

Monitoring Coral Reef Health



GOAL: *Establish a nationally coordinated, long-term monitoring program to assess the condition of U.S. coral reef ecosystems by linking new efforts to successful, ongoing programs.*

Rationale for Action

Successful coral reef ecosystem conservation calls for management that is responsive to changes in environmental, economic, and social conditions. Such management requires implementation of monitoring programs capable of measuring and tracking indicators of ecosystem conditions over time. Integrated monitoring programs will also help assess the efficacy of management actions (e.g., no-take reserves, fishing gear restrictions, habitat restoration efforts) and provide

comparable data sets and products that can be used to adapt these measures.

The USCRTF's *National Action Plan To Conserve Coral Reefs* (2000) recommended establishing a nationally coordinated, long-term monitoring program for all U.S. coral reef ecosystems and developing mechanisms to disseminate the information to all users. The USCRTF considered this a priority action because no such coordinated monitoring program existed at the time. Since 2000, many USCRTF members have been working to realize this

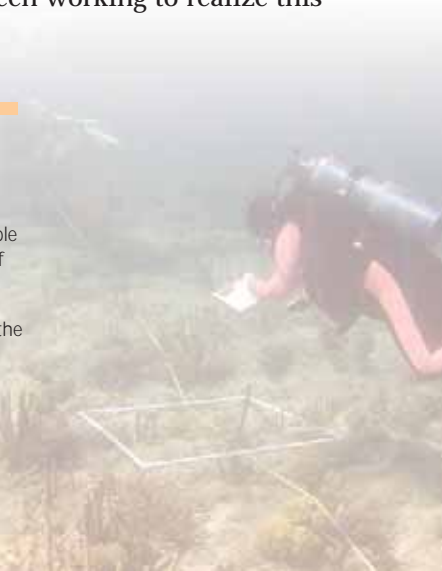
OBJECTIVES

OBJECTIVE 1: Working closely with partners and stakeholders, develop and implement a nationally coordinated, long-term program to inventory, assess, and monitor U.S. coral reef ecosystems.

OBJECTIVE 2: Develop a web-enabled data management and information system for U.S. reef monitoring and

data mapping with user-friendly GIS-based mapping and querying capability to present complex information in usable formats to all potential users while ensuring the security of sensitive place-based biological or cultural resource data.

OBJECTIVE 3: Develop and produce a biennial report on the state of U.S. coral reef ecosystems.



goal. Ultimately, this collaboration will allow the Nation to:

- Assess the current status of ecologically and economically important reef species and habitats;
- Track changes to species and habitats in response to environmental stressors and human activities;
- Evaluate the effectiveness of specific management strategies; and
- Forecast future conditions in a consistent manner to help design and evaluate effective management actions.

Summary of Implementation

USCRTF member organizations and their extramural partners have made progress in developing and

implementing a nationally coordinated, long-term monitoring program with emphasis on *in situ* monitoring conducted by the states and territories. The program aims to assist each jurisdiction in monitoring key parameters of water quality for benthic habitats and organisms (e.g., coral and algal cover), and associated biological communities (e.g., reef fish) identified as necessary for understanding the health of reef ecosystems (see table 4). Increasingly, these jurisdictions are also incorporating monitoring of meteorological and oceanographic variables. State agencies and academic partners have refined their monitoring approaches and increased the substantive and geographic coverage of these activities with grant and technical support from NOAA and the Environmental Protection Agency (EPA). Developed to meet the needs of local managers, these long-term monitoring efforts generally focus on populated coastlines where management is needed, and are

Table 4. Summary of Coral Reef Conservation Program State and Territory Coral Reef Ecosystem Monitoring Activities: 2000–2003

Overall program goals include support of water quality, benthic habitat, and associated biological community monitoring in all regions.

