites, producing species inventories for each location, and use other necessary specialized collections to further characterize macroinvertebrate communities
- Install, collect, and analyze ARMS to further characterize macroinvertebrate communities
- Monitor size frequency of reef fish assemblages, assess the status of target, indicator, or keystone reef fishes, and assess species response by fish community to potential ecosystem impacts (e.g., fishing, ecotourism, pollution habitat damage, sedimentation, and typhoons)
- Assess reef fish species composition and diversity, by area, and the effectiveness of temporal monitoring of areas managed by time and area closures
- Collect targeted species of reef fishes, providing scientific bases for life history and stock management assessments
- Conduct surveys with Bottom Camera (BotCam) bait stations, using a nonextractive method to assess the relative abundance and size composition of fish populations in deepwater habitats
- Perform conductivity, temperature, and depth (CTD) casts to gather continuous profiles of temperature and salinity against depth in shallow-water environments
- Conduct microbial, nutrient, and chlorophyll-*a* sampling in conjunction with a subsection of the CTD casts to establish values that can serve as an effective measure of trophic status, phytoplankton community health, and water quality
- Measure and monitor seawater carbonate chemistry to offer insight into the effects of increased CO_2 on the biological calcifying community over various spatial and temporal scales across ocean basins
- Install, maintain, and replace various oceanographic instrument arrays and acoustic monitoring devices that are intended to serve as long-term scientific features at specific sites
- Collect bathymetric, backscatter, and ground truthing data, providing baseline depth maps, backscatter imagery, and optical validation data to better characterize the seafloor of the Pacific Island region

4.1.1.1 Rapid Ecological Assessment Summary

REA methods provide an efficient, effective, and repeatable means to quickly yet accurately characterize the key components of coral reef ecosystems. Monitored components of reef ecosystems include algae and algal disease, corals and coral disease, other macroinvertebrates, and fishes.

At each REA survey site, 3 temporary 25-m transects using removable lines are laid out by divers and are the focal point for algal, coral, invertebrate, and fish surveys. Divers assess benthic elements falling at fixed intervals along these transect lines. Data are collected using underwater notepads and photographic equipment. In addition to the survey methods, outlined below, that use these transect lines, divers conduct random or roving swims at REA sites to record the presence of macroinvertebrates and fishes or collect algal specimens.

Line-point-intercept Method: Swimming along 2 of the 25-m transects, divers tally and characterize benthic elements, producing data to quantify cover of live and substrate components of the benthos and generating inventories of live elements down to the species or lowest taxonomic level possible.

Belt-transect Method: At each site, divers record the number, size class, and species of coral colonies and fishes observed along 2 or 3 of the 25-m transects. This method is also used to survey for non-coral invertebrates and cases of coral and coralline-algal disease or affliction.

Photoquadrat Method: Divers document relative abundance of macroalgal species and algal functional groups in and photograph several 0.18-m^2 quadrats along 2 of the 25-m transects.

Stationary-point-count Methods: Two types of stationary-point-count surveys are used for fish surveys. In both, divers record the number, size, and species of all fishes observed within cylinders with diameters of 15 or 20 m. Photographs of the reef benthos also may be taken.

4.1.1.2 Towed-diver Survey Summary

Pairs of divers are towed 60 m behind a small boat targeting the benthic contours at depths of 15–16 m. In each towed-diver team, one diver collects benthic data while looking down, and the other diver quantifies fish populations while looking ahead and up. Each benthic towboard is equipped with a downward-looking, high-resolution, digital still camera programmed to photograph benthic substrate every 15 s. Each fish towboard is equipped with a forward-looking digital video camera.

4.1.1.3 Assessment Methods for Algae and Algal Disease:

Line-point-intercept Surveys: Data are collected on macroalgal species, algal functional group, or substrate type. Samples are collected of new algal species. A random swim at the end of each dive is used to collect specimens not present within the immediate range of a transect.

Photoquadrat Surveys: Two divers work closely together along 2 of the 25-m transects. One sets the frame of the 0.18-m^2 quadrats and takes photographs, and the other takes notes. Samples of algal species observed in quadrats are collected for later identification in the laboratory.

Belt-transect Surveys: Afflictions to coralline algae observed along 2 of the 25-m transects are enumerated and classified into 3 general categories: coralline lethal orange disease, coralline white band syndrome, and coralline cyanobacterial disease.

Towed-diver Surveys: Divers, towed 60 m behind a small boat and looking downward along a 10-m survey swath, record benthic habitat composition using categories that include macroalgae and crustose coralline red algae.

4.1.1.4 Assessment Methods for Corals and Coral Disease

Line-point-intercept Surveys: Data are collected on coral species or substrate type. Characterization of benthic elements includes live corals and recently dead corals.

Belt-transect Surveys: Within regularly spaced segments along 2 of the 25-m transect lines, coral colonies are identified to the species level and their diameters measured. Colony mortality is estimated, and cases of disease and states of compromised health are recorded. Along with photographic documentation of coral lesions, biopsies or samples for histological, microbiological, or molecular studies are sometimes procured as needed. Samples representing each species or taxon and disease state measure no more than 7 cm. In no case are specimens collected if a diver judges that doing so might inhibit the capacity of a taxon to replenish itself at a site.

Towed-diver Surveys: Divers, towed 60 m behind a small boat and looking downward along a 10-m survey swath, record benthic habitat composition using categories that include hard corals, stressed hard corals, and soft corals.

Collection of Corals for Computerized Axial Tomography (CAT) Scan: The collection of coral cores from massive colonies and branch samples from other branching colonies are used for comparisons of coral calcification rates between locations exhibiting differing nutrient regimes.

4.1.1.5 Assessment Methods for Non-coral Macroinvertebrates

Belt-transect Surveys: At each REA site, divers count non-coral macroinvertebrates observed along three 25-m transects. Then, during a roving swim, divers collect data for rare and cryptic organisms and survey habitats not found along the transect lines. Specimens of organisms that cannot be identified in the field are collected and further analyzed.

Towed-diver Surveys: Divers, towed 60 m behind a small boat and looking downward along a 10-m survey swath, record numbers of conspicuous macroinvertebrates.

Autonomous Reef Monitoring Structures (ARMS): ARMS are typically deployed in close relation to REA sites. An ARMS device is a small, long-term (1–3 years) collecting device designed to mimic the structural complexity of a coral reef and is intended to attract colonizing macroinvertebrates. ARMS are placed on substrates of pavement (flat, featureless terrain) or sand in proximity to coral reef structures specifically to avoid coral damage. A global positioning system (GPS) waypoint is recorded for each ARMS after deployment to document its location so that equipment can be readily found and retrieved by CRED personnel at a later date.

Several opportunistic surveys are conducted when applicable:

- Obtaining current and accurate documentation of spatial distribution and demography of the pearl oyster (*Pinctada margaritifera*) and the crown-of-thorns seastar (*Acanthaster planci*), which feeds prolifically on corals
- Collecting specimens of crown-of-thorns seastars to understand gene flow and population connectivity across the Hawaiian Archipelago
- Conducting initial surveys of macroinvertebrate and algal communities that colonize marine debris to identify the extent of invasive species populations

4.1.1.6 Assessment Methods for Fishes

Several complementary, noninvasive underwater surveys are used to enumerate the diverse components of fish assemblages that are active during the day on shallow-water reefs. Fish length-class is estimated for all quantified fishes to provide estimates by taxa of numerical size structure and biomass densities.

Random Swims: A pair of divers conducts a random swim throughout each selected REA site, recording the presence of fishes visually encountered by species or lowest recognizable taxon. This method is typically used at deeper, time-limited sites or where current is too strong to conduct transects.

Belt-transect Surveys: This type of survey is used mainly to quantify relatively small-bodied and abundant fishes.

New Stationary-point-count (nSPC) Surveys: This type of survey is used to quantify diurnal non-cryptic coral reef fishes. This type of survey is also used to quantify fish species that are relatively larger and more agile than species surveyed with the belt-transect method.

Towed-diver Surveys: Divers, towed 60 m behind a small boat and looking forward and upward along a 10-m survey swath, document to the lowest possible taxon all fishes with a total length > 50 cm. The presence of species of concern outside the survey area is also noted. Footage from the digital video camera mounted on each fish towboard serves as a visual archive of each survey track and can be used to evaluate changes in reef environment, particularly following episodic events such as coral bleaching and vessel groundings.

Sample Collections for Life Histories: The CRED is working toward a goal to collect specimens from the entire size range of up to 80 reef fish species that are not threatened or endangered. No more than 100 specimens of each of these species will be collected. Specimens are collected using a three-prong spear or spear gun.

Sample Collections of Undocumented Species: Divers may collect a few specimens of undocumented reef fish species or an individual of notable significance. If the identity of a fish is uncertain, photographs are taken so that fish biologists can confirm its species and determine if collection of specimens is recommended. Fishes are caught using small nets, then euthanized quickly with clove oil (an over-the-counter anesthetic and antiseptic), frozen, and transported to a zoological institution for further examination.

4.1.1.7 Oceanographic Assessments

Knowledge of oceanographic processes is essential for understanding and monitoring the health of coral reef ecosystems, as ocean circulation often determines the abundance, types, and diversity of species within a particular local ecosystem. It also determines where marine debris accumulates and how it may impact a particular reef ecosystem. Local changes in seawater temperature and chemistry can have drastic effects on coral health, and episodic storms and other high-energy events can radically change these ecosystems in a very short time. In order to assess these impacts, the CRED program deploys a variety of sensors that monitor the environment. These sensors are either moored on the seabed or deployed in the water column to measure and record parameters such as ocean temperatures, salinity, wind and wave energy, tides, currents, ambient noise levels, and solar radiation. These seafloor instruments are deployed on sites that are intended for use for at least 25 years, but individual instruments are recovered for data collection every 2–3 years.

Instruments Moored on the Seafloor: Instruments that are deployed to measure parameters at a specific location are affixed to the seabed by anchors, pins, or cable ties. Section 7.3, "Physical Effects of Moorings, Pins, and Cable Ties on the Seabed and Corals," summarizes the protocols used to deploy these instruments. NOAA-certified working divers locate these instruments by hand to minimize their effect on the environment. Heavier equipment and anchors are carefully lowered with an air-filled lift bag to place an instrument on the seafloor. Wherever possible, divers minimize the potential for environmental effects by ensuring that moorings are located on benign, durable substrates, such as rubble and sand.

The following descriptions are of various pieces of equipment that are moored on the seabed:

- **Wave-and-tide recorders (WTR), acoustic Doppler current profilers (ADCP), and salinity sensors** passively collect information on water velocity, water level, and movement of salinity through waves and the water column.
- **Ecological acoustic recorders (EARs)** passively collect information on natural ocean sounds, as well as sounds caused by human activity, and was developed specifically for monitoring sounds made by fishes, macroinvertebrates, and human activity in marine habitats.
- **Subsurface temperature recorders (STRs)** are used to construct a time series of water temperature data at various locations on a reef.
- **Sea-surface temperature (SST) buoys** provide high resolution water temperature data sets.
- **Coral Reef Early Warning System (CREWS) buoys** provide high-resolution SST, barometric pressure, wind speed, and wind direction data. Enhanced versions also provide salinity, UV-B ultraviolet light, and photosynthetically available radiation (PAR) data. Subsets of these data are transmitted daily via satellite telemetry.
- **Subsurface ocean data platforms (ODP)** provide high resolution current profiles, directional wave spectra, and temperature and salinity data.

Instruments Not Moored to the Seafloor:

- **BotCam**, or Bottom Camera, is a remote, stereo-video camera system designed to sample the distribution, relative abundance, and size composition of deepwater (100–300 m) fishes and associated biological and physical characteristics of their habitat. BotCam provides a cost-effective and nonextractive method of assessment. This system is deployed with weights that hold a camera at depth while an arm with bait attached attracts bottomfish species into the camera frame for up to 60 min. When an acoustic release is tripped, this positively buoyant station detaches from its weights and returns to the ocean surface. The weights that remain on the seabed are designed to be environmentally relatively benign and are composed of materials such as concrete aggregate blocks tied together by rope constructed with natural fibers such as Manila hemp.
- **Conductivity, temperature, and depth (CTD) casts** are used to collect information about the vertical salinity and temperature structure of the water column. Shallow-water CTD casts are performed from small boats to a depth of 30 m. Deepwater CTD casts are conducted from NOAA research vessels down to a depth of 500 m and are capable of collecting several water samples.
- **Oceanographic water sampling,** using 4 Niskin bottles to take samples at various depths from a small boat, provides data on basic water properties, including chlorophyll-*a*, nutrients, microbiology, and, in some cases, carbonate chemistry.
- **Dissolved-inorganic-carbon (DIC) sampling** is used to monitor seawater carbonate chemistry in coral reef ecosystems and thereby understand the consequences of the ocean acidification process. In situ temperature, salinity, DIC concentrations, and total alkalinity are measured by collecting water samples.
- **Microbiological water sampling** requires the collection of seawater to obtain data on microbes and other microscopic biota, evaluate water chemistry, culture common bacteria, and archive microbial DNA samples.

4.1.1.8 Methods for Benthic Habitat Mapping

Mapping is conducted using multibeam echosounding sonar mounted on the PIFSC-owned survey launch R/V *AHI* and the NOAA Ships *Hi`ialakai* and *Oscar Elton Sette*. The frequency and power of the acoustic signals from these multibeam sonar units are classified as high-frequency sonar (International Council for the Exploration of the Sea [ICES] 2005) and as such are not appreciably different than navigation echosounders used by commercial shipping for safety of navigation. The *AHI* can survey in depths of 5–200 m, and data collection with this launch focuses on shallow waters. Shipboard data collection aboard the *Hi`ialakai* and *Sette* occurs in deepwater sites, well away from potentially dangerous shoals.

4.1.2 ACTIVITIES, METHODS, AND PROTOCOLS INVOLVED IN ASSESSING BIODIVERSITY IN CORAL REEF ECOSYSTEMS

Coral reefs are the most biologically diverse of all marine ecosystems, according to the hypotheses of Paulay (1997) and Reaka-Kudla (1997). Despite the fact that they occupy less than 0.2% of the ocean’s area, coral reef ecosystems are estimated to provide habitats to about 25% of all marine species (Buddemeier et al. 2004). However, because of historical under sampling in tropical regions, the number of species associated with coral reef ecosystems is not even known to the nearest order of magnitude.

Scrutiny of the taxonomy of species at both the ecosystem and molecular levels shows that endemism on reefs is higher and that larval and genetic connections among them are more limited than previously suspected (Taylor and Hellberg 2003; Barber et al. 2000; and Meyer et al. 2005). In a paper published in 2006 by the National Academy of Sciences and a study that is part of the Census of Marine Life's International Census of Marine Microbes, scientists revealed that marine microbial diversity may be some 10 to 100 times greater than expected and that the vast majority of species are previously unknown, low-abundance organisms theorized to play an important role in the marine environment as part of a "rare biosphere" (Sogin 2006).

The danger that much reef biodiversity could be lost before it is even documented is clear, and researchers and managing agencies will be left with a limited and poor understanding of undisturbed reef communities on which to base future management decisions. The recent rapid decline of remote reefs as a result of massive coral bleaching events and increased incidences of widespread disease makes recording their biota especially urgent. The observed increases in coral bleaching and other diseases in recent years might suggest that coral reefs are particularly vulnerable to changing climate conditions, likely because of their high sensitivity to increasing water temperatures and CO_2 levels. In light of their high biodiversity and increasingly threatened status, coral reef ecosystems are ideal candidates for focused biodiversity assessment.

The overall objective of the CRED's biodiversity assessment project is to investigate and document the biological diversity of non-coral macroinvertebrates, turf and coralline algae, and microbial communities. This project documents diversity in ecologically critical but noncharismatic, commercially unimportant organisms across a range of habitats. These organisms have historically been understudied because of a lack of taxonomic expertise or logistical difficulties in sampling. In addition to using traditional morphological taxonomic identifications, DNA from these species is used in a bar-coding study to help future researchers identify taxonomically challenging taxa. Data collected are input into regional and global databases. This project assists managers by providing baseline biodiversity information on the coral reef ecosystems they manage and the species that they are charged with protecting.

The protocols for these proposed activities have been designed to minimize any disturbance to the surrounding environment. The collection of and procedures to collect non-coral marine invertebrate samples for biodiversity and connectivity research is intended to have little to no significant impact on the reef habitats and ecosystems being studied. Several collections are nonlethal and, for others, the targeted sample numbers are small. For collections based on the ARMS methodology, all organisms are newly recruited. Nothing beyond that which inhabits the ARMS unit when recovered is taken from the surrounding reef. ARMS provide substrate for organisms to inhabit and are, therefore, excellent mechanisms through which to conduct biodiversity surveys. ARMS will collect a relatively small number of invertebrates in total. Thus, collection is recruiting by chance and has minimal impact on a coral reef ecosystem.

Currently, when conducting biodiversity assessments, 14 different sampling techniques are used to investigate a range of unknown or understudied coral reef species over an array of benthic habitats. These can be broadly separated into 3 categories: (1) methods involving collection by divers, (2) methods involving collections in deep water, and (3) ARMS.

4.1.2.1 Methods Involving Collections by Divers

Hand Collection: Species are taken from either a reef surface or under loose pieces of coral rubble. Animals are placed in bags, jars, or buckets with ample seawater and taken on board for study.

Rubble Extraction of Live Rock: Divers gather pieces of loose rubble no larger than 20–40 cm from a small area underwater and place each sample in a bucket to prevent escape of small organisms.

Rubble Brushing: Brushing coral rubble is an effective method for collecting small macroinvertebrates that are either difficult to see because they are cryptic, small, or numerous and, therefore, easily collected from a surface. Coral rubble is held by the diver over a basket lined with a fine screen and gently brushed with a soft brush, so that animals fall or swim off the rubble into the basket. After brushing, the rubble is replaced on the bottom in the same area in which it was found.

Sand Sampling for Dead Assemblages of Fauna: Sand sampling involves gathering and washing sand in freshwater and air drying. The fauna studied using this method is dominated principally by mollusks, although small sea shrimp and other taxa could also be collected.

Sand Sampling for Live Assemblages: Sand sampling involves sieving sand underwater over a screen with a 1-mm mesh and taking the retained fraction on board for sorting.

Extraction from Crevices with Yabbie Pumps: The Yabbie pump is a simple, stainless steel suction device that is hand operated and used to extract burrowing organisms.

Microbial Collection: Diver-deployable Niskin bottles are used to collect seawater at REA sites. All samples are collected 50–100 cm above the reef surface at a depth of ~ 10 m and transported back to the ship for microbiological water sampling. Since microbial and viral loading and the dominance of heterotrophic bacteria in reef waters are linked to coral disease, the need to observe these processes involves fluorescent microscopy and flow cytometry. These methods are the most direct and accurate means for assessing and monitoring changes in size and abundance of these microbiological components. Flow cytometry can also be used to differentiate heterotrophic and autotrophic bacteria.

