



4 *Reduce Impacts of Pollution and Coral Disease*

Introduction

Anthropogenic and natural causes have produced major structural and functional changes among coral reefs worldwide that have escalated over the last 30 years. Land-based and marine pollution, diseases, and bleaching concomitant with global climate change are among the most recognized, widespread, and pervasive threats impacting coral reef ecosystems. Many locations are subjected to multiple, sequential stressors with synergistic interactions that are especially detrimental to reefs, culminating in precipitous declines in coral cover, and ecosystem shifts to a dominance by macroalgae. Projects in this spend plan category work to reduce these impacts.

The complex interactions among stressors and their effects on corals and coral reef ecosystems are generally poorly understood, making it difficult to establish causal links to local or regional declines in coral health. Reef species experiencing persistent environmental disturbances may respond with acute mortality (manifesting as visible signs of “disease” and recent tissue loss), resulting in rapid loss of diversity and abundance. Corals also display sub-acute, sub-lethal effects when exposed initially or at low levels to these stressors, which can have measurable (but not necessarily directly visible) effects on growth and reproduction. When unchecked, these stresses may ultimately result in cascading ecosystem deterioration.

Some of the most important and least understood interactions are relationships between coral health and anthropogenic stressors such as pollution. Environmental stressors associated with degraded water quality (e.g., high nutrients, toxins and sediments) and climate changes (e.g., elevated temperature) are often cited as potential factors causing coral disease, bleaching, and mortality. Yet rarely have there been adequate measurements and studies causally linking coral disease to exposures to environmental stressors, and several recent studies suggest that disease prevalence has also increased in more remote locations that are removed from direct human impacts. Through better understanding of interactions between pollution, disease agents and the responses of coral reef species, the management community will be better poised to mitigate the stressors and manage their impacts before irreparable damage is done. Responding to these threats requires: 1) removal of marine debris and efforts to reduce future accumulations; 2) implementation of comprehensive strategies to reduce discharge of pollutants into coral reef ecosystems; and 3) refinement of existing technologies and development of multidisciplinary approaches to understand disease mechanisms, track occurrence, and predict impacts of disease at multiple spatial and temporal scales.





This spend plan category includes three subcategories:

- Reduce Marine-Based Sources of Pollution
- Reduce Land-Based Sources of Pollution
- Reduce Impacts of Coral Disease

These subcategories are being addressed through:

- Refinement of strategies and development of tools to assess the biological, chemical, and physical conditions of reefs.
- Application of and training for managers, scientists and graduate students in standardized field and laboratory methodologies.
- Strategic laboratory and field research to forecast, characterize, and understand extent and impacts of disease and pollution.
- Direct actions to reduce pollution and remove marine debris.
- Technical assistance to government agencies, scientists, managers and stakeholders through workshops and other venues in the development of management and mitigation responses.
- Financial assistance for projects to understand and address impacts of pollution and disease.

Between 2002 and 2006, the CRCP provided \$16.4 million (M) to support 126 projects in this category, which accounted for 13% of the overall CRCP funding and 10% of overall number of projects (Exhibit III-4-1a).

Exhibit III-4-1a Investment in Reduce Impacts of Pollution and Coral Disease 2002-2006						
Spend Plan Category	Number of Projects	% Category Projects	% Total Projects	Funding	% Category Projects	% Total Projects
Reduce Impacts of Pollution and Coral Disease	126	9.7	9.7	\$16,427,256	12.7	12.7
Reduce Marine-Based Sources of Pollution	18	14.3	1.4	\$11,579,918	70.5	8.9
Reduce Land-Based Sources of Pollution	80	63.5	6.2	\$3,023,747	18.4	2.3
Reduce Impacts of Coral Disease	28	22.2	2.2	\$1,823,591	11.1	1.4

Exhibit III-4-1b shows the distribution of investments in each of these subcategories during 2002 to 2006.



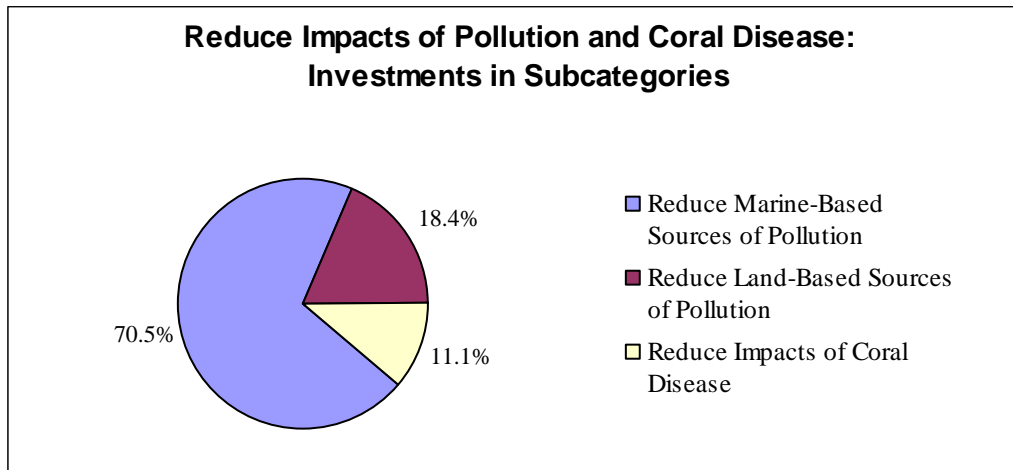


Exhibit III-4-1b. Distribution of Investments by Subcategory, 2002-2006

Subcategory: Reduce Marine-Based Sources of Pollution

a. Introduction to Subcategory

This category largely involves efforts to reduce the impacts of marine debris and interagency debris removal efforts. Much of this work is focused in the Northwest Hawaiian Islands (NWHI), which due to their location with respect to the Subtropical Convergence Zone, contain extraordinarily high densities of derelict fishing gear. Lost and abandoned fishing gear, primarily large trawl and drift nets from all around the Pacific Rim, float into the region. Upon entering the more protected, low-energy, shallow water environments inside the barrier reefs of the NWHI, the derelict fishing gear entangles and kills endangered Hawaiian monk seals, threatened green sea turtles, seabirds, and other wildlife. In addition, as in other jurisdictions impacted by marine debris, the gear damages sensitive coral reef habitat, smothers benthic flora and fauna, presents a hazard to safe navigation, and serves as a potential vector for the introduction of invasive species. CRCP set an internal goal to remove the major accumulations of marine debris in the NWHI by 2005.

Reducing marine-based sources of pollution is also addressed by the CRCP via outreach activities, workshops, and reference maps and models for oil and chemical spill responders.

Between 2002 and 2006, the CRCP provided \$11.6M to support 18 projects in this subcategory. This subcategory accounted for 70% of funding within the Reduce Impacts of Pollution and Coral Disease category and 9% of overall CRCP funding; and 14% of projects in the category and 1% of overall CRCP projects between 2002 and 2006 (see Exhibit III-4-1a). Regionally, 99% of the Marine Debris budget went to Pacific activities (see Exhibit III-4-3).

The distribution of funds by tool for this subcategory is shown in Exhibits III-4-2a and -2b.





**Exhibit III-4-2a
Reduce Marine-Based Sources of Pollution
Investments by Tool**

Tool	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
	2002		2003		2004		2005		2006		TOTALS 2002-2006			
	Ecosystem Research	0	\$0	0	\$0	1	\$4,500	0	\$0	0	\$0	1	5.6	\$4,500
Socioeconomic Research	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
Mapping and Monitoring	1	\$100,000	1	\$18,000	1	\$65,500	1	\$38,000	0	\$0	4	22.2	\$221,500	1.9
Outreach	1	\$15,000	0	\$0	1	\$4,000	0	\$0	1	\$21,000	3	16.7	\$40,000	0.3
Management: Direct Implementation	2	\$3,100,000	2	\$3,055,000	1	\$2,632,438	1	\$2,000,000	1	\$394,480	7	38.9	\$11,181,918	96.6
Management: Training and Technical Assistance	1	\$110,000	0	\$0	1	\$15,000	1	\$7,000	0	\$0	3	16.7	\$132,000	1.1
None or N/A	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
TOTAL	5	\$3,325,000	3	\$3,073,000	5	\$2,721,438	3	\$2,045,000	2	\$415,480	18	100	\$11,579,918	100