	2000			2001			2002			2003		
	Water quality	Habitat	Biological	Water quality	Habitat	Biological	Water quality	Habitat	Biological	Water quality	Habitat	Biological
American Samoa			X			X		X	X	X	X	X
Northern Mariana Islands		X		X	X		X	X	X	X	X	
Guam	X			X			X	X		X	X	X
Hawai'i		X	X		X	X		X	X		X	X
Florida								X	X		X	X
Puerto Rico		X	X		X	X		X	X		X	X
U.S. Virgin Islands		X	X		X	X		X	X		X	X
Freely Associated States									X	X	X	X

increasingly being refined to allow comparisons on a national level.

This baseline monitoring is complemented by a variety of other efforts including *in situ* monitoring in national parks, national wildlife refuges, and national marine sanctuaries by the U.S. Department of the Interior (DOI), NOAA, and their partners. These protected marine areas often provide key opportunities for more intensive monitoring and for investigating the results of management measures. For example, some of the longest coral reef monitoring data sets are from the Virgin Islands National Park. Recently, the National Park Service and NOAA have collaborated on expanding these monitoring efforts. The Florida Keys National Marine Sanctuary (FKNMS) Program, in partnership with EPA, NPS, the State of Florida, and numerous academic and nongovernmental partners, has perhaps the most intensive coral reef monitoring program in the United States. U.S. Department of Defense (DoD) monitoring of reef resources within its jurisdiction provides an additional complement that can be integrated into the national system.

NOAA, the U.S. Fish and Wildlife Service (USFWS), and states and territories have partnered to develop robust monitoring of remote reef areas. In the Pacific, NOAA leads annual monitoring cruises to the Northwestern Hawaiian Islands (NWHI) and biennial cruises to the Commonwealth of the Northern Mariana Islands (CNMI) and Guam (first cruise in 2003), American Samoa, the U.S. Line and Phoenix Islands (2002 and 2004), and Johnston Island (2004). In the Caribbean, NOAA and USFWS have collaborated on research and monitoring cruises to Navassa Island.


In 2002–2003, these collaborations covered a spectrum of monitoring and assessment activities ranging from the collection of large-scale, remotely sensed, near real-time measurements of oceanographic conditions to *in situ* monitoring of corals,



Scientists at work conducting multibeam mapping in the U.S. Virgin Islands in the dry lab of NOAA Ship *Nancy Foster*.

their associated biological communities, and the surrounding water quality. In 2002–2003, more than 50 complementary monitoring activities were supported by USCRTF organizations, including NOAA, DOI, DoD, EPA, states, territories, commonwealths, and the Freely Associated States. Furthermore, considerable support to monitor the Nation's coral reefs was made through contributions from nongovernmental organizations and private foundations (e.g., the Atlantic and Gulf Rapid Reef Assessment, Reef Environmental Education Foundation, and Reef Check Programs).

USCRTF satellite data collection monitoring is another source of critical information to coral reef managers in the United States and around the world. As part of the U.S. Integrated Earth Observation System, satellite remote-sensing technologies monitor sea surface temperatures and can therefore be used to help predict coral bleaching events on a global scale. These technologies are essential for monitoring on large spatial scales and for locations too remote to visit in a cost-effective manner. NOAA has partnered with other organizations to develop the Pathfinder Sea Surface Temperature project, a highly accurate record of



retrospective satellite-measured sea surface temperature being used to study subtle changes in ocean climate and reef conditions over time.

NOAA's Coral Reef Early Warning System (CREWS) deploys and maintains passive instrument arrays in domestic coral reef areas characterized by long-term monitoring and paleoclimatic information. CREWS instruments measure features of key coral reef areas to gain long-term, temporally intensive data coverage in near real-time. The developing and robust CREWS networks will establish long-term databases that coral reef marine protected area managers can use as tools in decision-making. Furthermore, data from these instruments can be used to validate satellite sea surface temperature products used for predicting coral bleaching.