Lipid Analyses of Sediment: Sediment samples are taken by scooping sediment into a whirl pack and returning it to the ship for analysis.

Water Sampling for DNA/RNA Extraction Using a Sterivex Filter: Sterivex filters are 0.22-µ capsules (Millipore) that are routinely used by NOAA scientists to concentrate water samples for further DNA or RNA sample extraction.

Algal Collection: The algal team hand collects specimens of turf algae, crustose coralline red algae, and fleshy macroalgae.

Suction or Vacuum Collection: A vacuum-type device is used to suction samples in an area to survey for small or cryptic, mobile macroinvertebrates on exposed hard-bottom substrates.

Baited Traps in Shallow or Deep Water: Standard commercial-style, polyethylene plastic traps are used, with a minnow trap placed in each trap to capture organisms smaller than the mesh of the standard traps, such as crabs, shrimp, and snails.

Light Traps: Light traps are designed to capture larvae and zooplankton that navigate nearby and are attracted to light. Target taxa include various planktonic crustaceans, such as mysids, cumaceans, isopods, and marine worms.

4.1.2.2 Methods Involving Non-trap Collections in Deep Water

Ekman Grab: The Ekman Grab is ideal for slow-moving or sedentary species and is used in sandy areas. The advantage of this method is that it can be deployed and retrieved quickly in deep water, bringing up a small amount of sediment and getting a perfect sample with very little bottom disturbance.

Scoop or Dredge: The dredge is designed to pick up sand, rubble, and benthic organisms, targeting large and small organisms living in and on the substrate in deep, flat sandy areas.

Plankton Nets: Plankton nets are used to sample plankton communities as subsurface tows.

ARMS Deployments: Routine deployment of ARMS has been incorporated into the CRED's mapping and monitoring project. A discussion of these devices and the protocols associated with their use can be found in Appendix A, Section A.1.5.

4.1.3 ACTIVITIES, METHODS, AND PROTOCOLS INVOLVED IN COLLECTING AND REMOVING MARINE DEBRIS

The PIFSC has been opportunistically collecting information about marine debris in the NWHI since 1979. The early surveys reported relatively pristine reefs; however, by 1996, reefs were suffering from substantial damage caused by human activity, primarily due to the effects of derelict trawl and gill fishing nets. Free-floating ghost nets typically are nets that have broken away from fishing vessels, and ultimately they often are deposited on coral reefs and beaches. While land-based sources may be responsible for the majority of marine debris in the world's oceans, debris of maritime origin may pose the greatest threat to ecosystem health in the NWHI because oceanic currents (specifically the North Pacific Subtropical Convergence Zone) provide a mechanism for debris accumulation in this region.

In 2001, the CRED began a targeted marine debris removal effort in the NWHI and began collecting data on the type, size, and distribution of debris. This work led to an accumulation-rate study that estimated that 52 t of derelict fishing gear collects on the coral reefs of the NWHI each year (Dameron et al. 2006). In addition, CRED removal teams determined that the largest percentage of fishing gear comes from non-Hawai`i-based fisheries. Trawl nets and monofilament gillnets accounted for ~ 33% and 34% of the debris removed from reefs in the NWHI by weight, and trawl-net debris alone accounted for 88% of debris by frequency.

The movement of derelict fishing gear, especially nets, across shallow atolls where they catch on coral reefs threatens the ecological balance of reef communities. Once derelict fishing gear snags on a reef, it begins a cycle of destructive activity. Derelict fishing gear modifies the structure of reef by damaging the coral substrate that comprises the physical habitat for reef biota. After net debris snags on a coral reef, wave action acting on that debris breaks the coral heads on which that debris is fixed, freeing it to subsequently snag and similarly damage additional corals. This action continues until derelict fishing gear is removed or becomes adequately weighted with broken corals to sink. The damage to corals caused by such nets can be substantial and continuous.

In addition to presenting an entanglement threat to wildlife and significantly damaging coastal and coral reef habitats, derelict fishing gear presents a hazard to boat navigation and is a potential conduit for the accelerated introduction of alien invasive species. Derelict fishing nets affect boat navigation by catching in propellers. Derelict fishing nets also pose a serious and lethal threat to fishes, marine mammals, sea turtles, crustaceans, such as lobsters, and diving seabirds, such as albatross, by catching, entangling, and subsequently drowning them. Reef communities support abundant populations of species protected under the ESA, *Marine Mammal Protection Act*, and *Migratory Bird Treaty Act*. Entanglement records have been documented for all marine turtles found in Hawaiian waters, including the endangered hawksbill, olive ridley, and leatherback sea turtles, as well as the threatened green sea turtles. Entanglement in derelict fishing gear is also a known cause of mortality to humpback whales and the critically endangered Hawaiian monk seal. All 6 extant breeding subpopulations of this seal are located in the NWHI, and this species suffers the greatest entanglement rates (averaging 15 seals per year) of any pinniped (seal or sea lion) reported to date (Henderson 2001; Boland and Donohue 2003). Mortality in long-line fisheries is a major global threat to most albatross and large petrel species, including listed species (Bergin 1997).

In recent years, these substantial concerns with derelict fishing gear have received greater attention from the media and communities that are struggling to address this pervasive problem that not only mars beaches but also presents a key threat to the environment. In response to this widespread concern, the U.S. Congress passed the *Marine Debris Act* (Section 2.1.3, "Legal Basis for Coral Reef Management").

The primary objectives of the CRED survey and removal efforts are to (1) assess and identify regions of marine debris accumulation and (2) conduct targeted removals at high-priority sites. Regions of interest include areas of high debris density, known as "hot spots," and accumulation sites used in ongoing scientific studies. Since 2001, the CRED's highly trained marine debris removal team, with small and large vessels and unmanned air support, have found and removed marine debris at high-priority coral reef ecosystems and nearshore locations.

4.1.3.1 Methods for Locating and Removing Marine Debris

NOAA research vessels, USCG vessels, and chartered vessels transport equipment and personnel to the NWHI and serve as support platforms for debris removal and research activities.

Marine debris specialists have been selected for this team for their in-water expertise and have been carefully evaluated by the NOAA Diving Program. Before field deployments, specialists undergo intensive field-based training in boat handling, towed-diver surveys, emergency response, and net recovery. During marine debris recovery operations, survey and removal methods—including in-water surveys (towed-diver and swim surveys), aerial surveys, boat-based removal from reefs, and removal of debris from beaches and other intertidal zones—are used as appropriate. For details about these methods, see Appendix A.

During training and operations, small boats are carefully anchored only on sand or rubble substrate so that benthic disturbance is minimized. The operational area is continuously monitored for listed species, and all activities are modified to minimize disturbances or interactions. The anchor is lowered rather than thrown overboard, and a diver checks the deployed anchor to make sure it does not drag or entangle any bottom organisms or listed species.

Team members systematically survey reefs using swim surveys and towed-diver surveys to locate submerged derelict fishing gear in shallow water at depths < 10 m, within a range generally workable by snorkel or free diving. Upon sighting a derelict net or net fragment, a GPS waypoint is taken. Debris type, size, fouling level, water depth, and substrate of the adjacent habitat are recorded. Nets are evaluated before removal actions to determine appropriate removal strategies.

Towed-diver Surveys: During a towed-diver survey, 2 snorkelers are towed ~ 10 m behind a lead boat, and they visually inspect the water column and benthos for marine debris.

Swim Surveys: Swim or snorkel surveys are conducted in areas where towed-diver surveys are not possible. Swim surveys are used in shallow waters at depths of < 2 m and regions with more complicated reef structures.

Intertidal-zone Removal: Nets and other debris observed along shorelines are also removed. When debris is found washed ashore but below or at the high-tide line, team members collect data such as size, type, and GPS location. Such debris is removed by hand or by helicopter sling load. This removal work is performed in the marine environment; thus, mitigation techniques for avoiding disturbances to marine protected species are used (Section 6.3.4, “Additional Procedures for Protecting Protected Species during Collection of Marine Debris”).

Aerial Surveys: Aerial surveys are conducted from long-range, fixed-wing aircraft, helicopters, and unmanned aerial systems (UAS). Aerial surveys provide the ability to survey large areas of open ocean. The goal is to proactively mitigate the problem of marine debris by identifying and removing derelict fishing gear from the open ocean before it has an opportunity to reach a reef and become ensnared.

In 2005, aerial surveys conducted by long-range, fixed-wing aircraft began to provide density estimates of debris at the North Pacific Subtropical Convergence Zone. Subsequently, the testing of a UAS has been used to survey the open ocean, and helicopters have been used to survey along the shorelines of Pacific islands.

Opportunistic ghost-net collection is conducted when, at open sea, a derelict net is sighted and deemed recoverable after considering size, storage capacity aboard, and overall safety of the vessel, crew and those involved in collection. Attempts to remove marine debris encountered at sea are very variable and can be unfeasible because of operational, vessel, or safety constraints. However, by attaching a satellite-tracked marker to debris, it will be possible to locate that debris in the future and to track and analyze its drifting patterns. Marker buoys are ~ 100 cm in diameter and 25 cm tall. When floating, only about 10 cm protrudes from the surface of the water. Buoys are tethered to conglomerations of marine debris using a length of nylon or polypropylene line. It is anticipated that attachment of marker buoys will not drastically increase the likelihood of entanglements with protected species or interactions (such as fish aggregation effects) over what an existing debris mass would already provide. Encountering debris at sea and attaching a satellite marker buoy is an opportunistic event that may occur in the open waters of the state of Hawaii, Papahānaumokuākea Marine National Monument, or U.S. government or the high seas.

4.2 Alternative 2: Continuation of the Current Program with Additional CRED Actions

This alternative includes 3 options that could be added to the current program. Each option includes continuation of the current program. Only 2 of the options (Options A and B) are described in this section, since the third one (Option C) is a combination of Options A and B. Because the CRED program provides valuable data and information to local, regional, and international resources managers and stakeholders, the CRED is not considering discontinuing its program.

Option A: Expanded ocean acidification investigations.

Option B: Expanded biological observations and sampling for coral reef fish stock assessment.

Option C: Both Option A and Option B.

4.2.1 OPTION A: EXPANDED OCEAN ACIDIFICATION INVESTIGATIONS

4.2.1.1 Introduction

Global climate change is warming ocean temperatures and increasing sea levels. New scientific research shows that the world's oceans are also beginning to face yet another threat due to global climate change: basic ocean chemistry is changing because of the uptake of CO_2 released by human activities (Feely 2006). Oceans act as the natural sink for CO_2, with ~ 25% of anthropogenic CO_2 entering the world's oceans. When CO_2 reacts with seawater, it forms carbonic acid, which disassociates to bicarbonate ions. These bicarbonate ions then react with carbonate ions, a reaction that increases the total number of bicarbonate ions. The net results of this reaction chain are that pH levels decrease to a more acidic level and carbonate ions, the building blocks for all calcifying marine organisms, are removed from the system. This lowering of pH levels of the world's oceans, which makes seawater less alkaline, has been labeled "ocean acidification."

Laboratory experiments indicate that coral reefs cannot easily adapt to the anticipated rapid increase in ocean acidity levels. As the availability of carbonate and aragonite ions decreases, pH levels decrease. As a result, the rate at which reef-building corals produce their skeletons decreases. Based on current CO_2 concentration models, by the middle of this century, the carbonate ion concentration in seawater is predicted to drop to a level at which coral reefs can no longer create carbonate skeletons. While the long-term consequences of ocean acidification are unknown, models indicate that this could have a disastrous effect on the geographic range of corals and all organisms with calcium-based shells in the next 50–100 years. This reduced rate of coral-reef building could also lead to diminished resiliency of coral reef ecosystems from bleaching and disease and to increased coral mortality caused by warmer ocean temperatures and local, man-made stressors, such as sedimentation, land-based pollution, and contaminated runoff.

As described previously in Section 2.2, "Purpose of Action," the CRED has conducted a program of assessing and monitoring coral reef ecosystems throughout the central and western Pacific since 2001. At least in part because of their remote location, many of these reefs have not experienced significant adverse anthropogenic effects and are expected to be among the most resilient to climate change and ocean acidification. The relatively pristine nature of these ecosystems makes them uniquely suited for assessing the ecological impacts of climate change and ocean acidification.

4.2.1.2 Expanded Activities for Assessment of Ocean Acidification on Coral Reef Ecosystems

Long-term monitoring conducted by the CRED combined with biennial, high-spatial-frequency, in situ measurements allow for an analysis of how various physical and biological factors affect the organic and inorganic carbon cycling in coastal waters. These measures are augmented with reference measurements of nearby offshore waters. Methods for assessing and monitoring seawater carbonate chemistry include measuring in situ temperature, salinity, dissolved inorganic carbon (DIC) concentrations and total alkalinity over a range of spatial and temporal scales using both samples from a hand-held Niskin bottle array and an in situ instrument called remote automatic sampler (RAS).

The CRED is considering expanding its activities in order to understand the ecological impacts of climate change and ocean acidification on the biological components of coral reef ecosystems and to ultimately predict ecosystem responses to future increases in CO_2. Standard operating procedures to protect coral ecosystems, including protected species, and diver safety protocols would be implemented as described in and Section 6, "Procedures, Permits, and Mitigation to Protect Personnel and Natural Resources." This potential expansion of research efforts includes the following activities:

- Coring of massive coral colonies to determine historical coral growth and accretion rates to provide paleoceanographic time series of calcification and growth rates to hindcast the carbonate chemistry climate of coral reefs from hundreds of years past. To quantify the size and density of annual growth bands in coral skeletons, core samples would be collected and preserved for analysis by nondestructive CAT scan and image analysis techniques to visualize growth bands that cannot otherwise be observed (Saenger et al. 2009). A core will be collected from a single colony of sufficient size and health such that extracting a very small core, 2.5 cm in width and 5–10 cm in length, is judged not to be destructive or detrimental to the longevity of a colony. Through analyses of data from current CRED monitoring efforts, the abundance of colonies meeting the criteria is established at each island and cores are only taken when and where there will be little impact. Only a few cores at an island are necessary, and, thus, the number of colonies sampled is low. Common species found throughout the regions of interest, *Porites* spp. are the target for coral core sampling. These species are typically stable and successful and not currently in danger or threatened. Upon completion of a coring, a cement plug is affixed to seal the hole, preventing invasion of a colony by bioeroding species. A cement plug provides a suitable surface over which surrounding coral tissue can grow. In 2 years, scars are typically completely healed and plugs are no longer visible.

- Development of a calcification plate system to be installed by divers near the seafloor and supported by stainless steel pins to monitor calcification rates of crustose coralline red algae.
- Surveys of variations of ocean carbonate chemistry across the central and western Pacific and across a broad spectrum of habitat types using ship-based flow-through seawater measurements of partial pressure of CO_2 to quantify aragonite and carbonate ion concentrations.
- ADCPs would be deployed to measure the spatial and temporal structure of water transport within a reef system.

Chemicals used for Option A activities include a bio-fouling substance that exterminates organisms that clog equipment and mercuric chloride ($HgCl_2$), which is used for the fixing of DIC samples.

Weather and limited space play a role in the collection of DIC samples from a small boat with a 1.75-L Niskin bottle array. DIC samples are collected in 300-mL glass bottles and then carefully injected with 200 µL of $HgCl_2$ so as not to spill any solution. If a spill does occur, the ship protocols for cleanup of hazardous materials are followed. The $HgCl_2$ solution and all gear associated with dispensing the $HgCl_2$ solution are kept in a dedicated cooler. Within that cooler, the $HgCl_2$ solution bottle is double bagged and kept upright. The 300-mL sample collection bottles are kept in their own carrying tote. The person assigned to carry DIC water sample creates a space within the small boat sufficient to safely handle the $HgCl_2$ and samples. If weather or sea state cause any difficulty, DIC sample collections stop. Once DIC samples are taken and injected with $HgCl_2$, filled bottles are returned to the padded carrying tote. The tote is secured upright in an air conditioned space aboard the research support vessel.

In the other sampling procedure, a RAS unit contains 48 sample bags with each bag containing 200 µL of $HgCl_2$. The RAS remains in the water a minimum of 1 d and a maximum of 2 years, automatically collecting 500-mL water samples at pre-programmed time intervals. The $HgCl_2$ contained in the RAS fixes the water sample so that it can be analyzed without changing the physical properties of the water. The $HgCl_2$ in the RAS is stored in separate sample bags to insure that, if in the highly unlikely event that a leak does occur, only 200 µL (~ 4 drops from a standard eyedropper) could possibly be discharged into the environment. When preparing to attach sample bags to the RAS, special care is taken to ensure that all bags are in good working order and secured properly to the unit.

4.2.2 OPTION B: EXPANDED BIOLOGICAL OBSERVATIONS AND SAMPLING FOR CORAL REEF FISH STOCK ASSESSMENT

4.2.2.1 Introduction

As recognized by the Western Pacific Regional Fishery Management Council (Council), there is a growing need for an ecosystem-based assessment of coral reef fish stocks in the U.S-affiliated Pacific Islands. In 2004, the Council organized a workshop to develop a plan for reliable assessments of coral reef fisheries resources. The recommendations made during this workshop form the basis of the proposal described in this section to improve the CRED's ability to conduct and support stock assessments.

The CRED currently conducts fisheries-independent surveys using underwater visual surveys as part of Pacific RAMP. From 2001 to 2006, these surveys were limited to specific reef zones and depths because of the constraints of limited sea days and relatively small field survey teams associated with ship-based work. Recently, these surveys have been expanded to allow for 2 independent fish-survey teams. These additional teams together with changes in methodology and survey design have allowed for an increase in the number of sample sites from 3 to ~ 8–10 per day. Using a stratified random design, fish-survey sites are allocated randomly across the entire range of hard-bottom habitats at depths of 0–30 m at survey locations.

These surveys have demonstrated striking patterns across gradients of human population and fishing intensity, including 80% lower total fish biomass around populated islands as compared to remote islands. Consistent with studies from elsewhere in the world (Mora 2008; Sandin, Smith et al. 2008), analyses of reef fish populations at locations surveyed by CRED have shown clear evidence that coral reef fish stocks are significantly depleted around human population centers (Friedlander and DeMartini 2002; Williams, Walsh et al. 2008). Yet, as pointed out by the panel members of the Coral Reef Fish Stock Assessment Workshop (Western Pacific Regional Fishery Management Council [WPRFMC] 2004), no stock assessments have been done for any species in the coral reef fisheries of the U.S. Pacific. The national standards set by the *Magnuson-Stevens Act* now require assessments.

Given the level of monitoring effort currently conducted, the CRED is in a unique position to combine fisheries-independent data, an existing and extensive ecosystem data set, and information on life histories of targeted species to provide analyses to the NOAA NMFS Pacific Islands Regional Office in support of its decisions on how to manage fishing pressure on coral reef fish species. This additional effort would provide fundamental biological information on priority species and a basis for a variety of stock assessment models.