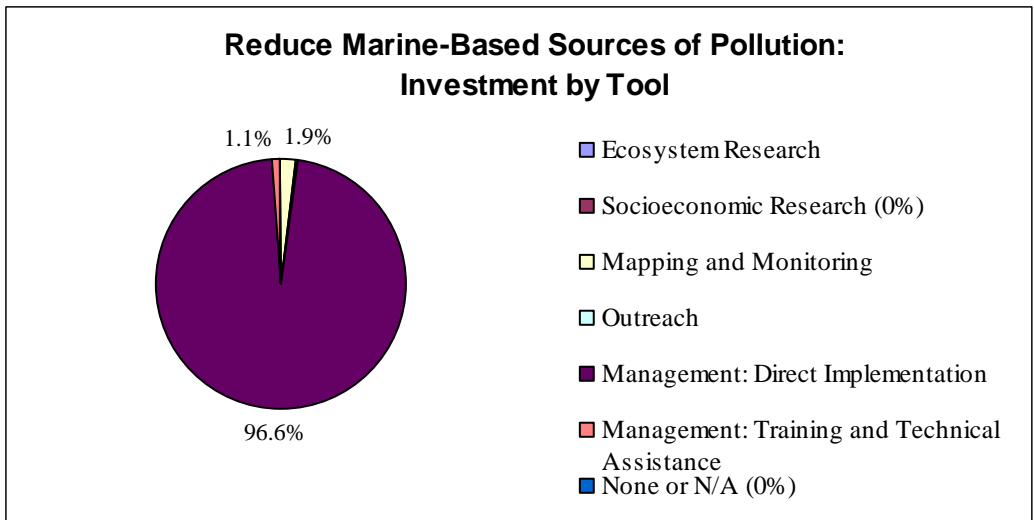


Exhibit III-4-2b. Distribution of Investments by Tool, 2002-2006

The distribution of funds by region for this subcategory is shown in Exhibits III-4-3a and -3b.

Exhibit III-4-3a Reduce Marine-Based Sources of Pollution Investments by Region

Region	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
	2002		2003		2004		2005		2006		TOTALS 2002-2006			
Atlantic/Caribbean	2	\$51,300	0	\$0	0	\$0	0	\$0	0	\$0	2	9.5	\$51,300	0.4
Pacific	4	\$3,246,200	3	\$3,073,000	4	\$2,709,438	2	\$2,038,000	1	\$394,480	14	66.7	\$11,461,118	99.0
Freely Associated States	1	\$27,500	0	\$0	0	\$0	1	\$7,000	1	\$21,000	3	14.3	\$55,500	0.5
International	0	\$0	0	\$0	1	\$7,500	0	\$0	0	\$0	1	4.8	\$7,500	0.1
All Regions	0	\$0	0	\$0	1	\$4,500	0	\$0	0	\$0	1	4.8	\$4,500	0.0
TOTAL	7	3,325,000	3	3,073,000	6	2,721,438	3	2,045,000	2	415,480	21	100	11,579,918	100



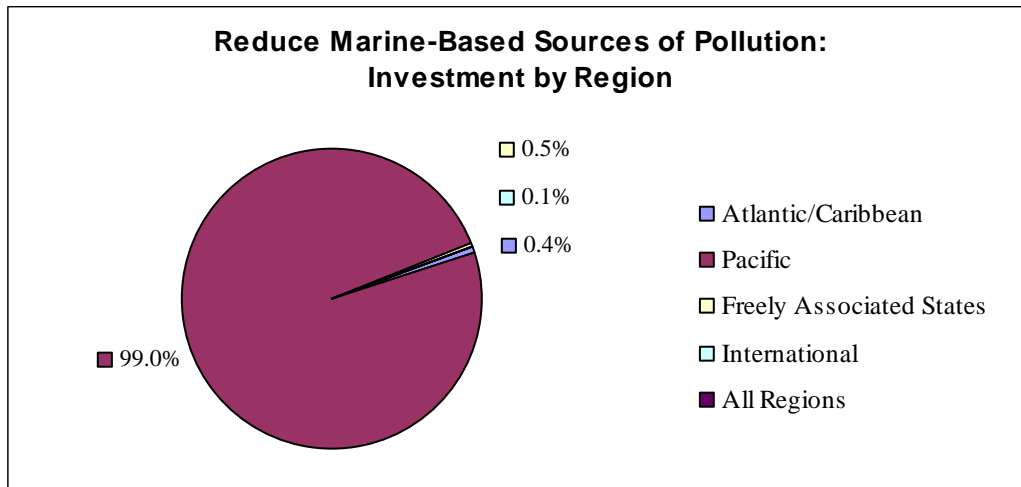


Exhibit III-4-3b. Distribution of Investments by Region, 2002-2006

b. Activities

- Specially trained teams of marine debris specialists systematically survey the reefs of the NWHI to locate derelict fishing gear and other marine debris. Once derelict gear is identified, locations/coordinates are recorded using Global Positioning System (GPS) units. Specialists also record descriptive data for both the derelict fishing gear (e.g., type, size, construction), and the habitat in which the debris is found. The debris is carefully removed by divers to avoid any further damage to the reef, and brought back to Honolulu and recycled with the cooperation of industry partners.
- Additional internal NOAA projects include developing tools to help managers predict the potential impact of an oil or chemical spill on sensitive reef resources.
- Grant-supported activities include educating boat owners in the Caribbean on how to best dispose of waste in marinas, marine debris removal from coral reefs in Puerto Rico, and damage assessment of coral reef organisms and endangered species impacted in Puerto Rico.

c. Funding Recipients and Partners

To carry out the projects in this subcategory, the CRCP partnered with the NOAA offices and external partners listed in Exhibit III-4-4.





**Exhibit III-4-4
Reduce Marine-Based Sources of Pollution
Funding Recipients and Partners**

NOAA Offices	Other Federal Agencies	States and Territories	Fishery Management Councils	Non-Governmental Organizations
<ul style="list-style-type: none"> • NMFS - Pacific Islands Fisheries Science Center • NMFS - Office of Habitat Conservation • NOS - Marine Debris Program • NOS - Papahānaumokuākea Marine National Monument 	<ul style="list-style-type: none"> • DOI - Papahānaumokuākea Marine National Monument 	<ul style="list-style-type: none"> • Florida 	<ul style="list-style-type: none"> • Western Pacific • Caribbean • Gulf of Mexico 	<ul style="list-style-type: none"> • Amigos de Amona • Environmental Protection in the Caribbean

Large-scale debris removal efforts were led by the CRCP through the NMFS Pacific Islands Fisheries Science Center and involved many other NOAA, Federal, state, corporate, and NGO partners. In 2005, the NOS Marine Debris Program, in partnership with the Papahānaumokuākea Marine National Monument, became a key partner in funding continuing removal efforts.

d. Outputs

The NWHI marine debris program, initiated in 1996, has removed over 511 metric tons to date. Most was removed between 2001-2006 from Kure and Pearl and Hermes Atolls, Lisianski and Laysan Islands, Maro Reef, and French Frigate Shoals (see Exhibit III-4-5).