Providing access to data is a key component of effective monitoring systems. To assist in delivery of this information, NOAA created the Coral Reef Information System (CoRIS), a web-enabled data and information access system for U.S. coral reef mapping, monitoring, and assessment. It will become the primary portal for NOAA coral reef information, and all programs that seek funding from NOAA's Coral Reef Conservation Program are obligated to provide data to CoRIS. CoRIS and the report on *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States* are, for the first time, providing a comprehensive outlook on U.S. coral reef ecosystems based on increasingly sophisticated monitoring programs.

Highlights of Task Force Member Activities

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Long-Term Monitoring at the East and West Flower Garden Banks

In 1988, DOI's Minerals Management Service (MMS) initiated a monitoring program at the Flower Garden Banks, a coral reef area located approximately 100 miles southeast of Galveston, Texas. The monitoring program was designed to monitor the long-term general health of the banks and possible effects of offshore natural gas and oil operations. The Banks were designated a National Marine Sanctuary in 1992, and since then MMS has continued this monitoring as a cooperative effort with NOAA. To date, results show the reefs are healthy and growing. In 2002, the monitoring program was extended to deeper reefs, down to 130 feet, with results showing living coral cover averaging 70 percent. MMS uses the results of this monitoring for lease stipulations, protecting the coral from possible adverse impacts of nearby oil and gas developments.

Reef Assessment and Monitoring Program Links Efforts throughout the U.S. Pacific

Scientists from NOAA and USFWS have collaborated with other federal, state, and territory agencies; universities; and nongovernmental organizations to initiate a long-term, comprehensive program to assess and monitor the coral reef ecosystems of the

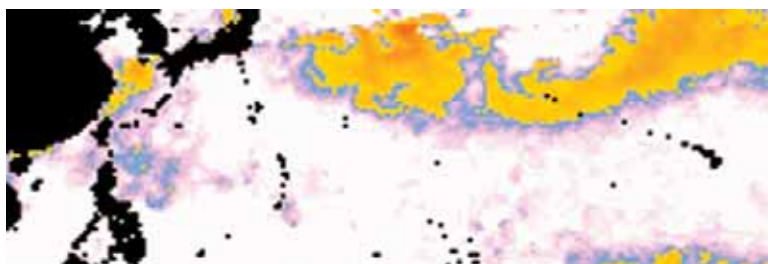
U.S. Pacific. Annual or biennial NOAA cruises have studied coral reef ecosystems of 42 islands, atolls, and reefs in the NWHI, American Samoa, Guam, the CNMI, and the remote National Wildlife Refuges in the Pacific, including sites explored for the first time, making this collaboration the most comprehensive, large-scale reef monitoring program in the world. Multidisciplinary monitoring efforts include detailed assessments of corals, other invertebrates, fish, and algae using a variety of methods.

Integration of concurrent observations of marine resources and their benthic and oceanographic habitats allows improved understanding of the spatial and temporal variability and complex biophysical linkages controlling these ecosystems. The program has greatly expanded the inventory of species known from these islands and discovered invertebrate and algae species new to science. Recent publications from the monitoring in the NWHI have quantified, for the first time, the high natural abundance of apex predators (and contrasted this with the depauperate state in the Main Hawaiian Islands) and their effects on prey fish; the importance of shallow, wave-protected microhabitats as nurseries for the juveniles of many species; and the relative importance of the three northernmost atolls as centers of endemism and recruitment sinks within the archipelago.

Over the past 4 years, these monitoring efforts have yielded 20 published manuscripts, 7 manuscripts in review, 13 manuscripts in preparation, 12 technical reports, and 61 oral presentations at scientific and resource management workshops and conferences. In October 2003, the USCRTF passed a resolution commending the Pacific monitoring program and calling for its continuation and expansion to the Freely Associated States.

Figure 2. Sea Surface Temperature Anomaly Map

An example of a sea surface temperature anomaly product used to convey potential bleaching events. This map of the Pacific Island region is a NOAA 50-kilometer HotSpot product for September 2002.