The CRED has several key partners in fishery survey efforts (for a complete list of partners, see Appendix B). At the University of Miami, the Fisheries Ecological Modeling and Assessment Research group, led by Jerald Ault, PhD, is collaborating to improve the stratified sampling design used in Pacific RAMP underwater visual censuses to obtain reliable population estimates. Stuart Sandin, PhD, from the Scripps Institute of Oceanography of the University of California, San Diego, is sharing his work on life history of coral reef fishes in the lower Line Islands. The CRED has also been working with local agencies and academic partners in the CNMI, Guam, American Samoa, and Hawai`i to coordinate specimen collection and prevent duplication of efforts.

4.2.2.2 Goals and Objectives

The objective of the Council's Coral Reef Ecosystem Fishery Management Plan (WPRFMC 2001) is to foster the sustainable use of multispecies resources in an ecologically and culturally sensitive manner. The panel members of the Coral Reef Fish Stock Assessment Workshop made a series of recommendations on how to attain this objective (WPRFMC 2004). The CRED has been acting on several of the more urgent and critical recommendations, such as standardizing methods and sampling design across the U.S. Pacific and developing structured databases. The CRED has also been working closely with the head of this panel on improving sampling design to support the development of estimates of population levels of fish species that are necessary for stock assessments (Ault et al. 2008).

To continue in this direction, the CRED proposes to collect life-history information on critical reef fishes and to dedicate staff to stock assessment work. This effort would include collecting fisheries-targeted species in the field and obtaining fundamental information on age, length, weight, maturity, natural mortality, and sex ratios. Collecting data on sex ratios was classified as "critical" by the workshop panel. Another aspect would be analyzing the CRED's data sets together with available life-history information using analytical and modeling approaches to derive fishery metrics, such as spawning potential ratio, fishing mortality, stock biomass, and stock biomass as a proportion of pristine biomass. These various assessment approaches will provide information which supports federal fishery management councils in their work to develop acceptable catch limits for reef fish taxa as required by the *Magnuson-Stevens Act* and, thereby, to protect the viability of coral reef ecosystems.

4.2.2.3 Methodology

From 2002 to 2009, the CRED staff used noninvasive quantitative belt transects and stationary point counts to collect data necessary for assessing baseline population status, including abundance, biomass, and size-structure of common coral reef fishes from 4 geographic regions: the Hawaiian Archipelago, the Mariana Archipelago (Guam and the CNMI), American Samoa, and the PRIA. These assessments provide snapshot estimates of the structure of the diurnal and non-cryptic reef fish assemblage of each region, including both fishery-targeted and non-targeted species.

Complementing abundance-based data, basic life-history data required for stock assessments—including size at maturity, growth rate coefficient, and theoretical maximum length—would be collected for common reef species for which that information is not already available (up to ~ 75 species). Working from shore or small boats during Pacific RAMP cruises, CRED staff would collect specimens of species for which life-history parameters are lacking. For each species, CRED staff would collect, measure, and dissect a maximum of 100 individuals across the largest possible range of body sizes. To ensure that specimen collection does not impact local fish populations, CRED staff will impose safeguards in terms of area searched and proportion of estimated population taken. Specifically, life-history collections will take place in no more than 1% of available habitat per island or reef area per 2-year Pacific RAMP survey cycle. Search area will generally be 100 ×100 m (~ 1 ha) or smaller, and available habitat area will be calculated as hard-bottom habitat found only at depths of 0–30 m, information that has already been extracted from bathymetric and habitat layers by CRED staff (for example, Rota in the Mariana Archipelago has 1365 ha of hard-bottom habitat at depths of 0–30 m, Maug in the CNMI has 313 ha, and Swains Island in American Samoa has 180 ha). In addition, prior to collecting a species, CRED staff will calculate local population per island or reef area using existing densities from existing survey data and habitat area calculations. Collections will be limited to species for which an adequate number of samples can be taken (up to 100 fishes) and for which that number is < 0.1% of estimated local population size. Therefore, the CRED will not collect species for which we have insufficient information to estimate local population. As the CRED's primary interest is in providing information for fishery target or trophically or functionally important species, restrictions on collecting locally rare species will preserve the intention of this work while safeguarding local population health.

4.2.3 OPTION C: SELECTION OF BOTH OPTION A AND OPTION B

This option includes the actions involved in both Option A and Option B as well as continuation of the current program. Option C is the preferred option.

The current CRED program uses a suite of standardized methods, including ecological assessments, oceanographic and water-quality measurements, and benthic habitat mapping to improve understanding of the spatial and temporal processes influencing the health of coral reef ecosystems throughout the U.S. Pacific region. In Option A, the CRED is considering expanding its activities to understand the ecological impacts of climate change and ocean acidification on the biological components of coral reef ecosystems and to ultimately predict ecosystem responses to future increases in CO_2. In Option B, the CRED is considering expanding efforts in fish stock assessments to provide information in support of the work of federal fishery management councils to develop acceptable catch limits for reef fish taxa as required by the *Magnuson-Stevens Act*.

5 Affected Environment

A primary objective of the CRED is to promote sound science to improve the understanding of coral reef ecosystems. The scope of the CRED program encompasses all areas with coral reef ecosystems in the Pacific Ocean within the United States, U.S.

territories, and Freely Associated States and includes coral reefs, mangroves, sea-grass beds, and other associated habitats as well as the corals, other benthic invertebrates, algae, and fishes that utilize these habitats. The United States has jurisdiction over an estimated 7607 square miles of coral reefs, not including the Freely Associated States. Thus, the environment potentially affected by the CRED program is quite substantial and includes all coastal habitats in state and territorial waters, offshore habitats within the U.S. exclusive economic zones (EEZ), as well as coastal areas that influence or affect coral reef ecosystems.

5.1 Range of Surveys

The spatial extent of the CRED program is described and potential regions of interest are acknowledged in this section.

5.1.1 ENVIRONMENTS OF CONCERN

The primary affected environment of this PEA includes coral reef environments in the Pacific Ocean under the jurisdiction of the United States, U.S. territories, and U.S.-affiliated islands (Figure 1). This scope includes the following regions:

- Eighteen islands and numerous banks in the Hawaiian Archipelago, including the NWHI, MHI, and Papahānaumokuākea Marine National Monument
- Fourteen islands and numerous banks in the Mariana Archipelago, including Guam, the Commonwealth of the Northern Marianas Islands, and the Marianas Trench Marine National Monument
- Seven islands and numerous banks of American Samoa, including Rose Atoll Marine National Monument
- Seven Islands in the Pacific Remote Islands Area (PRIA), including the unincorporated U.S. possessions of Wake Atoll, Johnston Atoll, Howland Island, Baker Island, Jarvis Island, Palmyra Atoll, and Kingman Reef, including the Pacific Remote Islands Marine National Monument

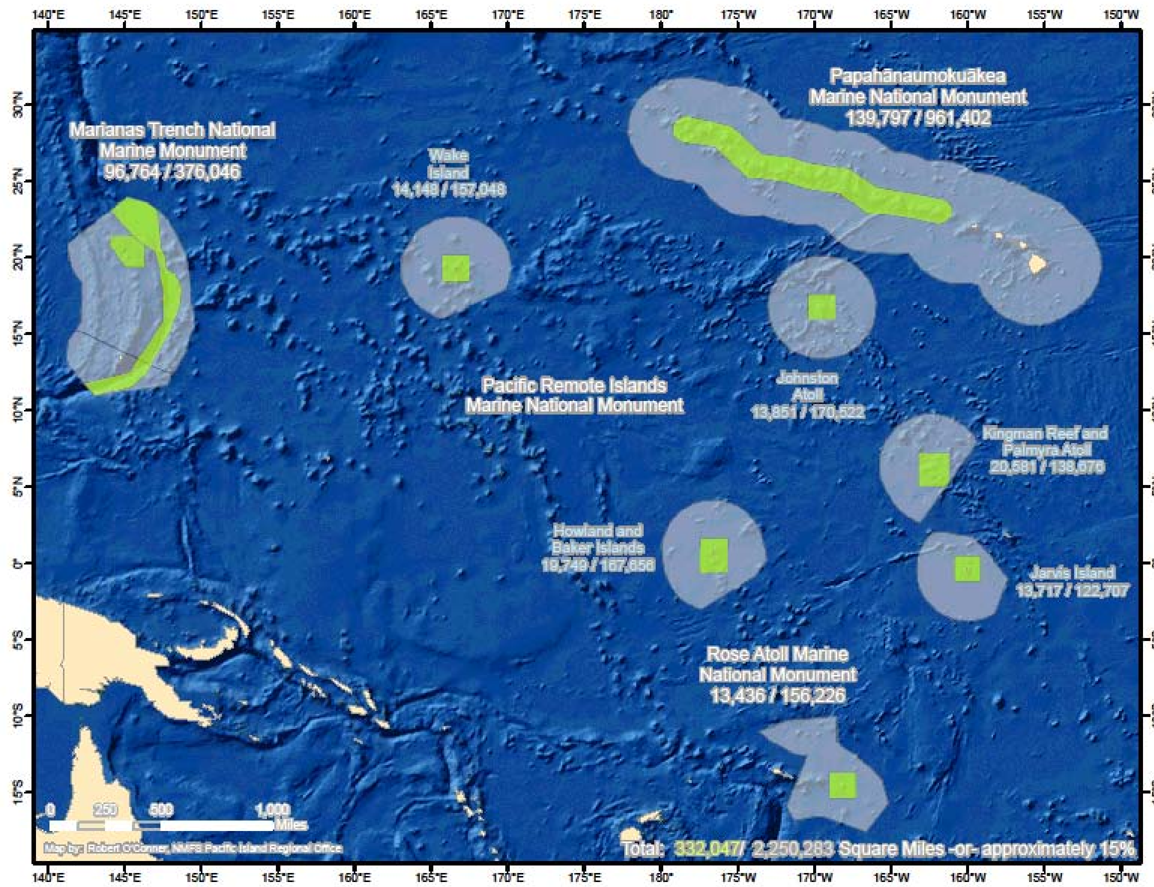

Figure 1: Primary operational area for the CRED in the US-affiliated Pacific Islands including the MHI, NWHI, PRIA, American Samoa, Guam, and the CNMI. Areas highlighted in green the four Marine National Monuments in the area. *Image courtesy of NOAA Fisheries Pacific Islands Regional Office*

5.1.2 POTENTIAL REGIONS OF INTEREST

Because the CRCP, the primary funding body for U.S. coral research, is currently expanding its international scope, it is reasonably foreseeable that CRED activities could be conducted in the waters of other Pacific countries (e.g., Freely Associated States and Australia), in the Coral Triangle (i.e., Indonesia, Malaysia, Papua New Guinea, Solomon Islands, Philippines, and Timor-Leste), in the Caribbean, or elsewhere. These actions could be subject to Executive Order 12114 on environmental effects abroad of major federal actions, which is independent of but furthers the purposes of NEPA. This executive order provides for the development of categorical exclusions but, to date, none have been approved. If the CRED is requested to conduct activities outside U.S. waters and these activities would be the same as the activities described in this PEA, it is highly likely that their impacts could be substantially different than the impacts evaluated in this PEA based on, for example, endangered species, varying oceanic and coral reef conditions, different legal frameworks, and other variables. Therefore, any international actions that have the potential to result in environmental impacts (e.g., actions involving more than the transfer of technical expertise and advice) would require additional analysis in, at a minimum, a supplement to this PEA.

Similarly, any actions in areas of the Caribbean or Gulf of Mexico that are under the jurisdiction of the United States (Puerto Rico and U.S. Virgin Islands), would likely have different impacts given potential differences in endangered species, oceanographic conditions, reef conditions, and fishery management plans per the *Magnuson-Stevens Act*. Thus, although such activities would be subject to compliance with NEPA, these actions would require, at a minimum, a supplement to this PEA.

5.2 Corals, Coral Reefs, and Coral Reef Ecosystems

Coral reefs consist of consolidated limestone or unconsolidated rubble constructed primarily from the skeletal remains of invertebrates and algae. Living corals and other benthic organisms form a thin veneer that overlies a limestone framework deposited over thousands of years by their ancestors and solidified by the cementing process of coralline algae, mechanical action of waves, bioerosion from boring sponges and other organisms, and the chemical action of rainwater. Reef-building scleractinian (hard) corals are the dominant organisms responsible for most of this framework growth, followed by coralline algae on wave-exposed reef slopes, and green algae (e.g., *Halimeda*) in back reef and lagoon depositional zones. Other important organisms contributing sediments to reef structures include mollusks, foraminiferans, and echinoderms.

Corals, as defined by the *Coral Reef Conservation Act*, refers to the species of the phylum Cnidaria:

- All species of the orders Antipatharia (black corals), Scleractinia (hard corals), Gorgonacea (horny corals), Stolonifera (organpipe corals and others), Alcyonacea (soft corals), and Coenothecalia (blue corals) of the class Anthozoa
- All species of the order Hydrocorallina (fire corals and hydrocorals) of the class Hydrozoa

The Cnidaria comprise more than 6000 known species, providing diversity, awe, and beauty known the world over. These soft and stony corals are often single organisms but also form colonies capable of producing massive coral reefs (reefs or shoals composed primarily of corals) that provide numerous benefits.

A coral reef ecosystem is defined by the *Coral Reef Conservation Act* as “coral and other species of reef organisms (including reef plants) associated with coral reefs, and the nonliving environmental factors that directly affect coral reefs, that together function as an ecological unit in nature.” The complexity of such a diverse system, which is subject to adverse perturbations when components of the system are disturbed and to potential rebound if perturbations are minimized, becomes clear when it is examined.

The importance of algae to coral reef ecosystems is staggering: algae form the base of the food chain, occupy much of the available substrate, and help to oxygenate water for animal life to thrive. Additionally, without microscopic symbiotic algae living in healthy coral tissue, most corals would be unable to survive—a scenario that is becoming all too real as coral bleaching events (i.e., processes where stressed corals expel their algal symbiots) become more common.

Although large, fleshy algal forms are the most recognizable floral components on reefs to most divers, tiny turf algae and crustose coralline red algae are also extremely prevalent and play significant roles in ecosystems. Turf algae are the first to colonize vacant substrate and cover essentially every nonliving hard surface on a reef. Turf algae are also among the most important food source for herbivorous fishes and invertebrates. Relatively fast-growing crustose coralline red algae act as glue that cements together loose components of a reef system and serve as a settling surface for larval invertebrates and other algae. Without crustose coralline red algae holding everything together, much of a reef would be washed into deep water or onto shore during heavy winter storms.

Coral reefs are generally found between 30º N and 30º S latitudes across the globe in what has sometimes been referred to as the “fragile ring of life.” While deepwater or cold-water corals exist, the focus of the CRED has been on the coral reefs and associated life forms found in this fragile ring.

Coral reef ecosystems subject to CRED activities are found in the U.S. Pacific Islands. These shallow-water reefs are extensive and include the main and Northwestern Hawaiian Islands, the territories of American Samoa and Guam, the Commonwealth of the Northern Mariana Islands, and 7 remote, unincorporated Pacific island areas (Baker, Howland, Jarvis, and Wake Islands, Johnston and Palmyra Atolls, and Kingman Reef).

5.3 Water Quality

Coral reefs thrive in oligotrophic waters that contain low levels of inorganic nutrients. Pollution enters reef ecosystems in many ways, ranging from specific point-source discharges, such as sewage pipes and vessels, to more diffuse sources, such as runoff associated with agriculture, coastal development, road construction, and golf course irrigation. Although excess nutrients are generally a problem, a continuous supply of inorganic nutrients is essential for the maintenance of metabolic processes, proper functioning of reef ecosystems, and persistence of communities dominated by corals and coralline algae. Many flourishing coral reefs occur in regions subjected to seasonal upwelling or other natural events, such as volcanic eruptions 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 will persist in areas affected by nutrient loading, provided that the herbivores are sufficiently abundant and diverse and are able to control proliferation of macroalgae.

In many locations, terrestrial discharge of nutrients and other pollutants to coastal waters has increased considerably from pre-industrial levels, reflecting increases in human activities in surrounding watersheds. Pollution, including eutrophication and sedimentation associated with land-based activities, has been associated with degradation in water quality and coral reef health and diversity (LaPointe et al. 2000). Some of these sources of pollution include improper coastal development, dredging and beach renourishment, land clearing for agriculture, chemical and oil spills, and discharges of untreated sewage, industrial waste, agrochemicals, and pharmaceuticals.

5.4 Ecological Functions

Coral reefs and their associated ecosystems perform important biological, ecological, and physical functions. 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 structures provide substrates 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 also are broken down into sediments that form beaches and soft-bottom habitats, are incorporated into 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 grazing and dislodgement, turf algae and frondose algae are maintained in an early stage of ecological succession when 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.

Some of the functional roles of coral reefs and associated habitats:

- Complex, high-relief habitat that serves as refuge for motile fishes and invertebrates and microhabitats for cryptic fauna and flora
- Breeding, feeding, and nursery habitats for a great variety of marine species
- Hard substrate for settlement and growth of sessile organisms
- Global biogeochemical cycles, including a storehouse of carbon dioxide
- High productivity based on sunlight and coral-zooxanthellae symbiosis supports a complex food web
- Repository of marine biodiversity and potential source of bioactive substances
- Protection for coastal areas from strong wave action and full impacts of storms
- Natural recorders of past climate and environmental variation

6 Procedures, Permits, and Mitigation to Protect Personnel and Natural Resources

This section identifies the mitigation measures, best management practices, standard operating procedures, and protective measures for minimizing and avoiding adverse impacts to the environment and human health and safety. Also discussed are the permits required to conduct research in various jurisdictions. The guidance or restrictions of each permit is incorporated into the CRED's standard operating procedures to develop a consistent set of best practices that govern all CRED's field activities regardless of where they take place.

6.1 Partners Affiliated with Proposed CRED Research Activities

The PIFSC and CRED have been involved with numerous partners (Appendix B) for consultations, development, and recommendations of the CRED's programs. The CRED has implemented mitigation procedures in coordination with numerous agencies and affiliated management groups since inception of the CRED in order to maintain the objective of coral reef ecosystems monitoring. Through informal consultations, editorial and research support, and other conferences, the CRED is an active participant in assisting other agencies with research, development, and/or operations as applicable. The CRED submits an average of 12 different Research or Conservation and Management permits each year to ensure the proper coverage of its monitoring activities throughout each region. The advancement of various techniques has been an evolving development through strong collaborative efforts with partner agencies, institutions, and individuals. The CRED's monitoring measures are conceived to alleviate adverse operations to any protected species, environments, and species being researched. The CRED continues to encourage collaboration between agencies to reach mutual mission objectives.

6.2 Vessel and Aircraft Operations

Because of the remoteness and inaccessibility of many areas where CRED research takes place, ships and small boats are used for a majority of CRED operations. Aircraft are used in a small subset of CRED operations. NOAA has well established safety and operational procedures for operation of NOAA-owned ships and small boats, diving, and for use of charter vessels. NOAA personnel are required to participate in numerous training activities for shipboard, small boat, and diving activities. In addition, individual jurisdictions add constraints in protected areas that further protect the environment.