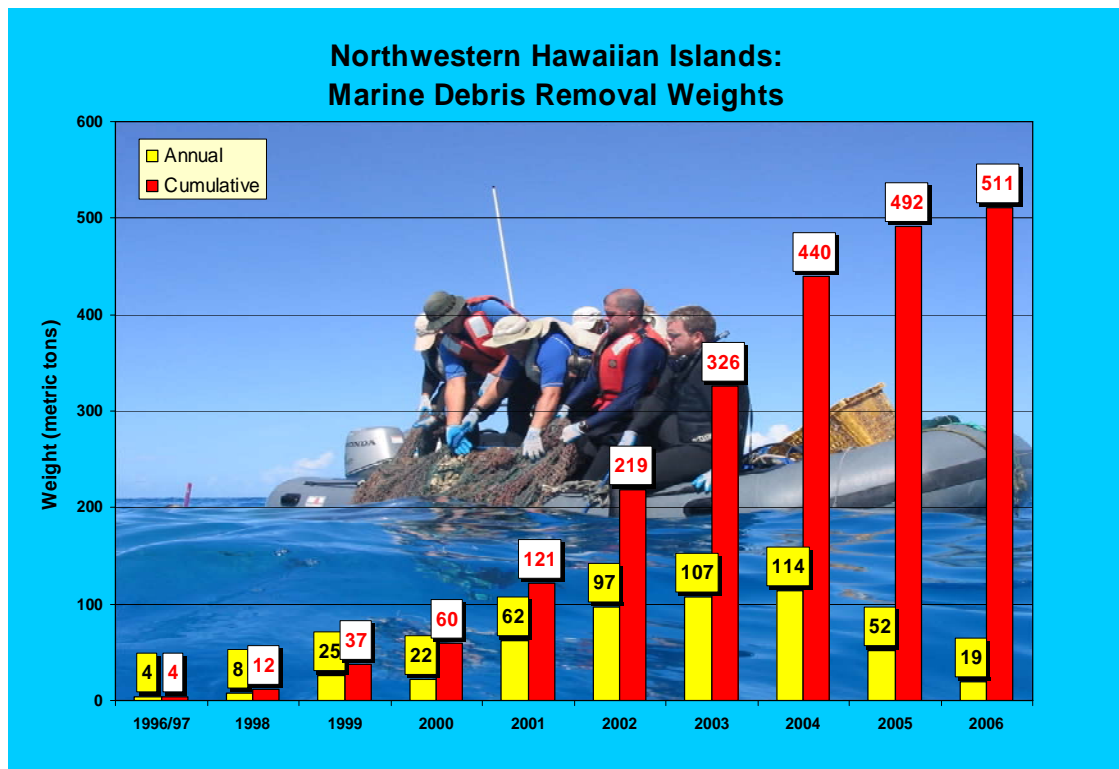


Exhibit III-4-5. Annual and cumulative total debris removed from the NWHI

In the Caribbean, 3,235 kg of marine debris were removed from coral reef and beach habitats of the Mona Channel (NE of Puerto Rico). Other key outputs include a public awareness campaign in Puerto Rico on the threats of marine debris to marine life, and the development of a clean marinas initiative for Simpson Lagoon, St. Martin.

Outputs for predictive tools include:

- Environmental Sensitivity Index (ESI) maps of American Samoa, Guam, and CNMI. ESI maps serve as quick references for oil and chemical spill responders and coastal zone managers. They highlight shorelines sensitive to oiling, sensitive biological resources such as coral reefs and seabird colonies, and vulnerable human-resources such as water intakes and swimming beaches.
- The 2003 *Oil and Sea Turtles: Biology, Planning, and Response* report, which provides basic information on response activities that might be considered in sea turtle habitat, including unintended adverse impacts to turtles that may be caused by response activities.
- Additions to NOAA's surface current models to evaluate the potential natural dispersion of a spill over coral reefs.





e. Outcomes

In the NWHI, the majority of the derelict fishing gear that was deposited on the reefs has been removed, eliminating this debris as a threat to threatened and endangered species and coral reef habitat. A study examining rates of marine debris accumulation in the NWHI (*Marine Pollution Bulletin*) found that accumulated debris densities and weights were greater in lagoonal reef areas, and that NWHI debris accumulation is higher than originally anticipated. This information is being used to design and change management plans to remove debris at a maintenance mode rate.

f. Challenges

The remote location of the NWHI poses significant challenges in addressing marine debris removal. Marine debris specialists must be highly trained to conduct safe operations and handle emergency situations without immediate external support. In addition, access to the NWHI is limited and expensive. Chartering a vessel with the necessary specifications is the most effective field option, but is not always feasible due to limited resources. An alternative is the use of NOAA vessels, which have been used during maintenance mode operations. However, ship time on NOAA vessels is highly competitive and often constrained by lack of available dates and times.

When the five-year, intensive removal effort was completed in 2005, it was anticipated that subsequent maintenance efforts would be able to keep up with annual debris accumulation. However, a recent study has found annual accumulation rates to be higher than originally estimated. The first year of maintenance mode resulted in 19 metric tons removed from the NWHI, while the annual accumulation rate is over 52 metric tons. How to address this gap remains a challenge.

A key challenge is addressing the sources of marine debris. In the Hawaiian archipelago, the largest percentage of derelict fishing gear comes from non-local sources, an international issue that concerns many Pacific Rim countries. Net identification is also problematic as nets can be manufactured in one country, but then change hands many times in different fisheries and in different countries. Time, space, and significant manpower would be required to untangle and sort the nets even if a “fingerprint” for the net source was available.

g. Future Directions

Future marine debris efforts among all partners involved will likely focus on debris removal in high density accumulation areas, removal of land-based debris, targeted research projects including invasive species studies and oceanographic circulation studies (with satellite tracked buoys), and development of at-sea debris detection and mitigation technologies.





The Marine Debris Program is addressing international cooperation to reduce marine debris through interagency committees, and Papahānaumokuākea Marine National Monument is funding field tests of unmanned aerial vehicles (UAVs) to find derelict fishing gear in the convergence zone (an area anticipated to contain a large density of debris) north of the Hawaiian archipelago. If successful, the use of UAVs will help direct targeted removal operations to find and remove debris at sea before it reaches coral reef ecosystems.

Subcategory: Reduce Land-Based Sources of Pollution

a. Introduction to Subcategory

Several federal agencies, including the U.S. Environmental Protection Agency and the U.S. Department of Agriculture, manage land-based sources of pollution as one of their key missions. Conversely, NOAA has a relatively minor role in the management of coastal pollution.

Accordingly, the CRCP has sought to develop a niche role in addressing this threat by providing expertise, guidance, training, and funding to existing coastal resource and coral management programs that currently lack the resources and technical proficiency to adequately address land-based sources of pollution (LBSP). The focus of NOAA's support is on building local capacity to address and effectively manage impacts to the reef ecosystem through assistance with planning and training in protection practices. States and Territories have played an essential role in developing Local Action Strategies (LAS) which bring together existing Federal, state and local programs for LBSP within their jurisdictions. States and territories have used CRCP grant funding to conduct watershed assessments, mapping, demonstration projects, and outreach, and to develop tools to assess the impacts of LBSP. In the process, they have leveraged just over \$10M for activities at the jurisdictional level.

NOAA scientists provide assistance through studies to measure pollutants and contaminants and establish linkages to coral degradation. Activities in this subcategory are often closely related to or overlapping with those addressing coral disease because pollutants can act independently or in synergy with other environmental stressors to make coral reef organisms more susceptible to disease. This section provides a summary of both internal NOAA projects and external grant projects (funded through the Coral Reef Conservation Grant Program and the NFWF Coral Fund).

Between 2002 and 2006, the CRCP provided \$3.0M to support 80 projects in this subcategory. This subcategory accounted for 18% of funding within the Reduce Impacts of Pollution and Coral Disease category and 2% of overall CRCP funding; and 63% of projects in the category and 6% of overall CRCP projects between 2002 and 2006 (see Exhibit III-4-1). Regionally, 60% of the LBSP budget went to Pacific activities, 38% to the Atlantic, 2% to International activities,





and less than 1% to the Freely Associated States. The distribution of funds and effort by tool for this subcategory is shown in Exhibits III-4-6a and -6b.

Exhibit III-4-6a Reduce Land-Based Sources of Pollution Investments by Tool														
Tool	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
	2002		2003		2004		2005		2006		TOTALS 2002-2006			
Ecosystem Research	1	\$149,916	3	\$144,000	6	\$251,613	6	\$135,842	0	\$0	16	20.0	\$681,371	22.5
Socioeconomic Research	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
Mapping and Monitoring	3	\$283,500	1	\$45,000	5	\$86,000	3	\$90,500	1	\$5,000	13	16.3	\$510,000	16.9
Outreach	1	\$15,000	2	\$40,500	3	\$62,000	2	\$65,860	0	\$0	8	10.0	\$183,360	6.1
Management: Direct Implementation	4	\$69,705	5	\$147,000	9	\$227,201	7	\$264,776	6	\$370,550	31	38.8	\$1,079,232	35.7
Management: Training and Technical Assistance	1	\$200,000	2	\$80,000	3	\$84,500	3	\$130,000	3	\$75,284	12	15.0	\$569,784	18.8
None or N/A	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
TOTAL	10	\$718,121	13	\$456,500	26	\$711,314	21	\$686,978	10	\$450,834	80	100	\$3,023,747	100



