CHAPTER 3

Supporting Strategic Research

GOAL: *Provide coastal and ocean managers with scientific information and tools to help conserve, protect, restore, and sustain coral reef ecosystems.*

Rationale for Action

In general, coral reef and other natural resource managers are responsible for reducing or mitigating impacts of ecosystem stressors while balancing environmental, social, and economic goals. Achieving this balance requires an understanding of the stressors to coral reef ecosystems, the ability to predict how these systems will respond to natural and anthropogenic changes, the identification of possible management strategies to mitigate negative impacts, and an evaluation of the effectiveness of these strategies after implementation. USCRTF research partners are committed to providing resource managers with science that is credible, relevant, and timely.

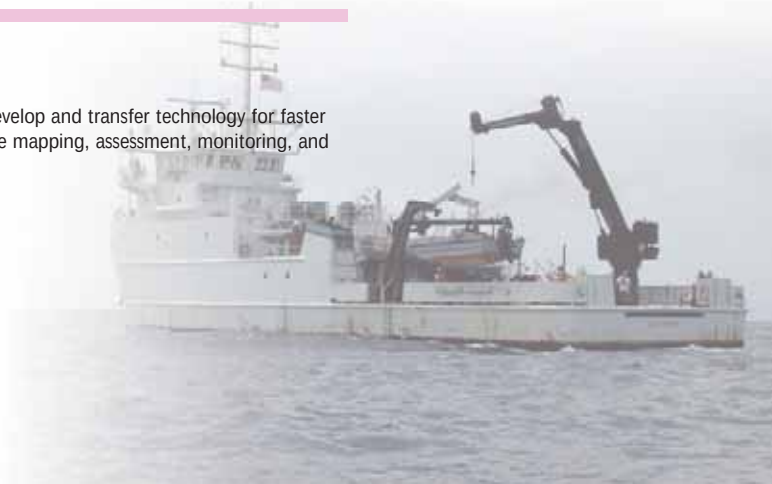
Strategic research enhances national, regional, and local capabilities to measure, understand, analyze, and forecast ecological change in response to natural and anthropogenic stressors. The goal of this research is to provide managers with tools to improve the integrity and sustainable use of the Nation's coral reef ecosystems. Such research requires a basic understanding of ecosystem structure, function,

OBJECTIVES

OBJECTIVE 1: Conduct a long-term regional and ecosystem-based research program to improve understanding of the processes that govern the structure, function, and health of coral reef ecosystems.

OBJECTIVE 2: Build capabilities to address such ecosystem-scale threats as disease, bleaching, and other sources of mass mortalities.

OBJECTIVE 3: Develop and transfer technology for faster and more accurate mapping, assessment, monitoring, and restoration.



productivity, and condition. It is also essential to understand the stressors contributing to declines in coral reef health and to analyze the social, economic, and institutional issues related to specific coral reef ecosystems.

Summary of Implementation

USCRTF members and partners, including NOAA, the U.S. Geological Survey (USGS), the National Park Service (NPS), the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense (DoD), the National Science Foundation (NSF), and many partners at academic and private institutions are conducting short-term strategic and long-term ecosystem-based research to understand coral reef community dynamics, the impacts of anthropogenic and natural stressors, and effective management actions. Short-term research answers specific questions and provides coastal and resource managers with the tools to enhance their ability to effectively manage and protect local coral reef resources. USCRTF short-term research has contributed to:

- Improved understanding of direct and indirect causes of coral decline;
- Emphasis on process-oriented research to separate natural variation from anthropogenic changes;
- Identification of specific physiological parameters indicative of nonstressed and stressed coral conditions;
- Development of tools to predict bleaching and identify resilient sites; and
- Understanding of the genetic linkages among species and populations and their relationships with oceanographic processes.

Long-term studies enhance an understanding of linkages among species and habitats within coral reef ecosystems, changes to these ecosystems resulting from natural and anthropogenic pressures, and the effects of management actions. Current efforts are providing the:

- Framework to determine the optimal placement, distribution, and size of marine protected areas (MPAs);
- Better understanding of the relationships between biodiversity and ecosystem function, including resistance and resilience to disturbances;
- Information on the processes affecting settlement and recruitment, growth and survival, movement patterns and ontogenetic shifts of ecologically and economically important coral reef organisms, and implications of management interventions; and
- Models to predict the cascading effects of zoning and other management measures on commercially and ecologically important reef fish and their habitats.