Daily research operations involve launching, operating, and recovering 2 to 6 small vessels of lengths between 5 and 10 m. Several multi-diver survey events occur at numerous sites around each surveyed island, shoal, or reef. Typically, the NOAA Ships *Hi`ialakai* or *Oscar Elton Sette* serve as support vessels for berthing, research, storage, and communication for the duration of cruises. Periodic stops at designated harbors occur for refueling and personnel transfer.

During mapping operations, sonar (hull-mounted or deployable) and optical equipment are routinely deployed from the ship or small boats.

6.2.1 NOAA SHIPBOARD OPERATIONS

CRED primarily uses 2 NOAA Ships for its cruises: The NOAA Ship *Hi`ialakai* and the *Oscar Elton Sette*. Both ships operate in similar manners under NOAA operational guidelines. The environmental effects of utilizing either ship as a research platform are analyzed as part of this Proposed Action.

The *Hi`ialakai* has the capability to accommodate 48 people including crew and scientific personnel, while the *Sette* can accommodate 42. In addition to traditional berthing and living spaces, both ships have wet and dry laboratory space, a SCUBA decompression chamber and have the capability to carry and launch 3-5 small boats.

Both ships conduct sustenance fishing operations, defined as "fishing for bottomfish or pelagic species in which all catch is consumed aboard ship, and that is incidental to an activity permitted under this part".

Each ship is dry docked every two years and the bottom and sides are cleaned using a high pressure water system to remove dirt and growth on the hull. The bottom is then repainted with an anti-fouling paint, which is approved by the U.S. Environmental Protection Agency (EPA) and retards marine growth and preserves the bottom surface. The hull is painted with a marine paint for protection in the salt water environment

Both vessels have a USCG type II approved Marine Sanitation Device aboard and a holding tank capable of holding and treating sewage, gray water and other waste generated aboard the ship. The ships are both capable of holding wastewater for approximately two days before the holding tank reaches capacity and grey water must be discharged. For operations within the Papahānaumokuākea Marine National Monument, all sewage would be treated and the grey water retained until the ship is outside of all Special Preservation Area (SPA) boundaries. For operations near island areas, it is routine to transit 3–12 mi offshore to pump tanks.

Both ships are capable of carrying between 200,000–250,000 gal of diesel fuel, 700 gal of gasoline, and up to 11,000 gal of lubrication oil, ten 16-oz cans of WD-40 and 20 gal of an EPA approved solvent. These are kept in designated holding tanks located in the engine room. Used oil is stored in a designated labeled drum until return to port. Excess oils from maintenance and repairs are cleaned up with cloth rags or oil absorbent pads. Used rags are stored in designated, labeled bins until return to port. Waste is retained on board until the ship returns to port for proper disposal.

Although an oil spill at sea is unlikely, the crew would address the spill in accordance with Shipboard Oil Pollution Emergency Plans as approved by the USCG. A Non-Tank Vessel Response Plan has also been submitted to the USCG. In the case of a hazardous material spill, the crew would follow procedures described in the Shipboard Safety Management Manual.

The Shipboard Safety Management Manuals also address solid waste management. Degradable waste that is ground would be discharged overboard at a minimum distance of 3 nmi from SPA boundaries, and degradable waste that is not ground would be discharge at a minimum distance of 12 nmi from SPA boundaries. All plastics are retained on board until the vessel returns to port. Laboratory waste is also retained on board until it can be properly disposed of at home port.

In accordance with USCG safety requirements, fire, abandon ship and man overboard drills are conducted at the required time intervals. All scientific personnel and crew aboard ship are expected to participate in weekly drills. All NOAA employees are also required to take online training or participate in classes on cardiopulmonary resuscitation (CPR), first aid, safety procedures, workplace violence, sexual harassment, or Equal Employment Opportunity (EEO).

Research has been conducted to determine the effect of the types of sonar equipment used aboard the *Hi`ialakai* and the *Sette.* It has been determined that neither the frequencies nor the power levels of these sonar units are of major concern for harm to protected species or the environment (Section 7.6).

Vessel anchoring has the potential to impact the ecosystem depending upon many factors, such as the size of the ship and anchor system, weather conditions, and the location and vicinity of the anchorage relative to sensitive ecosystems (e.g., coral reefs). Anchors and chains can destroy corals and live rock, directly affecting fishes and benthic organisms and their habitats. During routine CRED monitoring operations, neither the *Hi`ialakai* nor the *Sette* would drop anchor within operational areas except in emergency situations. Even in emergency situations, efforts would be made to drop anchor in areas that are relatively free of corals.

6.2.2 CHARTER OPERATIONS

In some instances it is not possible or appropriate to use NOAA vessels for CRED operations, and, therefore, it is necessary to charter ships or small boats. The CRED has used charter vessels or USCG vessels primarily for marine debris removal operations. NOAA requirements and procedures for obtaining vessel charters are described on the Web site of NOAA's Office of Marine and Aviation Operations (OMAO), which also makes available a draft NOAA Administrative Order for vessel acquisition and safety that discusses minimum safety and environmental standards for vessels chartered by NOAA. CRED charter operations will conform to all OMAO guidelines.

During marine debris removal operations, NOAA vessel, USCG vessel, or NOAA-chartered transport vessels conducting field operations often anchor in areas where they will be working for extended periods. All vessels must anchor in areas with low coral cover to minimize impacts at each site before launching small boats for day-to-day operations. Acceptable anchoring sites are also used repeatedly on an annual basis, whenever possible, to minimize damage.

6.2.3 SMALL-BOAT PROCEDURES

The PIFSC has well-established and documented small boat procedures that follow NOAA Small Boat Program guidelines and all small boat operators and coxswains are required to complete the Basic Small Boat Training or advanced small boat coxswain training. All CRED personnel who regularly participate in small boat activities are required to participate in the appropriate training courses. In addition small boat safety discussions are held on a daily basis before small boat operations aboard both the *Hi`ialakai* and *Sette.*

Transit from the open ocean to shallow-reef survey regions (depths of < 35 m) around atolls and islands is often dependent on prevailing weather conditions and regulations. Each team conducts surveys and in-water operations with at least 2 personnel observing for protected species nearby, 1 coxswain in charge of driving the small boat, and 1 additional spotter. Spotters may also work as coxswains, depending on team assignment and boat layout. Spotters and coxswains are tasked with specifically looking out for divers, endangered or protected species, and environmental hazards.

Divers, spotters, and coxswains take every precaution during operations to avoid interactions with any listed species by following the best management practices for boat operations and diving activities as provided by the NOAA Fisheries Pacific Islands Regional Office (PIRO), including but not limited to the following practices:

- Constant vigilance is kept for the presence of federally listed species
- When piloting vessels, vessel operators or coxswains alter course to remain at least 100 yards from whales and at least 50 yards from other marine mammals and sea turtles
- Vessel speed is reduced to 10 kn or less when piloting vessels in the proximity of marine mammals
- Vessel speed is reduced to 5 kn or less when piloting vessels in areas of known or suspected turtle activity
- Marine mammals and sea turtles are not encircled or trapped between multiple vessels or between vessels and the shore whenever possible
- If a vessel is approached by a marine mammal or turtle, the engine is put into neutral and the animal allowed to pass
- Unless specifically covered under a separate permit that allows activity within proximity to protected species, all in-water work is postponed when whales are within 100 yards or other protected species are within 50 yards. Activity recommences only after the animal(s) depart the area
- Should protected species enter the area while in-water work is already in progress, the activity may continue only when that activity has no reasonable expectation to adversely affect the animal(s)
- Attempts are never made to feed, touch, ride, or otherwise intentionally interact with any protected species

6.2.4 DIVE OPERATIONS

CRED personnel and all dive partners aboard NOAA vessels are required to take NOAA Dive Training, either as Scientific or Working Divers or as Divemaster. This dive training is conducted by the NOAA Diving Program and follows well established NOAA diving protocols.

The CRED follows a safe diver practice that limits a diver to 14 days of consecutive diving before a day out of the water must be taken; however, the transit times between islands is often several days and limits the number of dive operations during the cruise.

During CRED diver operations, up to 20 divers may be in the water for 3 to 4 hours per day. The amount of operational field time for each vessel or small boat would be 8 hours per day (180 hours total) for each cruise.

6.2.5 HELICOPTER AND AIRCRAFT OPERATIONS

NOAA aerial survey operations, such as humpback whale aerial surveys in the Hawaiian Archipelago, occur at no less than 800-ft cruising altitude during the September–April peak in humpback whale activity. Helicopter surveys for locating marine debris in the open ocean would follow the same protocol. Pursuant to requirements under 50 C.F.R. 224.103, the helicopter would increase altitude to 1100 ft if either the observer or pilot identifies a humpback whale in the immediate proximity of the helicopter or survey area. Once debris sites are identified, aircraft will reduce altitude to 100–300 ft to collect marine debris data only after thorough and comprehensive visual scans for humpback whales, monk seals, and other protected species are completed by both the NOAA observers and the pilot. In some instances it is necessary for CRED personnel to travel in small aircraft to reach remote areas. All personnel who will use small aircraft are required to complete air safety training conducted by an agency certified by OMAO.

6.3 Threat-specific Procedures

6.3.1 PROCEDURES FOR MINIMIZING THE SPREAD OF DISEASE AND INVASIVE SPECIES

The following actions are routinely required to minimize the spread of diseases to coral reef organisms and spreading invasive species on equipment and vessels..

6.3.1.1 Equipment and Gear

Equipment (e.g., gloves, forceps, shears) in direct contact with potential invasive species, diseased coral tissues, or diseased organisms are soaked in a freshwater 1:32 dilution with commercial bleach for at least 10 min and only a disinfected set of equipment is used at each dive site.

All samples of potentially invasive species, diseased coral tissues, or diseased organisms are collected and sealed in at least 2 of a combination of bags or jars underwater on-site and secured into a holding container until processing.

Dive gear (e.g., wetsuit, mask, fins, snorkel, BC, regulator, weight belt, booties) is disinfected by one of the following ways: a 1:52 dilution of commercial bleach in freshwater, a 3% free chlorine solution, or a manufacturer’s recommended disinfectant-strength dilution of a quaternary ammonium compound in “soft” (low concentration of calcium or magnesium ions) freshwater. Used dive gear is disinfected daily by performing the following steps: (1) physical removal of any organic matter and (2) submersion for a minimum of 10 min in an acceptable disinfection solution, followed by a thorough freshwater rinse and hanging to air dry. All gear in close proximity to the face or skin, such as masks, regulators, and gloves, are additionally rinsed thoroughly with potable water following disinfection.

6.3.1.2 Small Boats

Small boats that have been deployed in the field are cleaned and inspected daily for organic material, including any algal fragments or other organisms. Organic material, if found, is physically removed and disposed of according to the ship's solid-waste disposal protocol or in approved secure holding systems. The internal and external surfaces of vessels are rinsed daily with freshwater and always rinsed between islands before transits. Vessels are allowed to dry before redeployment the following day.

6.3.2 RESPONDING TO CHEMICAL SPILLS

6.3.2.1 Damage to crystalline mercuric chloride ($HgCl_2$) container:

The $HgCl_2$ crystals are stored in an amber, glass, resealable vial, which is stored in either a padded cardboard box or a padded, metal, 750-mL storage cylinder. The saturated (liquid) solution of $HgCl_2$ is typically prepared in advance of the cruise, and no crystalline form of the material is brought on board or into the field.

6.3.2.2 Spill of liquid $HgCl_2$ solution:

If solutions are spilled onto skin or clothes, staff members immediately flush their skin or eyes with plenty of water for at least 15 min, remove contaminated clothing and shoes, and get medical attention immediately. Staff members always wear safety gear during cleanup and select appropriate cleanup equipment, since anything that comes in contact with the solution would be considered contaminated. The quantities of $HgCl_2$ are so small that using 3 dampened paper towels to wipe the contaminated area thoroughly 3 times would be sufficient to mitigate any potential impact. Any spilled $HgCl_2$ and $HgCl_2$-contaminated items are disposed of in a plastic bag labeled "$HgCl_2$ Contaminated" and given to an appropriate hazardous waste disposal representative upon return to port.

6.3.3 PROCEDURES FOR REDUCING THREATS DUE TO MONITORING ACTIVITIES

Monitoring is conducted in shallow (< 35 m) water utilizing scuba gear. Research dives focus on the goal of data collection for research and monitoring purposes. Usually monitoring activities are conducted from small boats.

- The anchor is used on sand or rubble substrate to minimize disturbance of sensitive benthic areas and prevent coral damage. The anchor is always lowered rather than thrown overboard, and a diver checks the anchor to make sure it does not drag or entangle listed species.
- The operational area is continuously monitored for protected species, with dive surveys being altered, postponed, or canceled and small boats being put on standby or in neutral or relocating to minimize disturbances or interactions.
- To further avoid interactions with listed species during surveys and operations, team members and small boat coxswains monitor areas while in transit to and from work sites. If a listed species is sighted, the vessel alters course in the opposite direction. If unable to change course, the vessel is slowed or stopped

until the animal is clear of the boat, as long as diver, coxswain, and passenger safety are not compromised.

- Protected species monitoring continues throughout all dive operations by at least one team member aboard each boat and 2 divers working underwater.
- Mechanical equipment, such as PAM float lines, transect lines, or stabilization lines for oceanographic equipment, is monitored to ensure no accidental entanglements occur with protected species.
- Team members immediately respond to an entangled animal, halting operations and providing on-site assessment and an appropriate response. This response could include allowing the animal to disentangle itself or assisting with disentanglement unless doing so would put divers, coxswains, or other staff at risk of injury.
- Before approaching any shorelines or exposed reefs, all observers examine the beach, shoreline, reef areas, and any other visible land areas within the line of sight for marine mammals and sea turtles. The monitoring teams typically do not participate in terrestrial surveys/operations as part of their responsibilities, which minimizes the potential for disturbance of resting protected animals along shorelines.
- The CRED follows all federal, state, and local laws pertaining to marine mammal, sea turtle, seabird, and other resources protected by the ESA and *Marine Mammal Protection Act* when completing occasional requests for assistance with terrestrial surveys, such as nonnative plant surveys and vegetation surveys.
- The humphead wrasse (*Cheilinus undulatusi*) and the green bumphead parrotfish (*Bolbometopon muricatums*) are considered species of concern by the CRED because they are on the Red List of the International Union for Conservation of Nature and Natural Resources (IUCN) and are of great importance to the health of coral reef ecosystems. NMFS received a petition to list the Bumphead parrotfish as endangered in Dec. 2009 and a positive finding was posted in the Federal Register in April 2010. These species have been traditionally overfished by local fishers because they are large, easily caught, and considered a local delicacy. During all CRED activities, these species are only observed and recorded, and they are never collected, harassed, or sampled. Exact locations of these species are not released to avoid contributing further to overfishing.

6.3.4 ADDITIONAL PROCEDURES FOR PROTECTING PROTECTED SPECIES DURING COLLECTION OF MARINE DEBRIS

The following mitigating procedures were recommended by NOAA’s Protected Resources Division in the concurrences to the Biological Evaluations prepared by the CRED and will be followed during CRED activities for marine debris removal operations (Section 4.1.3.1, “Methods for Locating and Removing Marine Debris,” and Appendix A, Section A.3.).

- Avoid seabird nesting colonies
- Avoid marine turtles and Hawaiian monk seals, maintaining a minimum distance of 50 yards from all monk seals and turtles, and a minimum distance of 100 yards from female seals with pups

- Only disinfected equipment and gear are transported between the cruise point of origin to destination and return. Protocols are carefully followed to avoid transport of diseased or invasive materials between sites
- Decontamination of clothing and soft gear to be taken ashore must be conducted by freezing materials for 48 hours or by the use of new clothing or soft gear as indicated by U.S. Fish and Wildlife Service regulations and guidelines

6.4 Permit and Authorization Requirements

Any CRED action conducted within the land and waters in the jurisdictions of any marine protected area, marine national monument, or other action area managed by state and local agencies must be conducted under established scientific research and collection permits issued by the responsible managing agencies.

The permits and authorizations required by the current or expanded CRED program include those permits discussed in the remainder of this section.

Research in All U.S. Waters to 3 nmi: Research that involves placing equipment on the seafloor or in the water column that could affect navigation requires a permit from the U.S. Army Corps of Engineers.

Research in the MHI: Research in MHI state waters requires Federal Consistency Review of all projects by the Hawai`i Coastal Zone Management Program of the Hawai`i Department of Business, Economic Development, and Tourism.

Research in MHI state waters that collects aquatic life may necessitate the following permits:

- <u>Special Activity Permit</u>: required for any research, educational, management, or research institution to collect aquatic life or to use certain fishing gear or methods, that are prohibited or restricted by regulations. A Special Activity Permit, for example, is required for anyone conducting sea turtle research in the state of Hawai`i. Reports usually required as a condition of permit. No fee. HRS 187A-6.
- <u>Special Permit</u>: issued to exempt persons from various regulations in Marine Life Conservation Districts, Fishery Management Areas, or Public Fishing Areas. Reports and fees may be required.
- <u>Aquarium Permit</u>: required for any person to use fine-mesh net for collecting aquatic life for an aquarium. Report required if commercial. No fee. HRS 188-31.

Research that affects humpback whales requires no entry permit for the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS). However, researchers must follow regulations on distance from whales, discharging into HIHWNMS waters, and other requirements.

Research in the NWHI and Pacific Remote Island Areas: All activities within the Papahānaumokuākea Marine National Monument require a permit and must be categorized under one of 6 permit types: research, education, conservation and management, Native Hawaiian practice, special ocean use and recreational (Midway only).

Research to be conducted in waters to a depth of 10 fm around Nīhoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes, Palmyra, Johnston, Rose, Kingman, Baker, Jarvis, and Howland require the following permits:

- Federal: Special use permit required for entry to and any research in the Pacific/Remote Islands National Wildlife Refuge Complex area.
- American Samoa: Access to Rose Atoll is regulated by American Samoa with regulations that parallel federal regulations (i.e., special use permit required)

Research in American Samoa: Research in territorial waters of American Samoa requires following permits for these described activities:

- Federal Consistency Review of all projects by the American Samoa Coastal Management Program.
- Scientific collection permit to undertake any of a number of prohibited marine activities. Note that use of scuba to take marine organisms is prohibited. Also, annually, the government issues a proclamation that articulates restricted fishing areas and other fishing restrictions.

Research in Fagatele Bay, Tutuila, and American Samoa requires the following permits:

- Federal: No Sanctuary entry permit required. Sanctuary has regulations on allowable marine activities; researchers can obtain NOS permits to conduct activities that are otherwise prohibited (e.g., gathering corals, sea turtle take).
- American Samoa: this territory's regulations parallel federal regulations (i.e., no entry permit but special activity permits required if an exemption to regulations are sought).