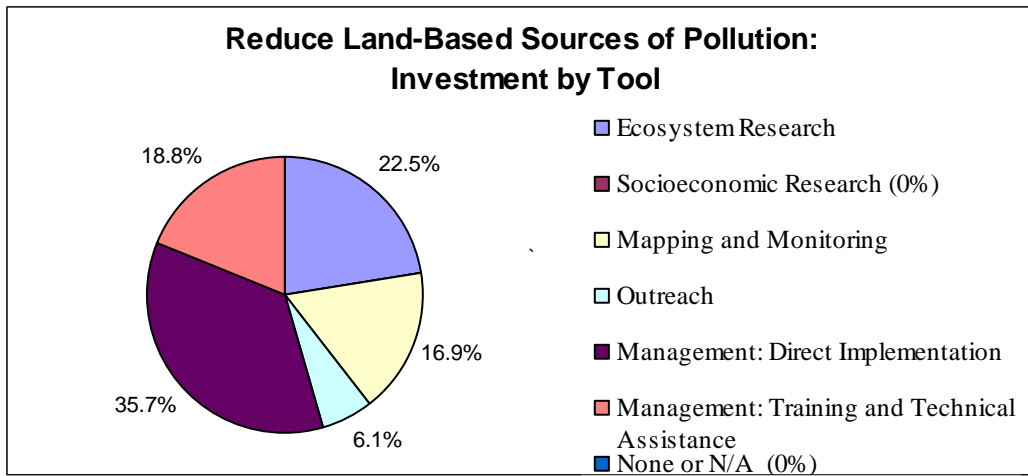


Exhibit III-4-6b. Distribution of Investments by Tool, 2002-2006

The distribution of funds and effort by region for this subcategory is shown in Exhibits III-4-7a and -7b.

Exhibit III-4-7a Reduce Land-Based Sources of Pollution Investments by Region														
Region	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
	2002		2003		2004		2005		2006		TOTALS 2002-2006			
Atlantic/Caribbean	4	\$150,000	7	\$231,000	11	\$257,615	11	\$405,816	4	\$97,300	37	43.5	\$1,141,731	37.8
Pacific	7	\$548,121	7	\$219,000	14	\$427,363	9	\$254,826	7	\$353,534	44	51.8	\$1,802,844	59.6
Freely Associated States	1	\$20,000	1	\$6,500	0	\$0	0	\$0	0	\$0	2	2.4	\$26,500	0.9
International	0	\$0	0	\$0	1	\$26,336	1	\$26,336	0	\$0	2	2.4	\$52,672	1.7
All Regions	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
TOTAL	12	\$718,121	15	\$456,500	26	\$711,314	21	\$686,978	11	\$450,834	85	100	\$3,023,747	100



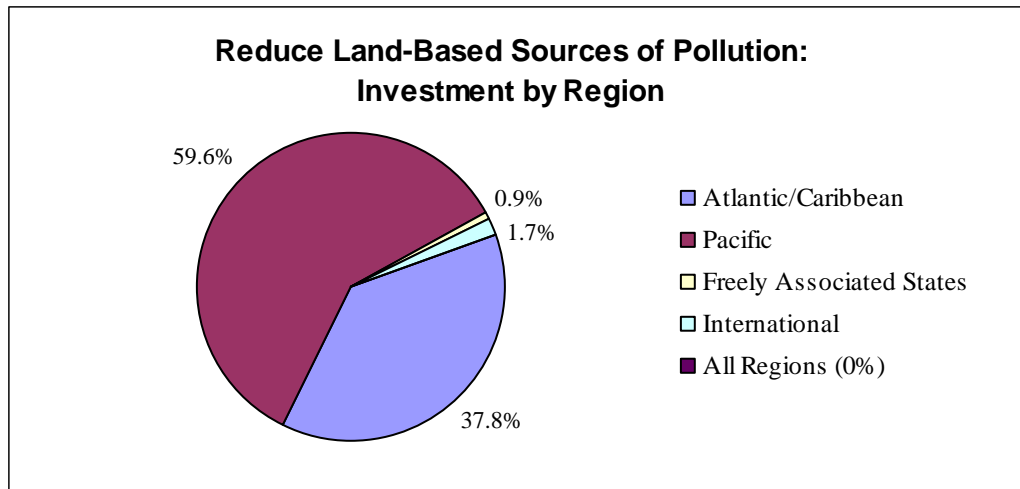


Exhibit III-4-7b. Distribution of Investments by Region, 2002-2006

b. Activities

The projects and activities supported by the CRCP use four primary tools to reduce land-based sources of pollution: management, assessment (mapping/monitoring), outreach, and biophysical/coral reef ecosystem research (Exhibit III-4-6a and 6b). Management projects (55% of subcategory total, \$1.6M) are mostly direct implementation activities, but include a number of training, technical assistance and stewardship activities as well.

Direct implementation management activities include a variety of Best Management Practices demonstration and watershed protection projects, revegetation projects, and improvement projects to address stormwater runoff.

Management-based training and technical assistance projects address community responses to coastal hazards, the use and application of GIS-based tools and models to predict future erosion potential and vulnerability to land-based sources of pollution, and adaptation of sediment and erosion storm water control practices to island environments.

Mapping and monitoring projects (17%, \$510K) include: creating GIS-based tools to demonstrate land-use impacts on benthic habitats; non-point source pollution assessments; a septic system inventory; watershed characterization studies; and state and local water quality standards reviews. A number of important research projects (23%, \$681K) have been supported both internally and through external grants. The research activities generally address linking pollution to coral conditions through biomarker or bioassay studies, coral response and survivorship after exposure to LBSP stress, basic characterization of contaminants in corals, and investigating the ecological role of sponges and deepwater macroalgae relative to anthropogenic eutrophication.





Outreach projects (6%, \$183K) under this subcategory include “know your watershed” and anti-arson campaigns (to reduce wildfires and subsequent erosion/LBSP), education campaigns aimed at boaters and fishers, and pollution reduction through community involvement in stream assessment and monitoring.

c. Funding Recipients and Partners

Exhibit III-4-8 provides example of CRCP’s funding recipients and partners who supported activities in this subcategory.

Exhibit III-4-8 Reduce Land-Based Sources of Pollution Funding Recipients and Partners				
NOAA Offices	Other Federal Agencies	States and Territories	Academic Institutions	Non-Governmental Organizations
<ul style="list-style-type: none"> • NOS - Office of Ocean and Coastal Resource Management • NOS - Office of Response and Restoration • NOS - Special Projects Office • NOS - Pacific Services Center • NOS - National Centers for Coastal Ocean Science • NOS - Coastal Services Center • NOS - International Programs Office • OAR - National Undersea Research Program (NURP) 	<ul style="list-style-type: none"> • U.S. Environmental Protection Agency • U.S. Department of Agriculture • DOI – U.S. Geological Survey • DOI - National Park Service 	<ul style="list-style-type: none"> • American Samoa • CNMI • Florida • Guam • Hawaii • Puerto Rico • U.S. Virgin Islands 	<ul style="list-style-type: none"> • Texas A&M • University of Hawai’i • University of Miami • University of North Carolina Wilmington (NURP Center) • University of Puerto Rico • University of South Carolina • University of the Virgin Islands • Woods Hole Oceanographic Institute 	<ul style="list-style-type: none"> • Coalition of Reef Lovers World Resources Institute • Hanalei Watershed Hui • Island Resources Foundation • Pacific American Foundation • Reef Relief, Inc. • Perry Institute for Marine Science (NURP Center)





d. Outputs

The following is a sampling of the key outputs and accomplishments in this subcategory.

- The seven coral jurisdictions each completed LAS to address LBSP, providing for more focused Federal, state, and local efforts.
- GIS-based tools and models include: an oil spill model for Miami; a digital watershed atlas and an erosion potential model for estimating sediment delivery to coral reefs in Guam; a GIS-based tool using Landsat images to show impact of LBSP on benthic habitats of USVI and Puerto Rico; an integrated data management program for LBSP projects in Florida; and contributions to Reefs at Risk, a map-based indicator of potential threats to coral reefs worldwide.
- Significant reports, publications and strategies produced include the South East Florida Coral Biomarker Local Action Study; Review of Land-Based Sources of Pollution and Water Quality Standards in Florida; a Coral Reefs and Watersheds strategy in Puerto Rico; and several ecosystem research LBSP project reports and publications.
- Workshops and trainings were held on topics such as the science of oil spills and dispersant use in the Florida Keys; a workshop for scientists and managers on monitoring LBSP impacts in Hawai'i; a series of customized workshops and trainings on stormwater management and sediment/erosion control in tropical environments; and a workshop in St. John, USVI to train managers on the use of the Summit-to-Sea GIS-based tool.
- Outreach products include an anti-arson campaign in Guam (anti-arson PSAs, awareness posters, and a teaching kit "Guam Island on Fire" distributed to schools throughout the island); and Know your Watershed in Lau Lau Bay, CNMI.