Near Real-Time Information Directs Field Monitoring Activities and Predicts Bleaching in the NWHI

In July 2002, NOAA's Coral Reef Watch (CRW) satellite and *in situ* sensors detected a sea surface temperature anomaly building in the central North Pacific Ocean (see figure 2). The anomaly grew as temperatures passed the threshold for coral bleaching at Midway Atoll National Wildlife Refuge on August 1 and remained above the threshold for more than a month. Based on the accumulated heat stress observed, CRW issued a coral bleaching warning on August 7. On September 8, NOAA, DOI, the State of Hawai'i, and other partners embarked on the fourth NWHI Reef Assessment and Monitoring Cruise. Although the CRW bleaching report did not instigate the cruise, the cruise plan was altered to focus attention on shallow reef habitats based on the reports. The fieldwork took place just 2 weeks after the thermal stress abated, and the scientists found evidence of extensive fresh coral bleaching at several atolls at the northwestern end of the island chain (Midway, Kure, and Pearl and Hermes). This first record of mass bleaching at these subtropical northerly reefs surprised many

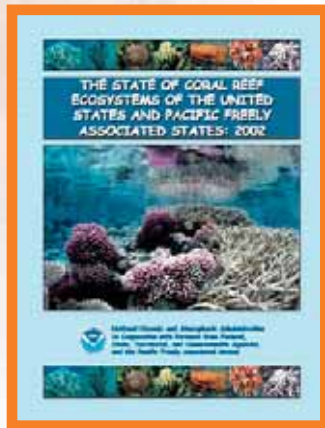
scientists although CRW had predicted the likelihood of the event. Documentation of this bleaching event has increased our knowledge of the resistance and resilience of different coral species and reef types in the NWHI and can assist in making management decisions as to which areas need increased protection.

FKNMS Zone Monitoring Program Completes Ecosystem Assessment

Data from the FKNMS Zone Monitoring Program, which is supported through NOAA and EPA, were used to complete an integrated assessment of the Florida Keys coral reef ecosystem in March 2003. This report presents results from 7 years of monitoring under EPA's Water

Quality Protection Program and 4 years of data from the FKNMS Zone Monitoring Program. The assessment addressed large-scale oceanographic processes, water quality trends, and the abundance, distribution, and community structure of coral, reef fish, and invertebrates. Additionally, the assessment included an analysis of long-term monitoring data collected in associated seagrass and other habitats. EPA and NOAA have also been collecting data on bleaching and disease through this program since 1997.

Much of the data was collected to assess the effects of zoning along the Florida Keys reef tract. For example, data collected on the density of yellow tail snapper showed that mean density of snapper was significantly higher in fully protected zones. This document stands as a model for collaborative integrated monitoring and its results will be used to compile the next biennial report on the state of



coral reef ecosystems. To view the full report, visit the FKNMS website at http://www.fknms.nos.noaa.gov/research_monitoring/welcome.html.

National Coral Reef Institute Expands Annual Monitoring in Florida

The National Coral Reef Institute, with funding from NOAA, is partnering with the State of Florida to conduct yearly monitoring at 10 permanent sites in Miami-Dade, Broward, and Palm Beach Counties. The monitoring follows the formal protocols developed by the Fish and Wildlife Research Institute (FWRI, formerly the Florida Marine Resource Institute) for the Coral Reef Evaluation and Monitoring Program (CREMP). The Florida Keys CREMP began in 1996 and is a cooperative program among NOAA, EPA, and FWRI. The expansion of CREMP to southeast Florida is closing monitoring gaps in Florida's coral reef ecosystems. NOAA has also expanded fish surveys to include these southeast Florida reefs. Data from the southeast CREMP will be incorporated into the current CREMP database, enabling reef researchers and state and county managers to better understand status and trends in Florida's coral reef system from the Dry Tortugas up to and including Palm Beach County.