Research in the waters of the National Park of American Samoa, National Park Service, around Tutuila, Ta`u, Ofu, and Olosega requires online scientific permit application.

Research in CNMI Waters: Research in CNMI waters requires the following permits for these described activities:

- Scientific collection permit to undertake any of a number of prohibited marine activities. Note that use of scuba to take marine organisms is prohibited
- Scientific research permit to conduct marine or terrestrial research

Research in Managaha Marine Sanctuary, Bird Island Marine Sanctuary, Forbidden Island Marine Sanctuary, Lighthouse Reef Trochus Reserve, Lau Lau Bay Sea Cucumber Reserve (all off Saipan), as well as research in Susanhaya Bay (off Rota)—all designated "no take" zones, requires a scientific collection permit to take any species in these areas. No entry permit required.

Research in Guam Waters: Research in Guam territorial waters requires the following permits for these described activities:

- Scientific collection permit to undertake any of a number of prohibited marine activities. Note that use of scuba to take marine organisms is prohibited.
- Federal Consistency Review of all projects by the Guam Coastal Management Program

In Tumon Bay, Piti Bomb Holes, Sasa Bay, Achang Reef Flat, and Pati Point Marine Preserves, trolling for pelagic fishes is allowed. In Pati Point Marine Preserve, hook-and-line fishing also is allowed. At Tumon Bay Marine Preserve, some bottom fishing, shorecasting, and cast netting also are allowed.

7 Evaluation of Environmental Consequences

The activities in the current research program (Alternative 1, no action) and the activities in the proposed expansions of this program (Alternative 2, Option A: Expanding Assessment of Ocean Acidification, Option B: Expanding Fish Sampling for Contributions to Fisheries Management, or Option C, a combination of Options A and B) contribute to the monitoring and assessment of coral reef ecosystems within areas under U.S. jurisdiction in the Pacific. Therefore, this section evaluates potential biological impacts from these activities on protected marine species and species of concern, physical impacts to the seabed and coral reef environments, chemical impacts on reef biota, and impacts of actions on traditional cultural values in Hawai`i, American Samoa, and the Mariana Archipleago.

As the proposed actions expand current CRED activities, the following impact analyses apply to both Alternative 1 and Options A, B and C of Alternative 2 as specified in the analyses. Option C is a combination of Options A and B. Option A expands the CRED program to include an assessment of ocean acidification, and Option B expands the program to include fish sampling for contributions to fisheries management. These activities are entirely different with no common factors. They will be conducted by the same field staff that is already conducting the current program, and, thus, there is unlikely to be a confluence of effects by choosing to conduct both sets of activities instead of only Option A or Option B.

7.1 Potential Impacts on Threatened and Endangered Species: Biological Evaluations

The PIFSC filed 3 Biological Evaluations (BE) for activities under Section 7 of the ESA, as amended, through the Protected Resources Division (PRD) of the PIRO, seeking consultation for the CRED to conduct the following activities:

- Pacific RAMP and benthic habitat mapping throughout the Hawaiian Archipelago in 2009 and 2010.
- Marine debris removal operations in the NWHI from 2008 to 2010.
- Pacific RAMP and benthic habitat mapping throughout the U.S.-affiliated Pacific Basin from 2009 to 2014.

As described in the BEs, the Pacific RAMP, marine debris removal, and mapping cruises support NMFS PIFSC ecosystem research, habitat mapping, and long-term monitoring of coral reef ecosystems. PRD provided letters concurring with the conclusions found in the BEs.

7.1.1 PACIFIC RAMP BIOLOGICAL EVALUATION AND NMFS PRD CONCURRENCE 2009–2010 (HAWAIIAN ARCHIPELAGO) AND 2009–2014 (U.S.-AFFILIATED PACIFIC ISLANDS)

The species evaluated in the BEs include the Hawaiian monk seal (*Monachus schauinslandi*, endangered), humpback whale (*Megaptera novaeangliae*, endangered), green sea turtle (*Chelonia mydas*, threatened), hawksbill sea turtle (*Eretmochelys imbricate*, endangered), sperm whales (*Sphyseter macrocephalus*, endangered), leatherback sea turtles (*Dermochelys imbricate*, endangered), olive ridley sea turtles (*Lepidochelys olivacea*, threatened), blue whales (*Balaenoptera musculus*, endangered), fin whales (*Balaenoptera physalus*, endangered), and sei whales (*Balaenoptera borealis*, endangered).

The Pacific RAMP BE determined that the monitoring activities are not likely to adversely affect, impose no incidental take, or have no effect at all on the animals present in survey areas, based on the following considerations:

- Pacific RAMP teams have observed green and hawksbill sea turtles during underwater transects, small-boat operations, and surveying and have had no interactions, zero mortality, or incidental takes over the last 10 years.
- The presence of cetaceans in nearshore coastal areas is typically low. The chance sighting of a whale during standard surveys is highly unlikely, since all operations are conducted in shallow waters outside the average range of the whale. There has never been a recorded sighting of a cetacean or pelagic sea turtle by Pacific RAMP personnel either while working in shallow water or in transit to the various islands.
- Vessel strikes are a possible threat for whales but have never occurred with any protected marine species by either the support or small vessels of the Pacific RAMP.
- Noise disturbance is minimal as cleaner, quieter, 4-stroke engines are used on most small boats. The use of jet-driven engines reduces the risk of propeller strikes.

The NOAA PRD concurrence letter made the following observations:

- Currently, there are no known strikes or incidental takes of a listed protected species from a vessel or propeller of a Pacific RAMP vessel in the NWHI or other surveyed areas around the Pacific.
- We do not expect any adverse behavioral changes from disturbances that would affect feeding, breeding, resting, etc.
- The Pacific RAMP teams typically do not participate during terrestrial surveys or operations as part of their mandate and, therefore, minimize the potential for disturbances of resting animals along shorelines.

The NOAA PRD concluded:

- **Disturbance from humans and vessel operation:** We expect that disturbances related to this action will be infrequent and non-injurious, resulting in insignificant impacts on the sea turtles and whales covered by this consultation.
- **Collision with vessels:** Based on the expectation that vessels will be operated as described and the expected low density of sea turtles and whales in the pelagic

environment where the research vessels' speeds are expected to be greatest, we consider the risk of collisions between action-related vessels and protected species to be discountable.

- **Exposure to wastes and discharges:** Exposure to vessel wastes from this action will likely have insignificant effects on marine species listed under the ESA.

Therefore, NMFS PRD concurred with the determination that the Pacific RAMP activities are not likely to adversely affect ESA-listed marine species or their designated critical habitat. This concurrence is based on the finding that the effects of the proposed actions are expected to be insignificant, discountable, or beneficial as defined in the *Endangered Species Consultation Handbook*, produced jointly by the USFWS and NMFS (1998), NMFS File No. (PCTS): I/PIR/2009/00682 PIRO Reference No.: I-PI-08-741-LVA.

NMFS concurs with the determination that Pacific RAMP and related activities fall under the category of coral reef assessment/monitoring and habitat mapping and characterization, and therefore are considered covered under the programmatic consultation that was issued for CRED activities conducted in the Hawaiian Archipelago: NMFS File No. (PCTS): P/PIR/2008/02296 PIRO Reference No. I-PI-08-687-CY.

7.1.2 MARINE DEBRIS REMOVAL OPERATIONS IN THE NWHI 2008–2010 BIOLOGICAL EVALUATION AND NMFS PRD CONCURRENCE

The species evaluated in this BE include the Hawaiian monk seal, humpback whale, green sea turtle, hawksbill sea turtle, and sperm whales.

The marine debris removal BE stated that marine debris removal operations would have no effect on listed marine species, including cetaceans and sea turtles, and would impose no incidental take on any listed species. They may affect but are not likely to adversely affect the endangered Hawaiian monk seal and its designated critical habitat, based on the following considerations:

- The CRED debris teams have observed Hawaiian monk seals and green and hawksbill sea turtles and have had few interactions, zero mortality, or incidental takes over the last 10 years. Despite the possibilities of disturbances resulting in interactions, the occurrence with in-water surveys and operations is expected to be low, of short duration, and insignificant. This determination is based on the longest average hours spent in the NWHI each year for debris teams (over 7000 hours over 120 days). There are no expected adverse behavioral changes from disturbances that would affect feeding, breeding, resting, etc.
- The presence of humpback whales around Hawaiian coastal waters is typically low during the summer to early fall months during which the cruises are typically conducted.
- There has never been a recorded sighting of either a humpback whale or a sperm whale by marine debris personnel, either while working within shallow reef waters or while in transit to the support vessels in open water or in transit within the Hawaiian Archipelago. Vessel strikes are a possible threat for whales but have never occurred with any protected species by either the support or small vessels of the CRED marine debris project.

- Noise disturbance is minimal as cleaner, quieter, 4-stroke engines are used on the small boats.

NMFS concurred that there is potential for some temporary disturbance to listed species, such as the Hawaiian monk seal or green sea turtle, from activities of removing derelict fishing gear and marine debris, but any disturbances are considered insignificant, discountable, or beneficial within the Hawaiian Archipelago:

"Debris removal reduces exposure potential and susceptibility of entanglement, ingestion to ESA-listed marine species or damage to coral reef habitats. Proposed actions may cause disturbance yet it provides a net effect of beneficial outcomes to the ESA-listed marine species and habitat; aids in removal of navigational hazards; and involves the removal of potential vectors for invasive species and other threats to near-pristine habitats."

NMFS concurred with the determination that coral reef assessment, monitoring, habitat mapping and characterization, and marine debris removal within the Hawaiian Archipelago is not likely to adversely affect the Hawaiian monk seal or critical habitat (NMFS File No (PCTS): P/PIR/2008/02296, PIRO Reference No. I-PI-08-675-CY).

NOAA PRD requires that consultation would be reinitiated if one of the following actions occurred:

- An incidental take of a listed species occurs
- New information reveals that actions may affect listed species or designated critical habitat in a manner or to an extent not previously considered
- The identified action is subsequently modified in a manner causing effects to listed species or designated critical habitat not previously considered
- A new species is listed or critical habitat designated that may be affected by the identified action

In May 1988, the NMFS designated critical habitat for the Hawaiian monk seal from shore to 20 fm in 10 areas of the NWHI. No other critical habitat is designated or proposed for an ESA-listed marine species in the central or western Pacific. There would be no adverse impact to Hawaiian monk seal critical habitat.

7.2 Potential Impacts to Species of Concern or Species Currently Petitioned under the ESA

The humphead wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) are at times observed by CRED divers. Both species are on the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List. IUCN is the world's main authority on the conservation status of species. The IUCN Red List is determined by precise criteria to evaluate the extinction risk of thousands of species and subspecies. On December 31, 2009, a petition to list the bumphead parrotfish as endangered was received by the NMFS, and a positive find was issued in April 2010; a Status Review is currently underway to determine the status of the bumphead parrotfish. All observations of these 2 fish species by CRED staff are documented with little to no disturbance of the species. No individuals are ever taken and exact locations of observations are not released to the general public.

The Hawaiian reef coral (*Montipora dilatata*) is a species of coral endemic to the Hawaiian Archipelago and is only found in Kaneohe Bay, Oahu, Hawai`i, and in the NWHI at Midway Atoll, Pearl and Hermes Atoll, Lisianski Island, Laysan Island, Maro Reef, and French Frigate Shoals. This species is observed by divers and documented during standard research dives. Since this species is in decline because of a varied number of threats, a tissue sample of a diseased coral would be collected if possible, using procedures described in Appendix A, Section A.1.4, "Assessment Methods for Corals and Coral Disease," to better understand the potential causes. In no case would a sample be collected if it is judged that doing so might inhibit the capacity of the taxon to replenish itself at the site.

In October 2009, the NMFS received a petition to list 83 species of coral under the ESA, 75 of which occur in the Pacific. A positive finding was published in February 2010 and a Status Review of these species is currently underway. In so far as possible, the proposed species will be observed by CRED divers and documented during standard Pacific RAMP dives. In no case would a sample be collected if it is judged that doing so might inhibit the capacity of the taxon to replenish itself at the site.

The inarticulated brachiopod (*Lingula reevii*) is a rare brachiopod species only known to occur in shallow, sandy reef flats in Kaneohe Bay, Oahu, Hawai`i. If CRED divers encounter these brachiopods on surveys, they will be photographed and observations will be documented. No other disturbance would occur.

Therefore, there would be no adverse impacts to species of concern identified here.

7.3 Physical Effects of Moorings, Pins, and Cable Ties on the Seabed and Corals

The CRED conducts a wide variety of observations on or near the seabed. Some are made directly by divers, while others are taken by automated instruments that are deployed by divers or other means and then retrieved at a later time. At depths greater than that at which divers can effectively work, observations are made using subsurface vehicles equipped with cameras and other instruments. For each activity, protocols have been developed to minimize the impact to the habitat under observation. Those activities with the potential for causing an adverse impact to the seabed include the following activities:

- Placement of temporary or permanent markers that identify a specific location
- Placement of a weight or other type of anchor to secure an instrument to the sea floor or to tether an instrument so that it can be positioned in the water column or at the sea surface
- Anchoring of a boat used to support divers and equipment
- Operation of a subsurface vehicle near the seabed

To allow divers to repeatedly visit a specific location for consistent data collection, permanent markers must be placed on or near the seabed. Two types of markers are used: steel pins or plastic cable ties. The most permanent of these pins are composed of stainless steel rods that are either driven into the seabed by divers using hand-held hammers or inserted into a hole in the seabed created by divers using a pneumatic drill. The pins are located in hard substrate to avoid damaging coral colonies. Pins or eye bolt anchors are installed into drilled holes are held in place by an epoxy adhesive. Large (36 × 0.5 in), black cable ties are often used instead of pins. They are strapped to porous benthic structures, so that they are secure yet do not impact any organism on the seabed and they provide a readily identifiable visual cue to divers. Small floats are also used to identify a location. These floats are held in place by cable ties (1–2 ft long) that are again strapped to the instrument or the seabed. All markers are inspected by divers on each biennial visit and replaced or refurbished as needed. If warranted, the steel pins or cable ties can be completely removed.

A variety of sensors are installed by divers and left to collect information until they can be recovered at a later date. Most sensors are held in place by anchors composed of concrete or metal. Anchor blocks fabricated from metal are encapsulated by a thick layer of polyurethane (e.g., Rhino Liner) or polyvinyl chloride (PVC). A common metal used in anchor blocks is lead, because of its high density. These anchors weigh between 5 and 1200 lb and their maximum footprint on the seabed is 3 × 4 ft. Divers place the anchors on the seabed where they will not damage corals or other fragile structures. Anchors weighing more than a few pounds are lowered using lift bags so they can be precisely located on the seabed. These diver-installed anchors are used to support instruments that are part of a long-term monitoring program. As such they are inspected each time instruments are recovered and replaced, and the anchors are replaced if needed.

Some instruments, such as ARMS, are held in place by pins and anchors. Up to 4 stainless steel pins are installed and the instrument is strapped to the pins with cable ties. The pins are used to support instruments that are part of a long-term monitoring program. As such, they are inspected each time instruments are recovered and replaced, and the pins are replaced if it is worn or if the protective coating shows signs of decay.

Many of the monitoring instruments are strapped to anchors on the seabed, but others are buoyed and float on the surface or are suspended in the water column. These moorings are tethered to anchors with a floating line and subsurface buoys. These moorings are designed so that the line does not damage the nearby seabed or pose an entanglement risk to endangered species, such as monk seals or turtles. Tethers are replaced when the associated instruments are replaced.

A few instruments, such as the BotCam, are placed in deep water beyond the reach of divers. Depending on the type of BotCam survey operation, the anchors for these instruments may or may not be retrieved, and are designed to minimize their impact on the bottom habitat. Anchors which will not be recovered are composed of concrete that has been selected to mimic the structure of the habitat and to decompose without significant impact. As with the shallow-water anchors, the footprint of the BotCam anchors on the seabed is minimal, less than 3 × 4 ft. Because divers cannot precisely place these anchors, they are deployed in bottom environments that have been acoustically characterized as being hard and sloping but not rough and, thus, not likely to be inhabited by coral communities that might be damaged by the anchor.

The divers conducting CRED activities are transported from the ship to their work areas using small boats. These boats are equipped with ground tackle (the anchors and chain or line used to anchor the boat) required for the safety of the boat and those onboard. Whenever possible, the boat operator keeps the engine on to keep the boat on station while divers are in the water without anchoring. If the boat must be anchored, divers place the anchor carefully on the seabed so as not to damage the habitat. The ground tackle is designed so the majority of the anchor line is above the bottom to prevent damage.

In depths greater than divers can routinely operate, subsurface vehicles are used to observe the bottom habitat. These include autonomous underwater vehicles (AUVs), which are programmed to follow a course of action, remotely operated vehicles (ROVs) and towed camera sleds that are tethered to the ship (or boat) and are under the active control of ship-based observers. The AUV used by the CRED is programmed to follow a predetermined track, operates at low speeds (< 1 m/s) and maintains a constant distance off the seabed. If for some reason the AUV strikes the seabed, it does so at such an insignificant speed that it minimizes any potential damage. Observers using ROVs and towed camera sleds monitor the vehicles during their deployment. An ROV can hover above the seabed and allow the operator to control the height off the seabed using thrusters. When using a towed camera sled, the operator can maintain the sled’s height above the seabed by controlling the amount of tether deployed from the ship. Operators using ROVs and towed camera sleds are trained to maintain the vehicle above the seabed without striking the seabed and thus minimize any potential damage to the habitat.

7.4 Potential Impact Caused by Epoxy Adhesives and Other Supplemental Anchoring Systems

Construction epoxies are high-strength anchoring adhesives used for a broad range of applications and conditions and are designed to bond to various building elements. The epoxies are 2-component systems that include injection adhesives in plastic cartridges or 2-part putties that are mixed prior to application. These adhesives are designed for bonding threaded rod and reinforcing bar hardware into holes in concrete base materials. The CRED would only use an epoxy to reinforce a stainless steel stake that is loose rather than placing a new stake into the substrate in a new position. Stakes function as geo-referenced transect markers or attachment points for moored instruments that prevent the instruments from moving on the substrate; thus, it is necessary to have strong, fixed positions. The epoxies are separate pastes in contained tubes, combined on site with specialized mixing tubes that dispense only the amount required. The water insoluble mixture is specifically designed for underwater application and can be applied quickly and carefully without disturbing the surrounding area. The amount of epoxy used is variable for the sites; however, only a minimal amount is required per stake. The impact to the adjacent environment is negligible.

7.5 Potential Impacts of Chemicals Used in CRED Activities

This section discusses the potential impacts to coral reef ecosystems and their components from chemicals used in CRED activities.

7.5.1 POTENTIAL IMPACTS OF MERCURIC CHLORIDE

The CRED has clear and careful protocols for handling $HgCl_2$ that make the chance that it would enter the environment during operations very unlikely (Section 6.3.2, "Responding to Chemical Spills"). Only micro liters of this biological fixing agent are required per sample. Only small containers of this material are utilized in the field, minimizing quantities of potential spills. Dilution and mixing in the ocean seawater would quickly result in undetectable concentration levels. The use of $HgCl_2$ as a fixing agent for water samples, particularly in DIC sampling, is a standard and widespread method in the field of chemical oceanography.