Program Highlight: Florida Biomarker Pilot Study

This pilot project, undertaken by the Southeast Florida Coral Reef Initiative with CRCP management grant funds, integrates traditional coral monitoring techniques with a novel biotechnology – cellular diagnostics – to address how land-based sources of pollution affect coral reefs.

Cellular diagnostic techniques can be used to assess coral health using enzymatic biomarkers of specific cellular processes known to reflect environmental stress. Environmental stressors overwhelm the natural defenses of coral organisms beginning at the molecular and cellular level with cascading effects resulting in weakened structure, function, and resilience of coral reef communities. Recent evidence suggests that environmental stress and the synergistic effects of multiple stressors may increase the susceptibility of corals to disease.

The objective of this pilot study, conducted in partnership with the University of Central Florida, National Coral Reef Institute, College of Charleston, Haereticus Environmental Laboratory, and Broward County Environmental Protection Department, was to test the feasibility of using cellular diagnostics to link land-based sources of pollution with coral reef degradation.

The study found that corals near sewage pipes and inlets - where urban and agricultural runoff flows into the ocean - showed elevated biomarker levels in tissue samples and harmful changes in levels of molecules associated with the ability to heal wounds. These results suggest that land-based sources of pollution may affect coral community health and implies a tentative link between sewage pipes and coastal runoff to coral damage off southeast Florida.

The next phase of this biomarker project is currently underway and consists of a more extensive study intended to tie the coral tissue damage to specific chemicals, such as particular fertilizers, nutrients or pharmaceuticals. By explicitly testing the chain of causality, researchers can provide evidence that resource managers, citizens, and legislators need to evaluate when making critical decisions about managing the effects of land-based sources of pollution on southeast Florida coral reefs.

e. Outcomes

CRCP-funded projects increased state and territory capacity to tackle LBSP, provided information to managers and decision makers that was used to improve LBSP management, and changed views and behaviors of public stakeholders. Examples include:

- CNMI completed agricultural and engineering designs for stormwater control in Saipan and is implementing portions of the design plan for stream crossings as well as watershed renegotiations. CNMI also completed a study on nonpoint source pollution tracking for the Garapan watershed, which led to the development of a conceptual Stormwater Management Plan.
- The Hawai'i LBSP LAS is organizing a local advisory committee on Maui, including the Maui Land and Pineapple Company (MLP). MLP is planning to establish several committees to deal with cultural issues, recreational use, and other issues that impact the Honolua watershed.
- The GIS-based tools developed to support the characterization, assessment, and management of LBSP on shallow water coral ecosystems in Puerto Rico and the U.S. Caribbean resulted in a major new joint project (NOAA, USDA, EPA, and local agencies) to assess conservation practices in the Jobos Bay watershed in Puerto Rico. The project includes water quality, sediment, and estuary monitoring to begin to track possible changes in the watershed and associated coral ecosystems over time, following implementation of BMPs in agricultural areas.





- A study investigating the effects of globally transported African dust on Caribbean marine ecosystems revealed that sea urchins exposed to seawater solutions prepared with dust samples exhibited dramatically impaired fertilization success and development. Microbial analyses dust samples indicated the presence of viable bacteria and fungi, including some potential coral pathogens.
- The first quantitative characterization of chemical contaminants in U.S. corals and coral habitats and relationships between contaminants and disease was conducted in southwest Puerto Rico. More than 120 organic (e.g., petroleum hydrocarbons and pesticides) and inorganic (e.g., major and trace elements) chemical contaminants were analyzed in sediments and coral tissues from 43 sites. One outcome was the finding of a negative association between certain chemical contaminants in sediments and coral species richness.
- The customized stormwater management and sediment/erosion control workshops held in Hawai'i, Puerto Rico and USVI had several key outcomes. In addition to broadly building local capacity for addressing watershed protection, the workshops resulted in changes to several stormwater management ordinances in Maui Co., Hawai'i and efforts to streamline the permitting process for development in the USVI. In Puerto Rico, an MOU was agreed upon between the two local agencies to increase construction site inspection capabilities, and a construction and post-construction stormwater management ordinance is being initiated for the municipality of Caguas. Additionally, watershed protection demonstration projects are planned in Coral Bay, St. John, USVI and Guanica, Puerto Rico.
- The Keawa Nui Fish Pond Restoration Project on Molokai, Hawai'i successfully revitalized a 600-year old traditional fish pond that is culturally and environmentally significant as a site for community aquaculture industry and sink for upland sediment runoff during storms. The grantee also convinced the landowner to discontinue leasing upland property to a cattle ranching operation that is a major source of soil erosion and established a common seaweed, limu, as a bio-indicator of the water quality (and by extension the production potential) of the fishpond.
- A NFWF-funded Guam Urban Forestry Demonstration Project resulted in a successful community tree planting at a popular beach park in the Tumon Bay area, the development of a beach erosion control plan for the park, and increased community awareness through volunteer involvement in the plantings as well as advertising and media coverage for the event. More than 1,500 educational guidance brochures on urban best management practices were also produced and distributed to contractors, landscapers, and homeowners as part of this project.

f. Challenges

- Given the scope of NOAA's authority over LBSP, a key challenge has been coordinating with major actors and securing funding for integrated plans and implementation in terrestrial areas that nevertheless directly impact the reef ecosystem.





- Use of many of the GIS-based tools has been hampered by a general lack of GIS skills and the inability to incorporate data analyses into the decision making process within management agencies in the U.S. Caribbean.
- Field logistics and dedicated funding are common challenges, but the involvement of project partners greatly facilitates project success.

g. Future Directions

- There is a great need to move from management planning, project design, and tool development to plan implementation and applying tools and data to management decisions. Assisting with demonstration project implementation and BMPs to address land-based pollution and watershed protection is one avenue.
- Continued effort is needed to work with other Federal agencies to secure funding for watershed projects and BMP implementation in watersheds with coral reef resources.
- Innovative ways to increase and ensure compliance with existing rules and regulations for sediment/erosion control and stormwater management are also needed.
- Other key future investments include adequate long-term funding to support monitoring that tracks change over time. Environmental changes in nearshore shallow waters and coral reef habitat may take 10 or more years to appear once management changes are implemented.
- Another future direction is adding the quantification of chemical contaminants to integrated ecological assessment (IEA) for coral reefs. Without this information, managers may be missing important, and in some areas critical, information needed for the sustained management of coral reef ecosystems. The addition of coral biomarkers would increase understanding of the overall effects of pollution or chemical contaminants on coral reef ecosystems from the molecular to the community levels.

Subcategory: Reduce Impacts of Coral Disease

a. Introduction to Subcategory

Disease is a reduced performance in an organism that may be due to biotic or abiotic factors, or as a result of their interactions. Disease in corals and other coral reef species has dramatically increased in frequency and distribution over the last decade (see Exhibit III-4-10), contributing to unprecedented loss in live coral and altering the function and productivity of coral reef ecosystems. The Caribbean, in particular has been referred to as a “hot spot” for disease because of a rapid emergence of new, extremely virulent diseases, an increased frequency of epizootic events, and rapid spread of emerging diseases among new species and locations. Evidence of these impacts is provided by the loss of acroporids (formerly the most common coral species in shallow Caribbean reef ecosystems) as a result of white band disease outbreaks, and new, more virulent diseases (e.g., white plague) being found at deeper and remote locations, and affecting





slow growing massive corals that previously exhibited high resilience and resistance to disease. In the Pacific, the threat of coral diseases has been regarded as minor, possibly due to the large distances between reefs and island nations, fewer potential sources of pathogens, and a paucity of epizootiological studies. However, increasing evidence indicates an escalating abundance and prevalence of disease throughout Pacific locations.

The rising prevalence of diseases worldwide may be related to anthropogenic stressors such as pollution and sedimentation, elevated water temperature, loss of critical ecosystem linkages such as herbivores that controlled macroalgae, and the synergistic effect of multiple stressors. The potential relationship between these stressors and disease suggests that the emergence of disease as a major factor causing high levels of coral mortality is relatively new, and management strategies targeted towards reductions in anthropogenic stressors may reduce the likelihood of disease outbreaks. However, our ability to understand and manage coral disease is hampered by a lack of unified, globally accepted strategies and methodologies to investigate disease and assess coral health, inadequate mechanisms to communicate available information, and a paucity of data necessary to evaluate, track, predict, manage, or mitigate diseases.