Highlights of Task Force Member Activities

OBJECTIVE 1: Conduct a long-term regional and ecosystem-based research program to improve understanding of the processes that govern the structure, function, and health of coral reef ecosystems.

Coral Reef Ecosystem Studies

In 2002, NOAA awarded grants to support two long-term regional Coral Reef Ecosystem Studies (CRES)—CRES Caribbean and CRES Micronesia. CRES Caribbean has begun to examine the effectiveness of MPAs, assess sedimentation and water

quality, and study reef demographics and community flux. Information from these studies will help local agencies develop and revise management efforts. CRES Micronesia (with a focus on Guam) is determining the classes and concentrations of coastal pollutants associated with watershed discharge of greatest concern to coral reef health. To develop integrated management schemes, this study is also collecting quantitative data on physical and chemical characteristics of coastal waters affected by watershed discharge.

Students learn standardized approaches and techniques for laboratory studies on coral diseases at a molecular techniques workshop held in Hawai'i.

USGS Tracks Sediment Movement on Reefs

As part of the Land-Based Sources of Pollution Local Action Strategy effort in Hawai'i, USGS is currently conducting studies to assess sediment movement from Maui and Moloka'i watersheds onto the surrounding reefs and to evaluate the impact this sediment has had on reef habitat. For example, results from the monitoring studies have established baseline rates at which sediment is transported during storm events. USGS researchers have found wave resuspension of sediment is a key process causing turbidity, which can be damaging to the reefs. USGS is also employing high-resolution mapping to provide baseline maps from which change over small areas (approximately 1 meter) and time frames (approximately 1 season) can be measured. Initial results suggest there is an extremely long residence time for sediment on the reefs. Even after implementation of conservation practices on land has decreased sediment delivery to surrounding reefs, reef recovery could take years.

Long-Term Studies on Ecosystem Dynamics

In 2002 and 2003, NOAA funded several multiyear research projects through its extramural partners that focused on understanding coral ecosystem dynamics and the impacts of stressors, optimizing fish stocks, and designing and evaluating MPAs. Using NOAA's Aquarius operated by the University of North Carolina at Wilmington Undersea Research Program Center and located in the Florida Keys National Marine Sanctuary (FKNMS), scientists conducted research to:

- Determine whether recruitment and other demographic variables can help predict viability of coral populations;
- Understand the impact of currents on water quality and the degree to which nutrients and pollutants affect offshore coral reefs and seagrass beds; and
- Improve understanding of the effects of coral predation, bleaching, and disease on the condition of coral reef ecosystems.

In the waters surrounding the Caribbean Marine Research Center's Lee Stocking Island, Bahamas, scientists conducted long-term research focused on

the spawning behavior of the commercially important Nassau grouper. The information derived from this research prompted the Bahamas Department of Fisheries to close the 2004 Nassau grouper fishing season, the first closure for the Nassau grouper in Bahamian waters.

NSF Initiates Long-Term Coral Reef Ecosystem Study in Moorea

NSF continues to support long-term studies of coral reef ecosystems, including a 22-year-long data set from the U.S. Virgin Islands (USVI), which seeks to identify the mechanisms underlying coral recruitment, importance of high-temperature anomalies in affecting recruits and established coral colonies, and a predictive model to forecast the composition of future reef ecosystems. In 2004, NSF funded the first Long-Term Ecological Research program focused on the dynamics of a coral reef ecosystem in French Polynesia, on the island of Moorea. This coordinated interdisciplinary program involves 20 investigators from both the United States and Pacific Island nations in addressing both the abiotic and biotic influences on the ecological performance of reef-building corals in the tropical Pacific. These targeted, long-term programs are in addition to a wide diversity of short-term (2- to 5-year) projects supported by NSF through its core programs addressing coral reef biodiversity, ecosystem function, population connectivity, and effects of climate change, among others.