7.5.2 POTENTIAL IMPACTS FROM THE USE OF CLOVE OIL AS AN ANESTHETIC FOR FISHES

Ecological research within coral reefs often requires the use of anesthetics to immobilize or euthanize individual fishes for collecting specimens. For years, cyanide was used as an anesthetic to capture fishes, but it has been shown to have detrimental effects to the surrounding environment. Clove oil has recently been utilized in research as a better alternative to cyanide (Erdmann 1999). Clove oil is distilled from *Eugenia caryophyllata* stems, buds, and leaves, and the active ingredients are phenol derivatives. In Indonesia, it has been used on humans for centuries as a local anesthetic (Soto and Burhanuddin 1995), and it has also been used in dentistry as a temporary nerve block. Clove oil has been used for a number of years to anesthetize fishes in seawater, and, in fish farming, it is routinely used on individual fishes for performing basic procedures such as weighing, tagging, experimental work, and transport.

CRED researchers use clove oil on an infrequent basis to collect fishes that are potentially new to science or considered a part of a geographic range extension. In both cases, specimens are required to validate assumptions. Once scientists determine that specimens must be collected, hand nets are used in conjunction with clove oil to target individual fish. Clove oil is dispersed by a diver via a 1000-mL dosing bottle. Specific concentrations vary; however, clove oil is mixed with ethanol (10:1) in order to disperse the anesthetic effectively. Once dispersed underwater, clove oil has an effective range of 0.3–0.6 m^2 in waters with no current, and it begins to take effect after about 25 s after dispersal. The mean level of clove oil concentration in the water is negligible at $< 0.0008\%$ (Boyer 2009). Therefore, use of small quantities targeted at an individual fish in the dynamic conditions of shallow ocean waters would have a negligible potential for impacts on any other organisms other than the individual target fish. Once a specimen is collected, it is brought back to the lab to be photographed and preserved for further identification or validation.

7.5.3 POTENTIAL IMPACTS CAUSED BY THE ANTIFOULING PAINT TRILUX 33

The CRED uses Trilux 33, an approved, tin-free antifouling agent formulated to provide safe, effective protection for marine surfaces. It is based on the latest Biolux® technology for improved control of slime and algal growth. The paint is used on sensitive instruments deployed by the CRED where surfaces and small orifices must remain free of slime and algal growth. The surface area of an instrument coated with Trilux 33 is less than 5 × 10 cm, and the anti-fouling agent is placed on less than 50 instruments per year. These instruments are typically placed at different sites often hundreds of miles apart. Because of the small amount of paint being used per instrument, the extremely low potential that the agent would be used on several instruments in the same area, and the limited number of instruments being deployed, the impact on any particular coral reef ecosystem or organism other than algae growing on the treated instrument surface is negligible.

7.5.4 POTENTIAL IMPACTS CAUSED BY THE ANTI-CORROSION MARINE LUBRICANT AQUA SHIELD

AquaShield (formerly Aqua Lube) is a high-performance, multipurpose, petroleum-based lubricant and sealant that is compounded specifically to cling to metal and other surfaces. It provides long-term lubrication and prevents corrosion or rust. It is designed to seal out water and contaminants. Aqua Shield is particularly effective on bearings, water pumps, O-rings, gaskets, water filters, motors, and valves that must operate in hot or cold water, seam, pool chemicals, or salt water. The CRED uses Aqua Shield for moving metal parts (nuts and bolts) involved with moorings to prevent seizing and allow for functional use of the part during instrument replacement. Aqua Shield does not degrade in salt water, nor has it been found to release any chemical reagents into the surrounding water. CRED staff wear personal protection equipment such as gloves and eye protection when applying minimal amounts of the lubricant to threads of bolts aboard the support vessel before deploying instruments. Instruments collected after deployment are typically recovered with the same amount of Aqua Shield as when deployed years prior. Currently no ecological testing has occurred on this product, but, as very small amounts (< 1 oz) in any series of deployments are used, the impact on any particular coral reef ecosystem or organism has been determined to be negligible.

7.6 Potential Impacts to Reef Organisms from the Operation of Sonar

NOAA, including the CRED program, relies on underwater sound generated by sonar equipment for mapping and other assessments. A variety of sonar equipment is used to navigate safely in coastal waters and to collect data about the physical properties of the water column, the size and abundance of organisms that live in the water, and the structure and composition of the seabed. The PIFSC conducts research aboard the NOAA Ships *Oscar Elton Sette* and *Hi`ialakai*, PIFSC-owned survey launch R/V *AHI*, and several chartered commercial vessels as needed.

The sonar equipment used aboard the *Sette* and the *Hi`ialakai* include navigation echosounders and commercial fisheries echosounders, both of which are used for safety of navigation; an ADCP, used to measure ocean currents and how they change as a function of depth; and scientific echosounders, which quantitatively measure the biomass of fishes and other organisms that inhabit the water directly beneath the vessel.

In addition, the *Hi`ialakai* has two multibeam echosounders used to develop high-resolution maps of the seabed in support of benthic habitat mapping in waters at depths of 40–1000 m. The sonar used on the R/V *AHI* includes a navigation echosounder for safety of navigation and a multibeam echosounder to perform benthic habitat mapping in depths of 20–200 m. The charter vessels use standard commercial navigation and fisheries echosounders.

The sound of active (transmitting) sonar, such as those sonar used by the CRED program, has several major characteristics:

- **Source level or strength of the sound:** determines how loud the sound is and may be the primary indicator of the effect a sound may have on an organism
- **Frequency of the sound or how rapidly the sound waves vibrate:** determines whether the sound is within the audible range of an organism and how far the sound propagates from its source
- **Pulse width of the sound, or how long the sound is generated (duration), and pulse repetition rate, or how frequently the sound is repeated:** measures how long the sound is present in the water and how often it is generated
- **Directivity of the sound or how sound waves are focused on their target:** measures how efficiently the sound is used to achieve its purpose

Each of these characteristics is important in assessing the effect that individual sonar may have on the environment. The tables and narrative in Appendix 2, Section A.2, “Methods for Conducting Mapping,” summarize these characteristics for the sonar used in PIFSC research.

The sonar equipment used by the CRED program operates at frequencies of 12–300 kHz. As such, they are classified as high-frequency sonar (ICES 2005) and are not fundamentally different from sonar used by most recreational boats, fishing vessels, and commercial ships for navigation. The sonar operated by the CRED program performs at relatively low power and are typically directed at the water column or the seabed directly beneath the vessel. The more powerful sonar are highly directive, focusing more than 99.9% of their energy directly beneath the vessel with almost no energy directed outward. In addition, most of the frequencies used are highly attenuated by their transmission through water. Most transmit for very brief periods of time, spending most of their operating cycle passively receiving the ping response, which provides the required data.

It can be reasonably assumed, therefore, that cetaceans, sea turtles, and pinnipeds would not be adversely affected, and no adverse effects have been noted. While the acoustic signature of PIFSC research vessels undoubtedly does add to the ambient noise of the area in which they operate, their signatures are typical of many commercial vessels and would be inconsequential to marine mammal and sea turtle populations (Southall 2005).

7.7 Cultural Roles of Coral Reefs

Island and coastal communities in the U.S. Pacific region are intricately connected with the coral reef ecosystems that surround them. Much of the mythology, legends, and customs of native islanders encompass the surrounding marine environment as crucial components of life. Local coral reef resources provide food, cultural activities, subsistence, and revenue through artisanal, recreational, and commercial fisheries. Historically, the native people of the Pacific islands have had a strong cultural and economic dependence on the marine environment. For example, traditional Hawaiian fishery management activities centered on strictly enforced social and cultural controls on fishing. These fishery management activities were based on time and area closures to keep fisheries from disturbing natural processes (reproduction) and habitats of important food resources. Recently, the cultural focus has been reinforced when the state of Hawai`i supported the development of community-based subsistence fisheries areas in a few communities. Fisheries management plans have been prepared by these communities and are based on integrating traditional observational methods and modern scientific techniques. Traditional fishing activities are used to restore community values and stewardship while revitalizing a locally sanctioned code of fishing conduct.

Ancient Hawaiians developed a special relationship with the land and sea, which provided them with sustenance and recreation, molded their cultural values, and cultivated their deep sensitivity and respect for their environment. Fishing, gathering of ocean algae (*limu*), and subsistence use of ocean resources have been a traditional way of life for native Hawaiians. Fishes also provided the primary source of protein in the Hawaiian diet. The strict enforcement of traditional *kapu* system (forbidden or taboo) was an effective control to prevent overharvesting of ocean resources. *Kuleana* (responsibility), which interweaves honor and duty, describes the approach to Hawaiian resource management, and reinforces the idea of resource stewardship as opposed to resource management (Hawai`i Department of Business, Economic Development, and Toursim 2006).

The longest recorded traditional Hawaiian chant, the *Kumulipo* (source of deep darkness) is a history of how all life forms came and evolved, beginning with the coral polyp—the building block of all life. This creation chant tells the story of Native Hawaiians' ancestral connection with the gods who created the coral polyps, the Northwestern Hawaiian Islands, which are seen as *kūpuna* (or respected elders), and everything else in the Hawaiian Archipelago, including Native Hawaiians. The symbolism of the union of earth mother, Papahānaumoku, and sky father, Wākea, is the foundation for the name of the Papahānaumokuākea Marine National Monument (Papahānaumokuākea Marine National Monument 2008).

Historic fishing methods in American Samoa were documented in a 2008 PIFSC report (Herdrich and Armstrong 2008). Throughout the Samoan islands, common fishing techniques included gleaning, diving, rod and line, netting and trapping (including communal fish drives), and boat fishing, but there were slight differences in practices according to particular village rules and techniques related to the habits of marine resources. The village has been, and remains, an important organizing unit in Samoan society (Keesing 1934), and the village customarily controlled the usage rights to a lagoon and its produce. While individual and family fishing occurred on an almost daily basis, there were times when the village organized a communal drive for certain fish or when men fished outside the lagoons under the leadership of a fishing expert, a *tautai*. There were rules that certain fish were to be given to the chiefs, and restrictions were occasionally made regarding the lagoon and its produce. All of these practices were, in essence, under the control of the village and its decision-making body, the village *fono*.

The first people to arrive in the Mariana Archipelago about 3500 years ago were skilled fishermen. The aboriginal culture of Guam and the CNMI was based on fishing, agriculture, and gathering. A 2008 PIFSC report and a 1989 Western Pacific Regional Fishery Management Council report (Allen and Bartram 2008; Amesbury et al. 1989) describe the dependence on and engagement in fishing activities of the people of Guam and the CNMI, respectively, throughout history. Prior to the arrival of Europeans in the Mariana Archipelago, the indigenous Chamorro people possessed large sailing canoes, *proas*, which they used for fishing on offshore banks. A noble caste of deep-sea fishermen and interisland traders within Chamorro communities, the *matua*, monopolized the manufacture of these canoes. Over the centuries of acculturation, beginning with the Spanish conquest in the late 17th century, many elements of traditional Chamorro culture were lost. Despite dramatic changes in marine resources and ecosystems, human populations, and food sources, many of the indigenous people of Guam and the CNMI and their immigrant communities continue to depend on fishing and locally caught seafood to reinforce and perpetuate cultural traditions such as community sharing of food. Although fishing has made and continues to make economic contributions to these territories, the sociocultural influences of fishing are far deeper.

The CRED research program recognizes the importance of coral reefs as the basis of much of the biodiversity of the oceans and is committed to assessing and monitoring the conditions and health of Pacific reefs, improving reef health by collecting and removing underwater marine debris that damage reefs, and supporting the cultural traditions by providing science-based information on the status of natural resources. All CRED staff members entering the Papahānaumokuākea Marine National Monument attend a Hawaiian cultural briefing to raise awareness and sensitivity for an environmentally and culturally essential ecosystem.

7.8 Potential Cumulative Effects of CRED Activities

The Council on Environmental Quality (CEQ) defines cumulative effects as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions” (40 CFR 1508.7).

The CRED actions proposed in this EA will have a less than significant impact on the environment, both on an individual and cumulative basis. Past monitoring, assessment, and mapping of coral reef ecosystems and targeted marine debris removal in the Pacific have resulted in only short-term, temporary, localized, minor adverse effects on the environment. The removal of marine debris will have a small but long-term beneficial effect on the environment. Given that the proposed actions are located in remote areas, many with federally protected status, the potential for other adverse impacts, by people other than CRED, is small. Recurring research and monitoring activities conducted by CRED since 2001 have not identified any cumulative impacts within the scope of analysis. Furthermore, a number of new techniques and measures have been developed by CRED, in collaboration with partner agencies and affiliated management groups, to mitigate impacts on the environment.

The following measures will be implemented to avoid and minimize future adverse environmental impacts within the scope of analysis:

- Sites for actions that have potential ground-disturbing effects, such as anchoring boats, mooring equipment, or placing cable ties, are carefully selected using sandy or rubble substrate that would have no or minimal adverse impacts on sensitive resources (Section 7.3, "Physical Effects of Moorings, Pins, and Cable Ties on the Seabed and Corals").
- Markers for the beginnings of long-term transects are implemented so as to have as few changes as possible over the intended 25 years of monitoring (Section 7.3).
- Collecting specimens is limited to only the amount needed and would only be done if it is clear that taking specimens would have no adverse effect on populations (Section 3, "Description of Alternatives," and Appendix A). NOAA Protected Resources Division has concurred.
- Collecting marine debris that is submerged or found in intertidal zones is done carefully according to procedures designed to be minimally invasive and mitigate impact on marine environments and particularly on protected species (Section 4.1.3, "Activities, Methods, and Protocols Involved in Collecting and Removing Marine Debris;" Appendix A.3, "Methods for Locating and Removing Marine Debris;" and Section 6.3.4, "Additional Procedures for Protecting Protected Species during Collection of Marine Debris"). NOAA Protected Resources Division has concurred that the Marine Debris Program, with implementation of the identified standard operation procedures, would not have adverse effects on species protected by the ESA (Section 7.1.2).
- No other research or other actions that could potentially contribute to cumulative impacts when added to the CRED activities within protected marine national monuments would occur.
- In areas outside of the monuments, where actions are not controlled, CRED activities are intended to be sufficiently non-invasive to avoid adding to existing impacts, such as impacts caused by local fishing in the nearshore environment
- Use of chemicals during sampling would be conducted so as to ensure that contamination of the environment would not occur (Section 6.3.2, "Responding to Chemical Spills").

7.9 Potential Impacts of CRED Activities on Global Climate Change

As identified in Section 2.1.2.4, "Climate Change and Ocean Acidification," of this PEA, global ocean climate fluctuations are a direct threat to tropical coral reef ecosystems. Rises in sea levels could adversely affect coral reef ecosystems, and increased ocean temperatures and acidification have been identified as definite threats. Therefore, it is critical that the CRED and other NOAA programs minimize their carbon footprint as much as is possible. Traveling over vast expanses of the Pacific requires the use of fossil fuels for vessels, but travel is carefully conducted to support clear scientific objectives. Any change in circumstances or knowledge that would have environmental relevance would require additional analysis and appropriate management changes that might be integrated into the CRED program as appropriate.

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Appendix A. Detailed Descriptions of CRED Activities for Monitoring and Mapping

A.1 Methods and Protocols for Monitoring Coral Reef Ecosystems

The components of coral reef ecosystems monitored include algae and algal disease, corals and coral disease, invertebrates, fishes, and the physical and chemical composition of the ocean bathymetry.

A.1.1 RAPID ECOLOGICAL ASSESSMENTS

Rapid Ecological Assessment (REA) methods provide an efficient yet effective and repeatable means to quickly yet accurately characterize the key components of coral reef ecosystems. The same transects are used for many of the REA monitoring methods, minimizing bottom disturbance. The use of fixed, geo-referenced markers is intended to enable researchers to return to exact locations on subsequent visits so as to reduce imprecision in deploying transect lines and resurveying a site on subsequent visits, enhancing statistical power.

At each REA site, 3 temporary 25-m transects using removable line are laid out by divers and are the focal point for the algae, coral, invertebrate, and fish surveys. Divers swim over these lines and assess the benthic elements falling at fixed intervals along the transect lines. These transect lines are used in surveys using the line-point-intercept method, belt-transect method, and photoquadrat method. During line-point-intercept surveys, benthic elements are classified into categories that include live corals, recent dead corals, carbonate pavement, coral rubble, sand, rock, turf algae, macroalgae, invertebrates, and other. At REA sites, in conjunction with belt-transect fish surveys, divers conduct stationary-point-count surveys.

Manual installation of durable transect markers at REA sites occurs at the beginning of each transect on hard dead substrate, away from living corals. These transect markers consist of cable ties (1 m long) or a combination of cable ties and stainless steel shield eye-bolt anchors (7–10 cm long). Historically, stainless steel stakes measuring 36 ×3/8 in are hammered into the substrate. These stakes have been used successfully with no signs of corrosion over several years of observation. For ease of deployment, however, stakes will be replaced when appropriate with cable ties. At sites where the bottom offers the appropriate topographic complexity, at least 2–5 cable ties are secured to benthic features to create something that looks unnatural from the surrounding area so that the markers can be easily and repeatedly found by divers. In areas with less porous substrates, a stainless steel shield eye-bolt anchor is secured to a crack in the pavement or rock, and cable ties are attached for easy visibility. The bond between the eye-bolt anchor and the bottom may need to be secured by adding a small amount of underwater epoxy using an underwater epoxy applicator. All other equipment (hammers, epoxy applicators, transect tapes) are removed from the reef at the completion of each survey.

A.1.2 TOWED-DIVER SURVEYS

Shallow-water habitats around each island, bank, or reef are surveyed using pairs of divers towed 60 m behind a 19-ft launch targeting the 15–16-m benthic contours. In each towed-diver team, one diver quantifies the benthos while looking down and the other quantifies fish populations while looking ahead and up. Each towed-diver survey lasts 50 min, broken into ten 5-min segments, covering ~ 2 km. GPS position of the survey launch track is recorded at 5-s intervals using a Garmin GPS76Map GPS unit. A custom algorithm is used to calculate the track of the divers based on the track, speed, and course of the boat and depth of the diver. Each towboard is equipped with a precision temperature and depth recorder (Sea-Bird Electronics Inc. SBE 39), which records these data at 5-s intervals. At the end of each day, data are downloaded, processed, and presented in ArcGIS, creating data that can be displayed in conjunction with IKONOS satellite imagery, NOAA chart data or other spatial data layers.