In response to this growing threat, the CRCP is working with partners to improve scientific understanding and tools to:

- (1) Detect coral disease prevalence and incidence and assess its impacts.
- (2) Determine the causes of disease and mechanisms of infection.
- (3) Characterize the normal biology and physiology of corals to serve as a baseline for coral health and disease investigations, and to better distinguish between changes in health and natural changes (e.g., spatial and temporal changes).
- (4) Characterize the types and quantities of various pollutants and their role in disease processes.
- (5) Identify stressors that can be managed or mitigated, such as pollution and toxins, sediment and increased sea water temperatures, and evaluate effectiveness of management actions in reducing disease and recovering threatened species.



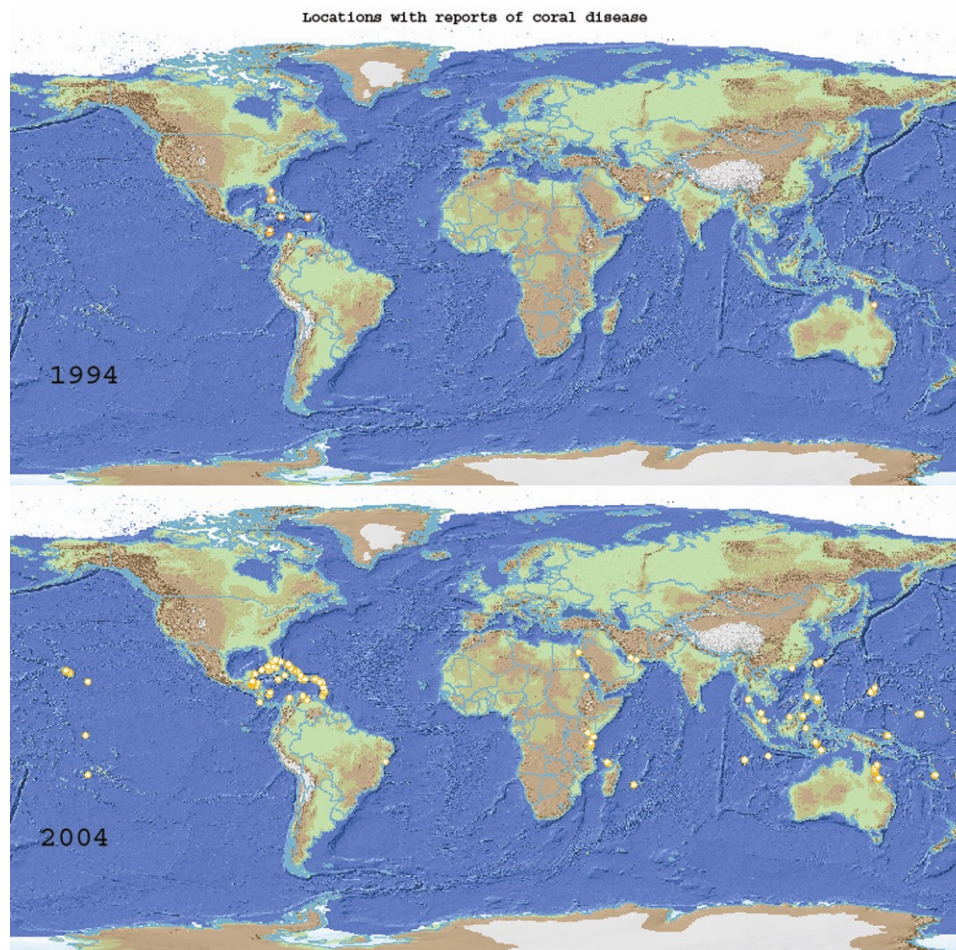


Exhibit III-4-10. Global increase in reports of coral diseases between 1994 and 2004

Between 2002 and 2006, the CRCP provided \$1.8M to support 28 projects. This subcategory accounted for 11% of funding within the Reduce Impacts of Pollution and Coral Disease category and 1% of overall CRCP funding; and 22% of projects in the category and 2% of overall CRCP projects between 2002 and 2006 (Exhibit III-4-1). The regional breakdown for the Coral Disease budget was as follows: 57% of activities were applicable to all regions (largely CDHC), 23% for the Pacific, 16% for the Atlantic, 1% for International activities and 2% for the Freely Associated States. The distribution of funds and effort by tool for this subcategory is shown in Exhibits III-4-9a and -9b.





**Exhibit III-4-9a
Reduce Impacts of Coral Disease
Investments by Tool**

Tool	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Funding
	2002		2003		2004		2005		2006		TOTALS 2002-2006			
	Ecosystem Research	0	\$0	1	\$185,000	4	\$352,921	9	\$380,421	9	\$516,751	23	82.1	\$1,435,093
Socioeconomic Research	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
Mapping and Monitoring	0	\$0	0	\$0	0	\$0	2	\$33,498	0	\$0	2	7.1	\$33,498	1.8
Outreach	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
Management: Direct Implementation	0	\$0	0	\$0	0	\$0	0	\$0	1	\$30,000	1	3.6	\$30,000	1.6
Management: Training/Technical Assistance	1	\$280,000	0	\$0	0	\$0	0	\$0	1	\$45,000	2	7.1	\$325,000	17.8
None or N/A	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0	0	0	\$0	0
TOTAL	1	\$280,000	1	\$185,000	4	\$352,921	11	\$413,919	11	\$591,751	28	100	\$1,823,591	100



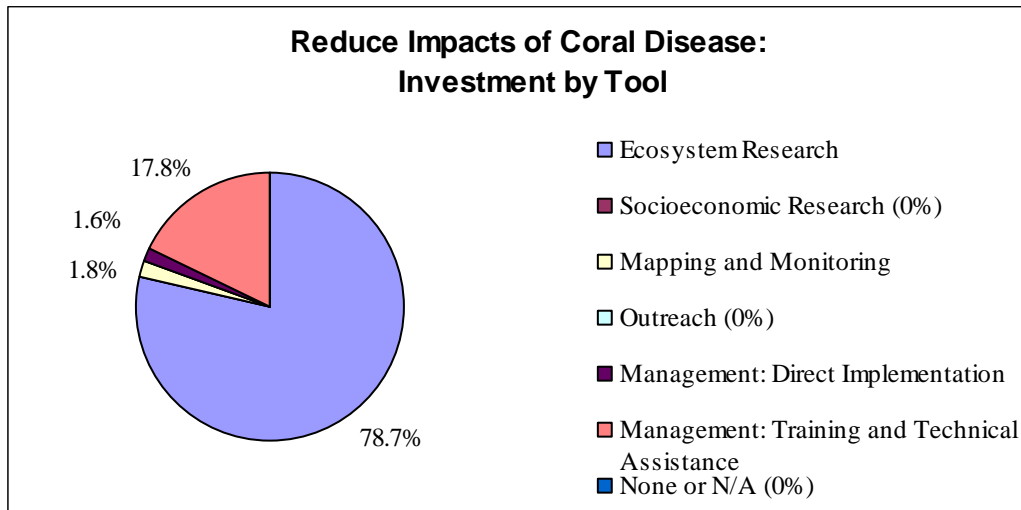


Exhibit III-4-9b. Distribution of Investments by Tool, 2002-2006

The distribution of funds and effort by region for this subcategory is shown in Exhibits III-4-10a and -10b.