OBJECTIVE 2: Build capabilities to address such ecosystem-scale threats as disease, bleaching, and other sources of mass mortalities.

Coral Disease and Health Consortium

The Coral Disease and Health Consortium (CDHC), an interagency partnership among NOAA, EPA, and the U.S. Department of the Interior, comprises more than 35 domestic and international partners. The partnership was formed at the recommendation of the USCRTF to organize and coordinate scientific resources and address ecosystem-scale threats to stony corals, such as disease and bleaching. NOAA convened the first CDHC workshop in January 2002 bringing together multidisciplinary field and laboratory scientists. At the workshop, scientists identified major gaps in the understanding of coral disease processes and identified and prioritized issue-driven research objectives to fill these gaps.

CDHC's *Coral Disease and Health: A National Research Plan* outlines strategic objectives, including:

- Creation of standardized terminology, methodology, and protocols;
- Research to define baseline measures of coral health, normal changes in physiology along environmental and physical gradients, and mechanisms of resistance and susceptibility to disease;
- Development of model coral species for controlled laboratory studies; and
- Development of diagnostic facilities, centralized data systems, and a website for information dissemination.

Implementation of the plan will improve understanding of the underlying mechanisms of coral pathologies. It will also increase the ability to manage coral diseases and bleaching by providing technical information on environmental and climatic stressors that may be mitigated through specific management actions and practical diagnostic tools. One example of a diagnostic tool is the *Field Guide to Western Atlantic Coral Diseases,* developed by NOAA to improve reporting of coral diseases by standardizing identification criteria and field nomenclature.

Rapid Response to Coral Disease Outbreak

A CDHC team, including ecologists and pathologists from DOI, EPA, NOAA, and the State of Florida, was mobilized in May 2003 in response to reports of a rapid die-off of *Acropora cervicornis*. Researchers conducted studies on the distribution and abundance of the event and its potential impacts on coral populations, collected samples for laboratory analysis, and recommended several potential management responses. The site was temporarily quarantined to reduce the potential for spread, and additional research is underway to understand the causes and consequences of the event.

Assessment of *Acropora spp.* Populations in the Caribbean

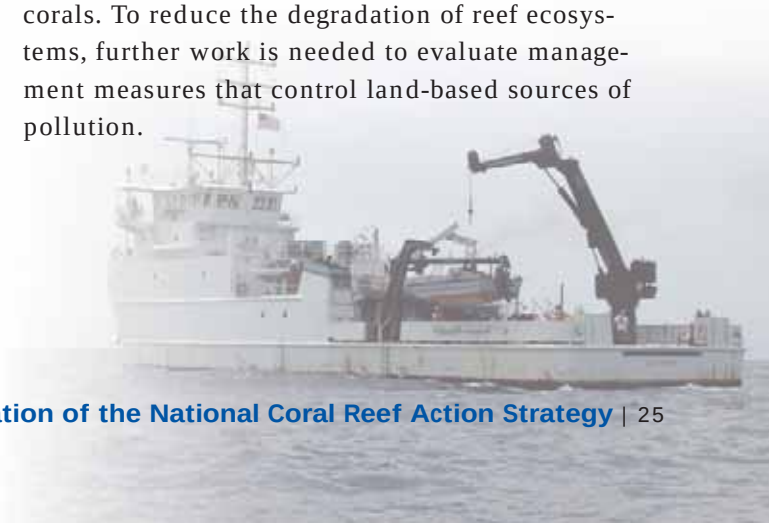
Populations of elkhorn coral (*Acropora palmata*) and staghorn coral (*A. cervicornis*) have declined drastically throughout the Caribbean region. In March 2005, these two species were proposed for listing as threatened under the Endangered Species Act. Ongoing monitoring efforts by USGS, NOAA, NPS, and other partners have documented losses of 80 to 98 percent of these species from a 1970s baseline. For instance, the aerial extent of elkhorn coral declined by 93 percent and staghorn coral declined by 98 percent between 1983 and 2000 within Looe Key National Marine Sanctuary, Florida. Although some areas in the USVI have experienced limited recovery since 2000 through sexual recruitment and the growth of fragments, others continue to show decline due to disease, predators, storms, and other factors. Between February 2003 and 2004, in the Virgin Islands National Park, 14 percent of monitored colonies died, 65 percent had disease, and 23 percent suffered broken branches. To assess potential recovery and population structure, NOAA scientists are examining genotypic diversity among elkhorn stands throughout the Caribbean, and USGS and NOAA scientists and their partners continue to monitor *Acropora spp.* populations in Florida, Puerto Rico, and the USVI, with an emphasis on prevalence of disease and its cause.