The benthic towboard is equipped with a downward-pointing, high-resolution digital still camera with dual strobes, which have been found to disturb fishes to a lesser degree than does constant lighting. This still camera is held 1–2 m off the bottom and is programmed to photograph benthic substrate every 15 s. The diver on the benthic towboard observes and records habitat composition (hard corals, stressed hard, soft corals, macroalgae, coralline algae, sand, and rubble) and tallies conspicuous macroinvertebrates, such as crown-of-thorns seastars (*Acanthaster planci*, COTS), sea urchins, sea cucumbers, and giant clams along a 10-m swath.

The fish towboard is equipped with a forward-pointing digital video camera that creates a visual archive of the survey track and can be used to evaluate changes in the reef environment, particularly following episodic events such as coral bleaching and vessel grounding.

A.1.3 ASSESSMENT METHODS FOR ALGAE

Specimens are collected by hand. Working at depths of 3–16 m, a line-point-intercept method for algal assessment minimizes the time in the water yet yields the greatest amount of data possible. Additionally, a high-resolution digital camera mounted on a 0.18-m² photoquadrat frame is used to quantitatively assess benthic marine substrates to create permanent historical records of each site.

Line-point-intercept Surveys: Macroalgal species, algal functional group, or substrate type are recorded at 20-cm intervals along two 25-m transect lines on a sheet of waterproof paper. Algal species inventories and percentage of cover are generated from data collected at each REA site.

Photoquadrat Surveys: To standardize and abbreviate note taking, relative abundance of macroalgae in each quadrat is recorded on a waterproof data sheet that includes space for recording the species found in the quadrat, a “map” area for identifying cryptic species in depressions (which may prove difficult to identify in computer analysis), and codes for the most common genera and species of macroalgae, corals, invertebrates, and substrate types. Two trained divers move along transects together, with one diver taking notes and the other diver placing the quadrat frame, operating the camera, and taking photos at predetermined random points. After a photograph is taken by the first diver, the second diver identifies algae within the photoquadrat, records the relative abundance of the 5 most abundant algae on a scale of 1 to 5 (with 1 being most abundant), draws a quadrat map locating species that may be hard to identify in a photograph, and collects representative samples of the algal species in the quadrat for later identification in the laboratory. Once data are recorded, the photoquadrat is moved to the next random point, and the procedure repeated. To prevent redundancy and minimize impact to the environment, in subsequent quadrats only samples of algal species not observed in previous quadrats are collected. A random swim at the end of the dive is used to collect specimens not present within photoquadrats.

Belt-transect Surveys for Algal Disease: densities of cases of coralline-algal disease are quantitatively assessed along two 25-m belt transects. Cases of 3 types of algal disease are recorded: coralline lethal orange disease, white band syndrome, or coralline cyanobacterial disease.

Towed-diver Surveys: Benthic towed-diver surveys provide data on habitat composition that is used to provide estimates of percentages of cover of macroalgae and algal functional groups.

A.1.4 ASSESSMENT METHODS FOR CORALS AND CORAL DISEASE

At each REA site, two of three 25-m transects laid out by the fish team are the focal point for the coral surveys.

Line-point-intercept Surveys: A single diver swims over the transect lines and assesses the benthic elements falling at fixed 20-cm intervals along each transect line. Each benthic element is tallied and recorded under characterizations that include live corals and recent dead corals. Corals are identified to the lowest taxonomic level possible. These data provide the basis for quantitative estimates of live coral cover.

Belt-transect Surveys: Within each of the 2 transects, five 2.5-m segments are surveyed (beginning points at 0, 5, 10, 15, and 20 m), and, within each segment, all coral colonies whose center falls within 0.5 m of either side of the transect line are identified to the species level and 2 planar size metrics recorded: maximum diameter and diameter perpendicular to the maximum diameter. The extent of colony mortality, both recent and old, is also estimated for each colony, with special attention paid to estimating, as best as possible, the extent of the former live colony.

In addition, cases of disease or compromised health are recoded and additional information collected, including type of affliction (bleaching, skeletal growth anomaly, white syndrome, subacute tissue loss, band diseases, necroses, pigmentation responses, algal and fungal infections, other diseases of unknown etiology, and predation) and severity of the affliction (mild, moderate, marked, severe, acute). Photographic documentation and tissue samples necessary for further identification may be collected as described in the next paragraph. Onboard the research vessel, coral tissue samples are catalogued and fixed in buffered zinc-formalin or the appropriate solution for further histopathological, molecular, or laboratory analyses.

Specimen Collection: Because a particular type of gross lesion can present multiple microscopic manifestations, coral assessments and studies sometimes require collection of biopsies or samples for histological (microscopic), microbiological, or molecular studies and verification. Hence, divers collect samples that represent each species or taxon and disease of interest, including tissue loss, skeletal growth anomalies, tissue necrosis, band diseases, and pigmentation responses, discolorations, and fungal infections. To provide for sufficient diseased and healthy tissue within each sample, collected coral tissue samples have maximum diameters of 7 cm. Additionally, opportunistic sampling of any potentially new diseases observed at the sites may be conducted. In no case are specimens collected if it is judged that doing so might inhibit the capacity of the taxon to replenish itself at the site. In the field, coral tissue samples are carefully collected using cutting pliers or hammer and chisel. Samples are placed in labeled specimen bags containing seawater and stored in a dark container. Aboard the ship, coral tissue samples are fixed in the appropriate solution and transported to Honolulu. Waste fixative solutions are stored on board for appropriate chemical disposal in Honolulu. In collaboration with scientists at different academic and governmental institutions, coral sample processing is conducted. Any residual tissue samples are subsequently deposited with an appropriate institution such as the Bishop Museum in Honolulu.

Towed-diver Surveys: Divers record habitat composition, including hard corals, stressed hard corals, and soft corals along a 10-m survey swath. These data are used to estimate percentages of cover of live and stressed corals.

Collection of Corals for Computerized Axial Tomography (CAT) Scan: The collection of coral cores and branch samples are used for comparisons of coral calcification rates. Colonies of *Porites* spp. with massive growth forms have the greatest potential to provide long growth histories and will be targeted for collection of coral cores using a small, hand-held pneumatic drill operated from a scuba tank. Branches of colonies of *Pocillopora* spp. will be collected to examine calcification rates in more rapidly growing species that are common components of many Pacific reefs. Each core will be collected from a single colony of sufficient size and health such that extracting a core 2.5 cm in width and 5–10 cm in length is judged not to be destructive or detrimental to the longevity of a colony. The hole will be filled with a small cement plug over which adjacent coral tissues can infill.

A.1.5 ASSESSMENT METHODS FOR INVERTEBRATES

Belt-transect Surveys: Surveys for non-coral marine invertebrates are conducted quantitatively along 3 separate 25-m transect lines. After the completion of the 3 transects, a roving swim is conducted associated with the original transects to collect qualitative data for rare and cryptic organisms and to survey any additional habitats present at the site but not along the transect line, such as sand, sea grass, and reef crests. Additional collections of organisms unable to be identified at the site are taken aboard for careful identification. Population size structure data are collected on urchins, and sand and sediment samples for organisms living within the substrates may also be collected and examined on board.

Towed-diver Surveys: Benthic towed-diver surveys provide data on habitat composition that is used to provide estimates of densities of 4 types of macroinvertebrates: giant clams, COTS, sea cucumbers, and sea urchins.

Specimen Collections for Determining Species Presence: Specimens of organisms that cannot be identified in the field are collected and brought back to the research vessel for further analysis. Organisms that are identified at the research vessel are returned to the field the same or the next day. Species that cannot be identified are preserved in ethanol, formalin, or frozen for further analysis at the University of Guam, University of Hawai`i, or the Bishop Museum in Honolulu. The analysis at these institutions involves the use of taxonomic literature to make tentative identifications, and specimens are subsequently sent to national and international experts for confirmation of these identifications. These findings and the field identifications are provided to the appropriate agency representatives sponsoring the expedition in the form of a final report and species list. Specimens are made available to researchers throughout the world through access to catalogued collections.

Autonomous Reef Monitoring Structures (ARMS): ARMS are typically deployed in close relation to REA sites. An ARMS device is a small long-term collecting device designed to mimic the structural complexity of a coral reef and is intended to attract colonizing invertebrates over the 1–3 deployment periods. Each of the ARMS measures 14 × 18 × 8 in and contains 9 layers (each 9 × 9 in) for colonization. ARMS are made of non-caustic PVC type 1 plastic and consist of layers that alternate between open surfaces and semi-closed surfaces containing triangular-shaped colonization sites. The top layer is a convoluted filter layer designed to provide a multitude of colonization sites and a large ratio of surface area to volume. The ARMS are placed by CRED divers on sites identified during REA surveys consisting of pavement or sand in proximity to coral reef structures specifically to avoid coral damage using stainless steel stakes and weights to insure that they remain in place for the duration of the deployment period. A global positioning system (GPS) waypoint is taken for each of the ARMS after deployment to record the location for documentation and so that the equipment can be readily found and retrieved. The CRED is responsible for maintaining and removing the ARMS during a follow-up cruise or in conjunction with local agencies and partners for data collection and analysis.

A.1.6 ASSESSMENT METHODS FOR FISHES

Several complementary noninvasive underwater surveys are used to enumerate the diverse components of diurnally active shallow-water reef fish assemblages. Each method is replicated at sites within or among the various habitat types present around each island or bank. Fish length-class is estimated for all quantified fishes to provide an estimate of numerical size structure and biomass densities by taxa.

Random Swims: To document simple species presence at an REA site, reef, or bank, a pair of divers conducts a random swim throughout the selected site, recording the presence of fishes visually encountered by species or lowest recognizable taxon. This protocol is typically used at deeper, time-limited sites or where current is too strong to conduct transects. Random swims also are used following completion of a belt-transect or stationary-point-count (SPC) survey, dive time permitting. These data complement the other visual protocols to assemble more complete reef-and archipelago-specific inventories of fish species at each island or bank.

New Stationary-point-count (nSPC) Surveys: These are intended as an all purpose survey approach suitable for diurnal and non-cryptic coral reef fishes. A pair of divers records the species, size, and number of all fishes observed within adjacent, visually-estimated cylinders (each 15 m in diameter, with an area of ~ 177 m^2) in 2 components: (1) an initial 5-min period, in which each diver records all fish species present within their cylinder; and (2) an enumeration period, in which each diver records the number and size of all fishes of the species listed during the intial 5-min component. At different times, survey pairs will conduct either 1 or 2 nSPC pairs per survey dive. After completing the fish counts, the dive pair may conduct a photographic survey of the reef benthos within the nSPC cylinders, by taking up to 30 planar photographs along a transect line running directly through the area that has just been surveyed for fishes.

Belt-transect Surveys: These surveys are used mainly to quantify relatively small-bodied and abundant fishes. A pair of divers conduct parallel swims along three 25-m transect lines, recording size-class-specific (total length [TL]) counts of all fishes encountered and idenfitication of fishes to species-level where possible, within visually estimated but defined belt widths. These belt widths are 4 m wide for fishes > 20 cm in TL (100 m^2 area) on the initial swim-out, and 2 m wide for fishes < 20 cm in TL (50 m^2 area) on the subsequent swim back. Transect lines are typically set at depths of 10–15 m. Reef ledges and holes are visually searched. Stations are completed on all sides of the island or atoll, weather and sea conditions permitting.

Stationary-point-count (SPC) Surveys: These counts are used to quantify relatively large (> 25 cm in TL) and more agile fish species. One SPC diver conducts surveys in conjunction with but at least 10 m away from the 2 belt-transect divers. All fishes > 25 cm in TL entering a cylinder (20 m in diameter, with an area of ~ 314 m^2) during a timed 5-min count are recorded to species level. Individuals or groups are classified into size classes, based on TL to the nearest 5 cm. At each REA site, 4 replicate, 5-min cylinder counts are conducted. Care is taken to avoid overcounting large transient or schooling species.

Towed-diver Surveys: The fish towboard is equipped with a forward-looking digital video camera which creates a visual archive of the survey track and can be used to evaluate changes in the reef environment, particularly following episodic events such as coral bleaching and vessel grounding. The diver on the fish towboard records (to the lowest possible taxon) all fishes greater than 50 cm in total length along a 10-m survey swath in each time segment. Fishes are recorded in terms of species and length in centimeters. Species of particular concern observed outside the survey swath are classified as presence/absence data and are recorded separately from the quantitative swath data.

Specimen Collections for Life Histories: the CRED intends to collect a maximum of 100 specimens from the entire size range of up to 80 non-threatened or endangered reef fish species. These specimens are collected opportunistically using spears or a spear gun between monitoring dives throughout the various research sites within the Pacific. Only the minimum numbers of specimens necessary for analysis within each size range are collected. The specimens are brought back for measurements pertaining to their life history (e.g., age, weight, and length). The resulting information is provided to local authorities and federal management agencies and will be used to support the management of coral reef fish stocks in U.S. Pacific waters.

Specimen Collections of Undocumented Species: Rarely, if a reef fish is encountered that appears to be an undocumented species or an individual of notable significance, CRED divers collect a few whole specimens of that fish species. The collection occurs after photographic evidence provides confirmation by fish biologists, who recommend collection of specimens. The fishes are caught using small nets, euthanized quickly with clove oil (an over-the-counter analgesic and antiseptic), frozen, and transported to a zoological institution for further examination.

A.1.7 ASSESSMENT METHODS FOR OCEANOGRAPHIC CHARACTERIZATION

Knowledge of oceanographic processes is essential for understanding and monitoring coral reef ecosystem health. Ocean circulation often determines the abundance, types, and diversity of species within a particular local ecosystem, as well as determining where marine debris accumulates and how it may impact a particular reef ecosystem. Local changes in seawater temperature and chemistry can have drastic effects on coral health, and episodic storms and other high-energy events can radically change these ecosystems in a very short time. To assess these impacts, the CRED has implemented a program that combines various monitoring platforms to measure and record ocean temperatures, salinity, wind and wave energy, tides, currents, ambient noise levels, and solar radiation. The seafloor instruments are deployed on sites intended for use for at least 25 years. Individual instruments are recovered for data collection every 2–3 years and replaced with new instruments to continue the time series.

A.1.7.1 Instruments Moored on the Seafloor

Deployments involve lift bags and NOAA-certified divers lowering instruments attached to a weight onto substrates determined to be locations where instrument placement would be environmentally benign.

Water Movement Instrumentation: Wave-and-tide recorders (WTRs), acoustic Doppler current profilers (ADCPs), and salinity sensors collect information on water velocity, water level, and movement of salinity through waves and the water column. These types of instruments are similar in size and shape and deployed in a similar fashion. The weight used for deployments of these instruments is typically a 300-lb anchor block measuring 32 × 9 × 3 in. However, larger anchors may be used at sites with high wave energy. The ADCPs operate at the following frequencies: SonTek/YSI, 500 KHz–1 MHz; Nortek, 1 MHz; and Aanderaa Data Instruments, 2 MHz.

Ecological Acoustic Recorder (EAR) Units: This equipment passively collects information on natural and anthropogenic ocean sounds and was developed specifically for monitoring sounds made by fishes, invertebrates, and human activity in marine habitats. EAR units are attached to weights and deployed by divers on the seafloor on a site where deployment will not damage sensitive benthic organisms. The weight used for this operation is the same as for the water movement instrumentation above.

Subsurface Temperature Recorders (STR): These instruments are used to construct a time series of water temperature data at various locations on a reef. The instrument is a cylinder that is 9 in long with a 2-in diameter and is attached and secured to the seafloor using a 5-lb weight and nylon fasteners. All fasteners are replaced or removed when the instrument is replaced.

Sea-surface Temperature (SST) Buoys: These buoys are < 21 in in diameter and moored to the substrate using a removable 250-lb anchor block measuring 18 × 18 × 5 in to anchor the buoy. Floating-line and subsurface in-line floats are used so that no anchor chain is required and no line drags along the seafloor. These buoys provide high-resolution data sets of SST that are transmitted daily via satellite telemetry.

Coral Reef Early Warning System (CREWS) Buoys: These moored buoys provide high-resolution SST, barometric pressure, wind speed, and wind direction. Enhanced versions additionally provide salinity, UV-B ultraviolet light, and photosynthetically available radiation. Subsets of these data are transmitted daily via satellite telemetry. The CREWS buoy has a diameter of 4 ft and is deployed in shallow water (< 50 ft deep) and typically moored to a ~ 1200-lb anchor block measuring 18 × 18 × 18 in.

Subsurface Ocean Data Platform (ODP): These platforms, equipped with a SonTek/YSI ADP acoustic Doppler current profiler and Sea-Bird Electronics Inc. SBE 37 MicroCAT conductivity and temperature recorder, are deployed on the bottom by divers and provide high-resolution current profiles, directional wave spectra, and temperature and salinity. The ODP and its mooring measures 44 × 36 × 24 in and weighs 1300 lb.

A.1.7.2 Instruments Not Moored on the Ocean Floor

BotCam: This instrument is a remote stereo-video camera system designed to sample the distribution, relative abundance, and size composition of deepwater (100–300 m) fishes and associated biological and physical characteristics of their habitat. This system, coupled with a standard method to analyze the collected video data, provides a cost-effective and non-extractive method to assess the relative abundance and size composition of fish populations in deepwater habitats. The station is deployed with a weight that holds the camera at depth while an arm with bait attached attracts bottomfish species into the camera frame for up to 60 min. Starting in 2009, the standard operating procedure is to recover the BotCam and anchor weight after each deployment. In the event of unforeseen circumstances; however, an acoustic release can be triggered and allows the positively buoyant station to detach from the weight and return to the surface. (This arrangement is similar to certain manned submersibles, where, in an emergency, a ballast weight can be released and the sub will float back to the surface.) A BotCam unit can be redeployed multiple times per day during a survey.

Conductivity, Temperature, and Depth (CTD) Casts: These instruments are used to collect information about the vertical salinity and temperature structure of the water column. The deepwater CTD cast is conducted from NOAA research vessels down to 500 m and is capable of collecting several water samples. These casts are mechanically conducted at historical deepwater sites but may be used at shallower levels (but never <

50 m from the substrate) where unique ocean circulation or activities occur. The shallow-water CTD casts are conducted by handline from small boats from depths of 1–30 m in association with deployed instrumentation, REA, and water sampling sites. A CTD is occasionally handled by divers above the substrate instead of lowered by line.

Oceanographic Water Sampling: Grab samples are taken using 4 Niskin bottles, 4 messengers, and deployment rope (~ 35 m long) at depth from a small boat for analysis of basic water properties, chlorophyll-*a*, nutrients, microbiology, and, in some cases, carbonate chemistry. The standard sampling depths are 1, 10, 20, and 30 m, and the seawater collected within each Niskin bottle is subsampled and collected in uniquely labeled bottles for post-cruise nutrient and salinity analyses. Chlorophyll-*a* samples are filtered through micro-glass filters, sealed, and frozen. All processed water is disposed of through the ship's marine sanitation device.