Exhibit III-4-10a Reduce Impacts of Coral Disease Investments by Region														
Region	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	Funding	Number of Projects	% of Total Subcategory Projects	Funding	% of Total Subcategory Investment
	2002	2003	2004	2005	2006	TOTALS 2002-2006								
Atlantic/Caribbean	0	\$0	0	\$0	3	\$69,111	4	\$70,911	5	\$152,843	12	31.6	\$292,864	16.1
Pacific	0	\$0	0	\$0	1	\$41,400	4	\$111,398	6	\$274,706	11	28.9	\$427,504	23.4
Freely Associated States	0	\$0	0	\$0	1	\$32,200	1	\$1,400	1	\$1,479	3	7.9	\$35,079	1.9
International	0	\$0	0	\$0	1	\$10,210	1	\$10,210	0	\$0	2	5.3	\$20,420	1.1
All Regions	1	\$280,000	1	\$185,000	1	\$200,000	4	\$220,000	3	\$162,723	10	26.3	\$1,047,723	57.5
TOTAL	1	\$280,000	1	\$185,000	7	\$352,921	14	\$413,919	15	\$591,751	38	100	\$1,823,590	100



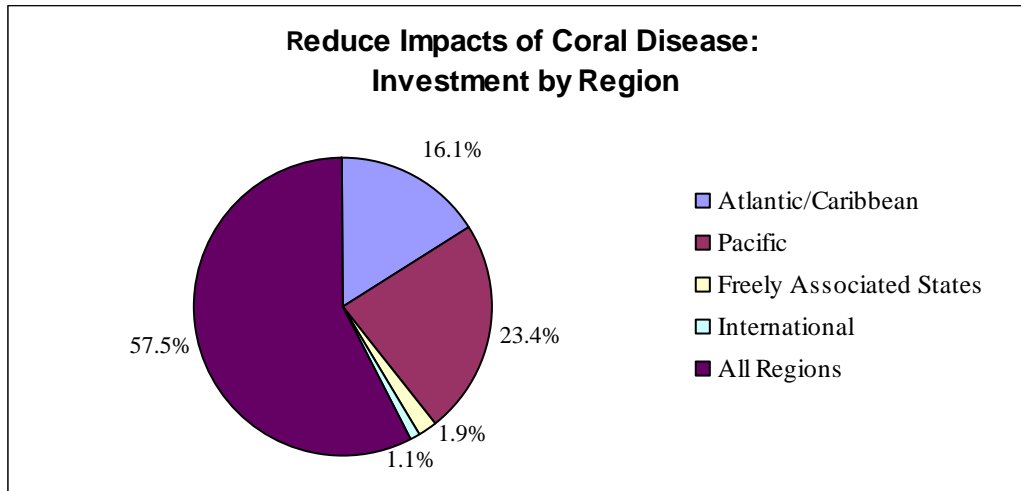


Exhibit III-4-10b. Distribution of Investments by Region, 2002-2006

b. Activities

The CRCP supports considerable activities conducted under the auspices of the Coral Disease and Health Consortium (CDHC), a multiagency partnership led by NOAA. The CDHC was established in 2000 to organize and coordinate national and international scientific resources, and has been a unifying effort in the coral community to address coral health issues. While many coral disease activities fall under the umbrella of the CDHC, CRCP supports additional independent and multidisciplinary disease research by NOAA scientists and external grant projects through the Coral Reef Conservation Grant Program. Activities in this subcategory include field surveys (research, monitoring and assessment of coral health and disease and bleaching), laboratory research, standardization of approaches and nomenclature, capacity building, training and development of educational and reference materials, development of a response network, and tool development/dissemination.

Field studies have focused on baseline surveys to identify types of disease present, establish surveillance programs to determine the incidence and impacts of disease and relationships with other stressors and ecosystem changes, and research on causal links and patterns of recovery following outbreaks. Atlantic baseline surveys began in 1998, with semi-annual to annual monitoring programs now occurring in the Florida Keys, Puerto Rico, USVI, the Flower Gardens, and Navassa Island. Baseline data on coral disease was first collected in the Pacific in 2004, and now includes Guam, CNMI, MHI, NWHI, American Samoa, and the Pacific Remote Island Areas.

Field studies in Puerto Rico are evaluating coral disease incidence and impacts across a gradient of human pressure, with comparative sites established in the Gulf of Mexico and the southern





Caribbean. These studies are being linked to research characterizing water quality and levels of toxins and contaminants. In addition, studies are being undertaken to compare disease prevalence inside and outside MPAs; linkages between diseases and coral community structure (e.g., size, condition, cover, and diversity of reef building corals); and effects of disease outbreaks, bleaching events, and loss of cover on reef fish assemblages.

In American Samoa, grant funding has supported the establishment of a Coral Disease Monitoring Program.

In CRCP-supported laboratory research, novel molecular approaches are being used in combination with traditional culture techniques to screen corals for change in microbial communities, identify potential microbial pathogens, develop DNA-based surveillance tests (molecular probes) to detect known bacterial pathogens, establish correlations between disease signs and pathogen presence, and identify environmental factors that effect microbial diversity and coral immune response.

Members of the CDHC are among the leaders in genomic studies to identify all genes in coral DNA, and understand their expression and regulation in normal and diseased states. Field surveys detect gross signs (e.g., lesions, death), but miss subtle changes in health (e.g., reduced performance in growth/reproduction). This strategy is designed to uncover fundamental mechanisms of disease, discern interactions between the host/agent/environment for possible mitigation actions, and provide early warning prior to a crisis.

Standardizing research methodologies has involved review of existing methodologies and standards applied to coral diseases and development of a process to translate advances in biomedical and veterinary sciences, pathology, toxicology, and biotechnology to coral disease and health research. Additionally, the CDHC has worked with partners to develop standardized frameworks for diagnostic criteria and coral disease nomenclature, including common field names and more detailed etiological nomenclature.

Two key strategic planning meetings have been held to address Caribbean and Pacific Coral Health issues and needs. The CDHC in collaboration with numerous partners also leads annual training workshops for graduate students, coral reef scientists, and managers. Key topics have included identifying disease in the field, advanced histopathology, ecological risk assessment, biomarkers, and physiological stress

The CDHC is implementing a network of Coral Disease Outbreak Investigation Teams to collect relevant epidemiological and environmental data along with biological samples for laboratory analysis to assist in diagnosing outbreak cause and significance in support of epidemiology efforts. Trained responders are now in place in Florida, Guam, Hawai'i and other locations. CRCP grant funding supported the development of a contingency plan for rapid response to coral disease and bleaching outbreaks in Hawai'i.





Work in the area of developing and disseminating information supports:

- Identification of early warning diagnostic biomarkers of pollutant exposure, prior to manifestation of disease lesions.
- Establishing scientifically accepted nomenclature and methodologies to precisely describe microscopic features of corals.
- New high resolution digital technology (Virtual Slides) to enable coral disease researchers to connect to experts and communicate in real time on issues of coral disease
- Enhancing the web-based Global Coral Disease Database.
- Expanding publicly available DNA sequences for coral, zooxanthellae, and associated microbes.
- Development of a Coral Culture Facility for propagation of genetic clones of model coral species (“lab rats”), coral cell lines and zooxanthellae for use by researchers.

c. Funding Recipients and Partners

Exhibit III-4-11 provides an example of CRCP’s funding recipients and partners who supported activities in this subcategory. There are over 100 additional partners.

Exhibit III-4-11 Reduce Impacts of Coral Disease Funding Recipients and Partners						
NOAA Offices	Other Federal Agencies	States and Territories	Academic Institutions	Non-Governmental Organizations	Inter-governmental organizations	Industry
<ul style="list-style-type: none"> • NOS – National Centers for Coastal Ocean Science • NMFS – Office of Habitat Conservation 	<ul style="list-style-type: none"> • U.S. Environmental Protection Agency • DOI – National Park Service 	<ul style="list-style-type: none"> • American Samoa • Guam 	<ul style="list-style-type: none"> • University of California, Davis • George Mason University 	<ul style="list-style-type: none"> • Perry Institute for Marine Science (NURP Center) 	<ul style="list-style-type: none"> • UNEP -World Conservation Monitoring Centre • World Bank Coral Disease Working Group 	<ul style="list-style-type: none"> • Haereticus Environmental Laboratory • UNEP WCMC
<ul style="list-style-type: none"> • NMFS - Pacific Islands Fisheries Science Center 	<ul style="list-style-type: none"> • DOI - U.S. Geological Survey 	<ul style="list-style-type: none"> • Hawaii 	<ul style="list-style-type: none"> • American University 			
<ul style="list-style-type: none"> • OAR - National Undersea Research Program (NURP) 	<ul style="list-style-type: none"> • Biscayne National Park 		<ul style="list-style-type: none"> • University of North Carolina, Wilmington (NURP Center) 			