Understanding Coral Resistance to Extreme Environmental Stress

USGS scientists are examining factors that enable corals to resist extreme environmental stress (e.g., temperature changes, wide ranges of dissolved oxygen, intense ultraviolet [UV] radiation) in the U.S. National Park in American Samoa. Examining corals transplanted into different stress conditions on the reef improves understanding of coral acclimatization, adaptation, and susceptibility to environmental stress, and the effects of water motion, dissolved oxygen, and habitat characteristics are being evaluated to help explain survival rates. The results of these studies may play an important role in designing coral reef protected areas to mitigate the effects of climate change on coral communities.

Statewide Resource Assessment and Monitoring Program for Alien Algae

The Hawai'i Coral Reef Initiative Research Program established a statewide resource assessment and monitoring program, completed the first assessments of alien algae, trained managers to identify problem species, and examined the relationship between water quality and the health of coral reef ecosystems. These efforts have resulted in an improved understanding of how nutrients and herbivorous fish affect the balance between algae and corals. To reduce the degradation of reef ecosystems, further work is needed to evaluate management measures that control land-based sources of pollution.



Atmospheric Dust Events Tied to Outbreaks of Disease

USGS scientists, along with their partners and collaborators, have been assessing the relationship between African dust storm events and the outbreaks of disease on reef systems in the Caribbean. A pathogenic strain of the fungus known to cause sea fan disease throughout the Caribbean region has been isolated from air samples collected in the USVI during African dust episodes. The fungus has also been isolated from lesions on diseased sea fans in the USVI and from soil in the Sahel, a region in Mali, Africa.

USGS has also been conducting studies that would ultimately enable researchers to hindcast global dust events by analyzing past coral skeleton growth. Overtime, seasonal fluctuations and specific environmental conditions are recorded in a coral's skeletal composition. USGS researchers have used high-resolution laser ablation techniques to measure up to 20 trace elements found in coral skeletons. These elements will help researchers determine past environmental events. USGS will continue to develop this technology and environmental interpretation over the next few years.

New Technology To Improve Scientific Modeling *In Situ*

The Submersible Habitat for Analyzing Reef Quality (SHARQ), developed and patented by USGS scientists, documents reef health. SHARQ helps quantify changes in water chemistry resulting from metabolism in the coral reef community. Researchers can change the environmental conditions of the submersible habitat to observe the response of the reef communities. Data from *in situ* experiments, combined with remotely sensed map data, are enabling scientists to model the effects of global climate change, turbidity, nutrients, temperature, and grazing on coral reefs.

Disease Prevalence Along South Florida

Since 1997, EPA with NOAA and Florida's FKNMS has surveyed coral bleaching and disease in the Florida Keys and Dry Tortugas. The assessments determine the frequency and distribution of coral disease, loss, and bleaching in the Florida Keys Reef Tract. Comparisons between different geographic zones and reef types have shown that back-reef corals near Key West and the Lower Keys have experienced the most serious declines. Since 2003, disease monitoring has included an assessment of coral size and the percent of partial mortality to better understand the ecological effects of disease. Continued assessments of coral health and prevailing physical, chemical, and biological parameters will help efforts to increase coral recovery and survival.