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NOAA Unveils Comprehensive, Consolidated Website for Coral Reefs

In 2002, NOAA unveiled the Coral Reef Information System (CoRIS), a new data management system

and Internet site designed as a single access point for data and information on coral reefs. In the past, users faced a confusing array of more than 50 NOAA websites regarding coral reefs. Now all of the information is available on a single site. Backed by powerful search engines and keyword browse lists, CoRIS uses a GIS-enhanced information system to provide users with a single, easily accessible web portal to NOAA's coral reef resources. By cataloging and indexing metadata and summarizing data holdings, CoRIS guides users to the desired data and information and ensures the data will be available in the future.

The website provides access to more than 4,000 aerial photos of coral regions, bathymetric products, benthic habitat maps, fish census data, tide stations, paleoclimatological studies, photo mosaics, coral reef monitoring data, bleaching reports, and more, including links to non-NOAA information. Since CoRIS went online in late 2002, it has become a featured website in *Science* and was chosen as one of the December 2003 "Digital Dozen" (a list of 12 exemplary websites for educators selected by the Eisenhower National Clearinghouse). CoRIS can be accessed at <http://www.coris.noaa.gov>.



States and Pacific Freely Associated States, the first national assessment of the condition of U.S. coral reefs. The report identified increasing risks to reefs, particularly in certain hot spots located near population centers. In addition, the report indicated that every U.S. reef system suffers from both human and natural disturbances. Developed by 38 coral reef experts and 79 expert contributors, the report assessed the health of reef resources by ranking threats in 13 geographic areas and identifying ongoing management efforts. It established a baseline for subsequent biennial reports on the status of U.S. coral reefs, and the second biennial report is under development for release in summer 2005.

Future Challenges


Although implementing the Strategy has resulted in a wide range of monitoring activities conducive to integration (e.g., CoRIS, *The State of Coral Reef Ecosystems*), the degree to which these activities are unified is still relatively low. The many partners involved in coral monitoring are systematically working on remedies, including a measured and deliberate drive toward standardizing minimum parameters being measured by all programs in all locations.

Establish common monitoring parameters and indicators. To understand the status of coral reef resources on large spatial scales, track reef conditions over time and between sites and regions, and accurately forecast future conditions at an integrated nationwide level (e.g., U.S. coral reef ecosystems), it is necessary to conduct field monitoring in a consistent and comprehensive manner. This requires the use of monitoring protocols, parameters, and indicator species structured around methods that can be linked together to contribute to regional and global networks, while providing information needed for effective management at local levels. The actual protocols and methods depend on the information needed for the specific

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First National Assessment of U.S. Coral Reefs Released: Report Highlights Key Actions and Ranks Threats to Reefs

In 2002, NOAA and its USCRTF partners released *The State of Coral Reef Ecosystems of the United*



reef, size of the area, questions asked, and available financial and human resources. However, the protocols should include specific biological, physical, and socioeconomic indicators and data standards that can be easily monitored and reported in a national report on the state of U.S. coral reefs. The first step toward this goal requires multiagency roundtable discussions to develop a list of criteria, indicators, and an implementation plan. It is important to note that developing and implementing even a short list of standard protocols will require substantial investment.

Expand CoRIS. NOAA's CoRIS provides a powerful tool to access coral reef monitoring data. The value of this website will increase as it is expanded to include the full range of monitoring data and is linked to other data systems, including USGS's National Biological Information Infrastructure and the international ReefBase.

Integrate monitoring tools. Using available technologies is essential to integrating monitoring data

into a robust assessment of systemwide conditions. For example, NOAA, through its Coral Reef Ecosystem Integrated Observing System (CREIOS), which encompasses the CRW and CREWS initiatives, has developed software that links data from *in situ* platforms and satellites to provide information to coral reef management and research communities. CREIOS is working to integrate data from these instruments and field-based biological monitoring activities into an environmental decision support system. This collective monitoring network could be expanded beyond U.S. coral reefs to include stations in other countries, thereby making use of available cooperative instruments (e.g., World Bank/Global Environment Facility). Recognizing that the interconnectivity of reefs extends beyond mere political boundaries is an important step toward understanding the dynamics of coral systems and implementing effective management actions in the future.