**Exhibit III-4-11
Reduce Impacts of Coral Disease
Funding Recipients and Partners**

NOAA Offices	Other Federal Agencies	States and Territories	Academic Institutions	Non-Governmental Organizations	Inter-governmental organizations	Industry
<ul style="list-style-type: none"> NOS Oxford Laboratory 	<ul style="list-style-type: none"> Virgin Islands National Park 		<ul style="list-style-type: none"> University of Puerto Rico University of Virgin Islands 			

d. Outputs

- CDHC has developed a standardized process to investigate diseases, based on approaches applied to other wildlife diseases, including a system for naming and describing diseases based on field information and more detailed morphological and microbiological data. This is being implemented to aid in the detection of disease, description of the disease event and determination of causality.
- Coral disease baseline assessments have been conducted in each jurisdiction in the U.S. and our territories, and several locations now have disease monitoring programs.
- A manual and operational plan and training course to provide a rapid response to coral disease and bleaching outbreaks in U.S. waters has been established.
- Workshops to identify research needs and information gaps, enhance partnerships, increase awareness about diseases, and promote establishment of a unified multidisciplinary research community have been completed in the Atlantic and Pacific.
- Framework for a model coral culture facility has been established.
- Numerous products have been generated (see Appendix III-4), including: peer-reviewed and gray literature manuscripts and technical reports; oral presentations; data sets and reports submitted to CoRIS and included in monitoring reports and State of the Reefs reports; underwater disease identification cards and disease ID compact disk; coral histology atlas; three DVDs (Histological Techniques for Coral Tissues, Disease Outbreak Investigation: Coral Collection Techniques, a training video and Field Guide for Outbreak Investigations); and a children’s book on coral health and disease.
- DNA Sequence Data have been compiled and made available through the web at www.marinegenomics.org. This includes more than 20,300 expressed sequence tags from *Montastraea*, *Porites*, *Oculina* and *Acropora* and more than 19,000 coral-associated microbial 16S ribosomal sequences.





- The Global Coral Disease database was developed, a web-accessible GIS database with over 9,000 global records of disease occurrence compiled from publications, researcher submissions, and grey literature.
- White plague II disease distributions were mapped using GIS and a spatially explicit epidemiological model of disease dynamics developed.

Performance goals

The goals of this subcategory are to improve scientific understanding, information sharing, and response capabilities for diseases and develop tools to:

- 1) Detect and assess trends in the health of reef species at the necessary scales for management and policy development.
- 2) Determine baseline (non-stressed) measures of a typical, normal healthy coral, normal changes (e.g., seasonal, spatial and ontogenetic changes), and deviations that indicate an altered state.
- 3) Determine the causes and consequences of increasing disease frequency and distribution, including relationships between diseases and pollutants and other anthropogenic stressors.
- 4) Characterize disease processes at individual, population, and community levels, and identify critical control points for management strategies.

Performance metrics

Performance metrics to track this category include:

- Number of sites adequately characterized and undergoing routine monitoring in terms of ecological, biological, and chemical parameters (habitat quality, water quality, disease prevalence and impacts, and contaminant levels).
- Percentage of regions, reefs, and species with increasing population trends.
- Number of new or updated information products and tools related to diagnostic criteria, disease nomenclature, epizootiological databases, molecular probes, and biomarkers to characterize health and disease.
- Number of technical assistance or training sessions conducted for graduate students, scientists, and managers.
- Number of sites with fully functional coral disease outbreak investigation teams, including coordinators and response personnel with expertise in disease identification, field investigations and sample collection, processing, and analysis and with necessary research supplies and logistical capabilities.

e. Outcomes

- The CDHC has laid the framework for an integrated, multidisciplinary effort to advance our understanding of coral disease and to begin developing strategies to mitigate diseases.





This includes consistency among nomenclature and protocols allowing better regional evaluation of disease trends; networks of multidisciplinary scientists, managers and agencies working together; and increased research emphasis on biotic and abiotic impacts on coral health all set the stage for progress in this area.

- Creating Coral Disease Outbreak Investigation Teams enabled coordinated response to disease outbreaks in Florida in 2003 (*A. cervicornis*) and the Flower Garden Banks in 2005.
- Baseline data on disease occurrences are now available from numerous locations in the Pacific, including remote locations, which may provide a basis against which to compare disease prevalence in human impacted coral reef environments.
- Long term data sets are available from the US Caribbean on the emergence and spread of disease through reef environments, the impact of these diseases on affected corals and long-term (10 year) consequences on coral population structure and diversity.
- Comparative studies of differences in disease prevalence between the MHI and NWHI led to development and adoption of a Coral Disease and Introduced Species Prevention Protocol which requires cleaning and disinfection of dive gear and vessels prior to conducting permitted activities in the NWHI.
- A Southeast Florida Biomarker Study successfully tested the feasibility of using cellular diagnostics to link land-based sources of pollution to coral reef degradation and disease. This project is a first step in identifying the chain of causality between land-based pollutants, responses of individual reef-building corals, and health of coral reef communities.
- Potential vectors (coral predators) responsible for the spread of disease in the Caribbean have been identified and pilot efforts to remove these have demonstrated the feasibility of a possible management strategy.
- Several causative agents for coral diseases have been identified and possible manageable sources (e.g., human sewage) of these microbes are being evaluated.
- Identification of the role of disease in the decline of Caribbean *Acropora* spp. is a major factor leading to the adoption of new protective measures through the Endangered Species Act (see *Emerging Issues*).

f. Challenges

- Basic coral biology (e.g., physiology, genetics, population structure, senescence) is poorly understood. Our knowledge of how corals function normally is inadequate to distinguish between disease states and natural variations in condition. Additionally, our lack of understanding of the underlying mechanisms of coral pathologies inhibits our ability to manage the growing coral health problems.
- A relatively small number of scientists have expertise in coral diseases, and an even smaller subset has background in other medical disciplines. This has resulted in significant disagreement and confusion among various groups regarding disease identification, nomenclature, and field monitoring and laboratory research approaches.





Lack of standardized disease nomenclature has resulted in a proliferation of disease names and an inability to compare results across regions.

- Traditional approaches to identify causative agents for diseases may produce different results than molecular tools, leading to questions about the validity of previous results and divisions in the research community.
- Conducting disease research has inherent difficulties. Outbreaks are typically short-lived and by the time targeted research is underway, the factor that caused the original outbreak may no longer be present. Comprehensive surveys and sampling are labor intensive, and results may be inconclusive due to the general lack of knowledge regarding most diseases.
- Other logistical issues include:
 - Building and maintaining local capacity to respond to disease outbreaks.
 - Building and maintaining international partnerships due to dive reciprocity and foreign national policies.
 - Issues regarding acquisition of permits, especially when transporting samples across international borders.
 - Limited data sharing due to lack of comparability stemming from the use of different methods and nomenclature and intellectual property concerns.
- Another challenge is fighting the misconception that there are no options for managing coral disease. By understanding the interactions among agents of disease, host populations, habitat and human activities, control points can be identified and manipulated as disease management strategies.

g. Future Directions

- Improve capacity to respond to disease outbreaks and implement a reporting mechanism for alerts and responses.
- Continue development of a system of laboratories to rapidly process coral disease samples acquired during disease outbreak investigations, and continue work on diagnostic field and laboratory tools to detect disease states, identify causes, and predict disease outbreaks, impacts, and prognosis for recovery.
- Expand capabilities to produce coral and zooxanthellae cell lines in culture to determine how corals respond to particular stressors and to determine non-stressed levels of various physiological parameters.
- Broadly integrate relevant disciplines to determine causes and possible control mechanisms for disease, and continue education for coral research scientists.
- Apply integrated principles of epidemiology and risk analysis to coral health assessments and standardized monitoring programs.
- Develop new tools to diagnose the health and diseases affecting corals, including a suite of biomarkers and molecular probes for specific pathogens.





- Move to managing coral health, reducing disease occurrence, and mitigating impacts not through stereotypic routes of medication and treatments, but by identifying causes of coral diseases, particularly manageable anthropogenic and environmental stressors.





Appendix III-4

Sampling of Publications and Presentations Resulting from CRCP Funding

PUBLICATIONS

- Bruckner, A.W. and R.J. Bruckner (2006) The recent decline of *MONTASTRAEA ANNULARIS* (COMPLEX) coral populations in western Curacao: a cause for concern? *Revista de Biologia tropical*.54:45-58.
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- Galloway SB, Work TM, Bochsler VS, Harley RA, Kramarsky-Winters E, McLaughlin SM, Meteyer CU, Morado JF, Nicholson JH, Parnell PG, Peters EC, Reynolds TL, Rotstein DS, Sileo L, and Woodley CM. 2006. CDHC Workshop: Coral Histopathology II. National Oceanic and Atmospheric Administration, Silver Spring, MD. 83p.
- Polson, S.W., M.L. Lundqvist, and C.M. Woodley. 2006. Systematic approach to a disease investigation: Case example. Proceedings of the 10th International Coral Reef Symposium, 138-141.
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