Dissolved Inorganic Carbon (DIC) Sampling: The goal of measuring and monitoring seawater carbonate chemistry in the coral reef ecosystems is to understand the consequences of the ocean acidification processes on the biological community and to ultimately predict coral reef ecosystem response to future increases in carbon dioxide (CO_2). Methods for assessing and monitoring seawater carbonate chemistry include measuring in situ temperature, salinity, DIC concentrations, and total alkalinity over a range of spatial and temporal scales, augmented with reference measurements of nearby offshore waters. Only seawater samples, ranging from 250 to 1000 mL, are collected. As a rough order-of-magnitude approximation, a few hundred water samples are collected during a typical cruise. The water samples will be fixed on site with mercuric chloride ($HgCl_2$), sealed, and sent to the appropriate labs for analysis. All equipment used in these processes are stored and disposed of within the appropriate containment units.

Microbiological Water Sampling: Diver-deployable Niskin bottles are used to collect 20 L of seawater (4 bottles with 5 L per bottle) at each study site. These samples are collected at 10-m depths and transported back to the vessel.

Microscopy: 1 mL of water from each sample are fixed with para formaldehyde, stained with the dsDNA staining SYBR-Gold, and filtered onto 0.02 Ano disc. The number of microbes, viruses, and other microorganisms are counted using a portable microscope. Filters are stored at -20ºC for archival purposes.

Water Chemistry: Water samples are pushed through GF/F glass filters and the filtrate collected in glass bottles. Hydrochloric acid is added to each bottle to remove DIC and the bottles frozen at -20ºC. These samples are analyzed for dissolved organic carbon at San Diego State University. The GF/F filters will be stored at -20ºC and analyzed for particulate organic carbon concentration and stable isotopes of carbon and nitrogen at San Diego State University.

To culture common bacteria found in coastal waters (*Vibrio* spp.), 1 mL from each Niskin bottle is spread onto Thiosulfate-citrate-bile-salts-sucrose (TCBS) agar plates, which are then incubated at room temperature and the number of *Vibrio* spp. counted after 24 hours. The plates are sterilized by autoclaving on board.

Archive Microbial DNA Samples: The rest of the water in each Niskin bottle is pushed through a 0.2 micron Stervix filter, which is stored at -20ºC until the DNA can be isolated at San Diego State University.

A.2 Methods for Conducting Mapping

Multibeam mapping is conducted using the PIFSC-owned survey launch R/V *Acoustic Habitat Investigator (AHI)* and the NOAA Ships *Hi`ialakai* and *Oscar Elton Sette*, both of which are capable of collecting data that meets the requirements developed by the International Hydrographic Organization (IHO) and described in *IHO Standards for Hydrographic Surveys*, Special Publication No. 44. The *AHI* can survey in depths of 5–200 m. Working together, the *AHI* collects data in shallower areas and the *Hi`ialakai* and *Oscar Elton Sette* survey depths > 40 m that are well away from potentially dangerous shoals. The *AHI* operates only during daylight hours, but shipboard mapping on the *Hi`ialakai* and *Oscar Elton Sette* can be done both during the day and night as other operations permit.

The *Hi`ialakai* is equipped with 2 multibeam echosounders, a Kongsberg EM300 and an EM3002D. The *AHI* is equipped with a 240-kHz Reson SeaBat 8101 ER multibeam echosounder. The *Oscar Elton Sette* can be temporarily outfitted with the *AHI's* Reson 8101 ER multibeam echosounder. The SeaBED AUV, which is described later in this section, also can be equipped with a multibeam echosounder.

Table A1. Sonar characteristics of the NOAA Ships *Oscar Elton Sette* and *Hi`ialakai*.

Sonar description	**Max. power (kW)**	**Frequency (kHz)**	**Pulse width (ms)**	**Pulse repetition rate (times/s)**	**Directivity (degrees)**
Navigation	~ 2	24	~ 10	0.5 to 20	~ 30
Navigation Echosounder (Simrad ES60)	2 2 1	12 38 (*Sette* only) 200 (*Sette* only)	16 4 1	0.1 to 10 0.5 to 20 6 to 30	~ 15 7 7
ADCP	1	75	1	4	30 per beam
Scientific Biomass (Simrad EK60)	2 2	38 200	4 1	0.5 to 20 6 to 30	7 7
Kongsberg Simrad EM3002D (*Hi`ialakai* only)	~ 1	300	0.15	6 to 30	1.5 × 170
Kongsberg Simrad EM300 (*Hi`ialakai* only)	9	30	0.7, 2, or 15	0.16 to 10	1 × 150

Table A2. Sonar characteristics of the survey launch R/V *AHI*.

Sonar description	Max. power (kW)	Frequency (kHz)	Pulse width (ms)	Pulse repetition rate (times/s)	Directivity (degrees)
Navigation	0.6	50 200	~ 4 ~ 1	6 to 30 6 to 30	~ 30 ~ 10
RESON Multibeam	~ 1	240	0.07 (typical)	6 to 30	1.5 x 170

Table A3. Sonar characteristics of SeaBED autonomous underwater vehicle (AUV).

Sonar description	Max. power (W)	Frequency (kHz)	Pulse width (ms)	Pulse repetition rate (times/s)	Directivity (degrees)
Imagenex Delta-T profiling sonar	~ 200	260 kHz	~ 0.1	Up to 20	3
RDI Doppler Velocity Log	8	1.2 kHz	~ 0.1	1 to 10	1.2

Sonar, such as those described in Tables A1, A2 and A3, can provide a wealth of information about the seabed, including depth and an indication of its roughness and hardness. However, direct visual observations must be used to further characterize the seafloor. If the water is shallow enough, divers can be used to collect the visual data. In most cases, however, unmanned platforms are used to collect still camera photographic or video data. These platforms include autonomous underwater vehicles (AUVs), towed optical assessment device (TOAD), and remotely operated vehicles (ROVs).

Autonomous Underwater Vehicle: Where possible, the CRED deploys a terrain-following SeaBED AUV used to collect high-quality optical imagery of sufficient quality to characterize the benthic structure as well as the motile and sessile benthic fauna that populate the sea bottom. This AUV was developed for NOAA by the Woods Hole Oceanographic Institution’s Deep Submergence Laboratory. The AUV is programmed to follow a predetermined route and is then deployed from a ship or small boat. Once in the water, it descends to the bottom, where it travels at speeds of 0.25–1 m/s at 2–5 m above the seabed. A 1200-kHz Doppler velocity log is used to determine the vehicle’s height above the seafloor and precisely measure the vehicle’s progress along the intended route. The vehicle can operate independently for 8 hours over routes up to 28 km long. It is powered by onboard Lithium ion batteries packaged in pressure housing and is propelled by 3 sealed, high-endurance electric motors. The AUV takes a pair of high-resolution photographs at fixed intervals along the transect line. The AUV is designed to be minimally invasive and can precisely control its distance off the seabed, thus avoiding collisions with the substrate especially as it operates at such low speeds. In an alternate configuration, the AUV can also be equipped with a 260-kHz Imagenix Delta T multibeam echosounder to collect extremely high-resolution bathymetric and rugosity (seabed roughness) data.

Towed Optical Assessment Device: the CRED sometimes uses a towed camera-sled to collect optical validation data. A Deep Ocean Engineering TARAS sled is towed from a ship or small boat at speeds of 2–4 kn. The TOAD is tethered to the surface with up to 330 m of umbilical cable that powers the vehicle's electronics. It carries a low-light color video camera, two 500-W underwater lights, and a pair of parallel lasers for scaling objects in the field of view. The sled is also equipped with a fluxgate magnetic compass to determine the camera's orientation, a pressure sensor to measure depth, and a 200-kHz sonar altimeter to measure the sled's height off the bottom. Where possible, the position of the TOAD relative to the ship or boat is measured using an ultra-short baseline underwater navigation system. The sled operator can view the TOAD video data on the surface and can deploy or retrieve cable to maintain the sled at a constant height off the seafloor. A 70-kHz location pinger is attached to the sled to aid in recovery should the TOAD be lost.

Remotely Operated Vehicles (ROV): the CRED also has access to a Deep Ocean Engineering DHD2+2 Phantom ROV that can be used to collect optical validation data. This vehicle can be deployed from a ship or small boat and is equipped with a low-light color video camera and underwater lights with a 1100-ft umbilical cable and surface control electronics. The ROV differs from the TOAD in that it is highly maneuverable. The surface operator can operate thrusters to change the vehicle's orientation and height off the seafloor and can maneuver it to observe features of interest.

A.3 Methods for Locating and Removing Marine Debris

NOAA research vessels, U.S. Coast Guard vessels, and chartered vessels transport equipment and personnel to the NWHI and serve as support platforms for debris removal and research activities.

Daily operations involve launching and recovering 2–6 small inflatable vessels called Avons from the larger support vessel. The Avon teams transit at speeds of 8–12 kn into the reticulated and shallow-reef regions of atolls and islands from the open ocean. Each Avon team conducts surveys with at least 2 divers, a coxswain driving the small boat, and a spotter designated to specifically look out for divers, endangered species, and environmental hazards. Team members visually inspect the water column and benthos for marine debris in shallow water at depths < 10 m, within a range generally workable by snorkel or free diving.

Towed-diver Surveys: During a towed-diver survey, 2 snorkelers are towed ~ 10 m behind a lead boat. While being towed, snorkelers use a resin-laminated wooden board to steer themselves. Divers are typically towed at speeds of 1–3 kn behind the small boats.

Swim Surveys: Swim surveys are used in shallow waters at depths of < 2 m and regions with more complicated reef structures. During a snorkel survey, 2 snorkelers swim a section of reef, making certain that they are always in view of each other and trailed by the boat.

A.3.1 PROTOCOLS FOR REMOVAL OF UNDERWATER DEBRIS

When a derelict net or net fragment is found, a GPS waypoint is taken and debris type, size, fouling level, water depth, and substrate of the adjacent habitat are recorded. Nets are evaluated before removal actions to determine appropriate removal strategies, including the use of lift bags for heavier and larger conglomerates of debris. If attached to a reef, debris is carefully removed by hand to avoid any further reef damage and is then hauled into the small boats using lines and manpower.

As much as possible, detached coral heads and fragments entangled in nets are extracted on-site and returned to the seafloor. Derelict nets with > 75% of their surface area incorporated into a reef structure and that are no longer an entanglement hazard are left in place to avoid additional coral damage. At the end of a field day, debris is offloaded onto the large support vessel. During each phase of operations, interactions with any protected species are avoided.

In addition to the standard collection procedures described previously, divers also record data about items of maritime archeological importance and non-net underwater debris that they may encounter, especially metallic debris that can change the chemical composition of water quality and damage coral reef areas. These data are submitted to the corresponding partner agencies.

A.3.2 PROTOCOLS FOR REMOVAL OF LAND DEBRIS

Hand Removal: When a net is found, team members collect data such as size, type, and GPS location. Nets are cut into smaller, manageable sizes and then carried or dragged on tarps by hand to truck beds. Partially buried nets are dug free using shovels and picks before being removed.

Helicopter Sling Load: If derelict fishing gear is found on a shoreline that is inaccessible by roads or by sea and the area is not known to have protected species, then helicopters are used for net recovery. All sites targeted for sling-load activities are prepped by cutting a net into sections and placing its pieces into a sling-load cargo net 1–2 d prior to helicopter arrival. A typical sling-load takes between 10–20 s to attach to a helicopter. A cable with an emergency release mechanism is used, and a load is then flown to a drop-off container to be transported to a recycling facility by partner agencies. Typically, a helicopter can carry between 272–363 kg per load, depending on conditions.

A.3.3 PROTOCOLS FOR AERIAL SURVEY METHODS

Aerial surveys are conducted from long-range, fixed-wing aircraft, helicopters, and unmanned aerial systems (UAS). Aerial surveys provide the ability to survey large areas and are effective complements to land-based surveys.

Fixed-wing Aircrafts fly at full speed while transiting to the North Pacific Subtropical Convergence Zone, and, once there, fly at the slowest speed possible within safety limits at altitudes of 213–305 m to conduct surveys. One observer is positioned on each side of an aircraft.

Helicopters fly at a speed of 20–60 kn on a flight path following the shoreline of each island at altitudes of 30–152 m. The doors of a helicopter are removed to enhance observer visibility. On the right side of a helicopter, 2 observers are positioned, and a pilot and data recorder are on the left side. When marine debris specialists observe debris, a GPS waypoint is logged and descriptive data about that debris is recorded (color, size class, and debris type). Four size classes have been developed as a quick means to estimate the amount of debris observed at each point during the brief time permitted by a moving aircraft. This rough size-class classification takes into account the apparent volume of an observed pile of debris helps to improve understanding of the level of debris accumulation throughout the Pacific islands and aids team members in allocating the appropriate level of resources when planning removal efforts.

A Prototype UAS is in the development-and-testing phase in partnership with the Papahānaumokuākea Marine National Monument. This development team is focusing on at-sea launching and recovery, sea-surface imaging, and debris detection. A UAS would be hand-launched from a support vessel and monitored and piloted by a shipboard control operator. The location of marine debris sites would be identified during such a flight using streaming video and known flight path data. At the conclusion of each survey flight, a UAS would complete a water landing and be recovered by small boats. If successful, a UAS could then be launched in the Pacific Subtropical Convergence Zone to help target removal efforts in the open ocean. A UAS must remain in line of sight at all times per current Federal Aviation Administration (FAA) requirements, but flights beyond line of sight may be allowed by the FAA in the future. At the time of such beyond-line-of-sight flights, operational protocols for safety and protection of sensitive resources will be developed.

Appendix B: CRED Contributers, Partners, and Affiliates

American Samoa Department of Marine and Wildlife Resources
American Samoa Environmental Protection Agency
Bishop Museum
City and County of Honolulu
CNMI Department of Fish and Wildlife
CNMI Division of Environmental Quality
CNMI Coastal Resources Management Office
Cornell University
Covanta Energy
Dalhousie University
Department of Aquatic Resources, Hawai`i Department of Land and Natural Resources
Florida Museum of Natural History
Guam Division of Aquatic and Wildlife Resources
Hawai`i Audubon Society
Hawai`i Department of Business, Economic Development, and Tourism
Hawai`i Ocean Safety Team
Hawai`i Pacific University
Hawai`i Humpback Whale National Marine Sanctuary
Horizon Waste Services Inc.
James Cook University
Matson Inc.
Mauna Kea Soil and Water Conservation District the Kohala Watershed Partnership
The Nature Conservancy
National Geographic Society
National Marine Sanctuaries Program
National Park Service
Natural Resources Consultants Inc.
NOAA National Ocean Service
NOAA Coral Reef Conservation Program
Nova Southeastern University Oceanographic Center
Ocean Conservancy
Ocean Futures Society
Pacific Sea Grant and the University of Hawai`i Sea Grant College Program
Schnitzer Steel Hawai`i Corp.
Scripps Institute of Oceanography, University of California San Diego
University of Guam
University of Hawai`i at Mānoa
University of Hawai`i at Hilo
University of Miami
U.S. Coast Guard
U.S. Department of State
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Navy
Western Pacific Fishery Management Council
World Bank Coral Reef Targeted Research and Capacity Building for Management Project
World Conservation Monitoring Centre, United Nations Environment Programme

Appendix C: NEPA Documents Prepared for Activities Associated with the CRED Program

CRED research activities have been conducted at various levels since 2001. The CRED's current program and specific activities within this program have been evaluated in a number documents related to the *National Environmental Policy Act of 1969* (NEPA) and associated documents related to the *Endangered Species Act of 1973*:

- Environmental Assessment and FONSI for NOAA's Pacific Island Fisheries Science Center Coral Reef Ecosystem Division 2005-2010 Activities (June 2005)
- Biological Evaluation, Marine Debris Aerial Surveys, Kauai and the Big Island, Hawai`i, NOAA Fisheries, Pacific Island Fisheries Science Center, Coral Reef Ecosystem Division, Marine Debris Program, submitted to Pacific Islands Regional Office, Office of Protected Resources (February 2006)
- Papahānaumokuākea Marine National Monument Research Permit to NOAA's Pacific Island Fisheries Science Center for Artificial Reef Matrix Structures (Permit No. NWHIMNM-2006-015) (October 16, 2006)
- Biological Evaluation: Amended for 2008-2010 Marine Debris Removal Operations for French Frigate Shoals, Kure Atoll, Pearl and Hermes Atoll, Midway Atoll, Maro Reef, Laysan Island and Lisianski Island; Papahānaumokuākea Marine National Monument and associated NOAA Pacific Island Regional Office (PIRO) concurrence letter (May 16, 2008)
- Categorical Exclusion for the Joint Institute for Marine Atmospheric Research (JIMAR) Artificial Reef Matrix Structures (ARMS) Project (PIFSC-08-10; June 05, 2008)
- Categorical Exclusion for the Joint Institute for Marine and Atmospheric Research Sustaining Healthy Coastal Ecosystems (BotCam component only) NA17RJ1230 (PIFSC-08-12; June 05, 2008)
- Categorical Exclusion for the Joint Institute for Marine and Atmospheric Research Sustaining Healthy Coastal Ecosystems (autonomous-underwater-vehicle mapping component only) NA17RJ1230 (PIFSC-08-14, June 05, 2008)
- Categorical Exclusion for the Joint Institute for Marine and Atmospheric Research Sustaining Healthy Coastal Ecosystems (Ghost net component only) NA17RJ1230 (PIFSC-08-11, June 05, 2008)
- Categorical Exclusion for the Joint Institute for Marine and Atmospheric Research Sustaining Healthy Coastal Ecosystems (passive acoustics component only) (PIFSC-08-13, June 05, 2008)
- Biological Evaluation: 2009-2014 Pacific Reef Monitoring and Assessment Program American Samoa, Guam, the Commonwealth of the Northern Marianas Islands, and the Pacific Remote Island Areas and associated NOAA Fisheries PIRO concurrence letter (March 05, 2009)

- Categorical Exclusion for Determining the Biodiversity of Coral Reef Ecosystems Using Time-Series Acoustic Data (PIFSC-09-04, May 20, 2009)
- Categorical Exclusion for the JIMAR Sustaining Healthy Coastal Ecosystems Autonomous Underwater Vehicle mapping component (PIFSC-09-13, June 5, 2009)
- Categorical Exclusion for the JIMAR Autonomous Reef Monitoring Structures (ARMS) Project (PIFSC-09-14, June 5, 2009)
- Categorical Exclusion for the JIMAR Sustaining Healthy Coastal Ecosystems Ghost Net component (PIFSC-09-15, June 5, 2009)
- Categorical Exclusion for the JIMAR Sustaining Healthy Coastal Ecosystems (BotCam component only) NA09OAR4320075 (PIFSC-09-16, June 11, 2009)
- Categorical Exclusion for the JIMAR Sustaining Healthy Coastal Ecosystems (EAR component only) NA09OAR4320075 (PIFSC-09-17, June 16, 2009)
- Categorical Exclusion for the Cooperative Institute for North Atlantic Research (CINAR) Image Analyses Tools for Quantitative Mensuration and Classification of High Resolution Optical Imagery proposal (PIFSC-09-26, June 29, 2009)