Understanding Coral Bleaching

EPA has initiated laboratory and field research to quantify the effects of temperature and solar radiation on coral physiology. Various coral species and coral symbionts are maintained in culture facilities and exposed to varying temperatures and doses of UV radiation. Research on coral symbionts demonstrates reduced growth rates at higher temperatures and an exacerbation of this effect by additional exposure to environmental levels of UV–B. This finding reveals an interactive effect of temperature and UV–B on coral symbionts that may lead to a bleaching response. UV–B attenuation in seawater is measured at various depths near coral reefs in the Florida Keys and has been found significantly altered by the amount of colored dissolved organic matter (CDOM) in the water column. This alteration in attenuation creates an added degree of vulnerability for corals exposed to UV–B because CDOM is derived from land (watershed) and seagrass sources. Information from these studies may be

used to justify management decisions to stop shoreline alterations and other deleterious activities that artificially modify the organic content in waters over reefs.

Basic Science of Coral Reef Diseases and Bleaching

NSF continues to fund a wide diversity of projects related to coral reef health through its core programs. In 2004, some of the new projects funded included:

- A study of the dynamics of the symbiosis between corals and their algal symbionts, including how this symbiosis is altered by stress;
- Biotic and abiotic factors influencing the establishment of fungal diseases of sea fans and sea whips;
- Research on the fine-scale flow of water through the branches of coral colonies;
- Emerging viral diseases in spiny lobsters on Florida coral reefs; and
- Mechanisms of dispersal, recruitment, and recolonization of coral larvae and coral reef fish larvae.

OBJECTIVE 3: Develop and transfer technology for faster and more accurate mapping, assessment, monitoring, and restoration.

Developing New Techniques To Rapidly Assess Coral Reef Health

DoD is developing advanced techniques to quickly and safely assess the viability and health of coral reef communities. DoD's Analysis of Biophysical, Optical, and Genetic Diversity of DoD Coral Reef Communities Using Advanced Fluorescence and Molecular Biology Techniques project seeks to assess coral reef health by identifying and quantifying natural and anthropogenic stressors. It also seeks to assess coral reef health by collecting a library of baseline data on the physiological, biophysical, bio-optical, and genetic diversity of coral reef ecosystems near DoD installations. The nondestructive sampling technique will establish a relationship between the color proteins of coral and the physiological status of the reef to develop a spectroscopic index. The index will then be used to interpret spectral images collected by advanced fluorescence instruments mounted at permanent monitoring stations or adapted to remotely operated vehicles. By applying advanced technology to reduce the intrusiveness of data collection and improve collection speed, the project will lead to a better baseline understanding of coral reefs and enhance reef management by DoD personnel.

Ground Water and Surface Water Hydrologic and Circulation Models

Newly partnered multidisciplinary research teams from NPS and USGS are conducting a rigorous examination of environmental data. Using state-of-the-art ground water and surface water hydrologic and circulation models, the teams are documenting and mapping current reef conditions and quantifying and modeling threats to the reefs. These modeling tools will test hypotheses concerning the influence of pollutants on the health of Biscayne Bay, and decision support systems will integrate information from these models and ongoing experiments to guide decisionmaking by park managers.

Future Challenges

Future research activities are needed to focus on effectively responding to cumulative impacts,

linking strategic research, performing long-term ecological studies, and evaluating socioeconomics to improve science-based management responses to critical coral reef conservation needs. Research is needed to emphasize four major objectives:

Strengthen the link between science and management. Research is needed to enhance national, regional, and local capabilities to measure, understand, analyze, and forecast stressors and related ecosystem impacts affecting the integrity and sustainable use of the Nation's coral reef ecosystems. One aspect of this research should focus on ecosystem dynamics involving specific environmental and socioeconomic causes and consequences, including the development and testing of tools and approaches to mitigate negative impacts. NOAA and USGS are developing strategies to better guide research efforts. These strategies will be completed in 2005.

Integrate research and monitoring. Integration of research and monitoring is needed to conduct comprehensive assessments of coral reef ecosystem resources and cause-and-effect relationships. This approach is essential for differentiating between actual and perceived environmental issues.

Integrate socioeconomic research with biophysical science. Federal and state management agencies often face a lack of information on social, cultural, and economic issues. Research is needed to close these critical information gaps.

Evaluate the impacts of coral reef management decisions. Management can help sustain and restore the health of coral reef ecosystems and ensure their sustainable use. Research is needed on the effectiveness of management actions to determine their efficacy and to improve their benefits through an adaptive management process.