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.

The overarching goal of strategic research on coral reef ecosystems is to provide managers with tools to improve the integrity and sustainable use of these ecosystems. The USCRTF and its many partners are conducting short-term strategic and long-term ecosystem-based research to:

1. Understand coral reef community dynamics and the impacts of human-caused and natural stressors;
2. Identify possible management strategies to mitigate negative impacts; and
3. Evaluate the effectiveness of these management actions after they are implemented.

Strategic research enhances national, regional, and local capabilities to measure, understand, analyze, and forecast ecological change in response to stressors. Targeted research answers specific questions and provides coastal and ocean managers with the tools needed to provide effective management and

A researcher with the Moorea Coral Reef Long Term Ecological Research site surveys fishes on the fore reef along the north shore of Moorea, French Polynesia. The data collected during these surveys will be used by scientists with the MCR LTER site to track long term changes in the fish community associated with Moorea's coral reefs and improve predictions of how coral reefs and coral reef communities will respond to changing environmental conditions.

protection of local coral reef resources.

To guide priority setting for coral reef ecosystem research, NOAA published the NOAA Coral Reef Ecosystem Research Plan for Fiscal Years 2007 to 2011. The plan provides coastal and ocean managers, scientists, and policymakers with the up-to-date scientific information to address the threats facing coral reef ecosystems and identifies priority research needed to advance management action. Covering all coral reef ecosystems under the jurisdiction of the United States and the Pacific FAS, the plan presents a national perspective on the research needed to address the range of stresses affecting the condition of coral reef ecosystems, summarizes the management issues and information needs driving research at the regional level and focuses on the use of research for effective implementation of ecosystem-based management strategies.

Research has improved knowledge of both global coral reef coverage and coral health. Coral disease and restoration research provides information to resource managers on the causes, predisposing factors, and effects of diseases of coral reef organisms. The Coral Disease and Health Consortium (CDHC), established in response to a need recognized by the USCRTF, has been instrumental in developing emergency response protocols to assess and identify potential disease outbreaks in corals. The National Science Foundation (NSF), in addition to contributing over $10 million per year for research and infrastructure to study coral reefs and their associated ecosystems, has initiated the first Long-Term Ecological Research (LTER) site focused on the dynamics of a coral reef ecosystem in French Polynesia; the site addresses the abiotic and biotic influences on the ecological performance of reef-building corals in the tropical Pacific. Other key research activities focus on understanding population connectivity of reef organisms and coral disease to provide fundamental

knowledge to guide management efforts and design of marine protected areas.

Accomplishments by Objective

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.*

NSF established the U.S. Moorea Coral Reef LTER site through the University of California, Santa Barbara. Research at the site will help scientists better understand coral reef processes affecting the reef ecosystem, the nature of animal and plant community structure and diversity, and the factors determining the abundance and dynamics of related oceanic populations. The Moorea Coral Reef program is coordinating with the Kenting Coral Reef International LTER site in Taiwan to conduct collaborative research.

From 2004 to 2006, NOAA—in partnership with the National Undersea Research Program Centers at the University of North Carolina at Wilmington, University of Hawai'i, and the Perry Institute for Marine Science—funded several multi-year research projects focused on understanding the processes governing the structure, function, and condition of coral reef ecosystems. Project scientists conducted research to:

> *Assess the threats to remnant populations of Acropora palmata in the upper Florida Keys National Marine Sanctuary and to establish the ecological significance of each population;*
>
> *Evaluate the utility of marine protected areas as tools for fisheries management by testing whether demographic rates of the schoolmaster snapper (Lutjanus apodus) change as a function of population size, documenting the occurrence of the spillover effect, and examining any underlying ecological mechanisms causing this effect; and*
>
> *Determine the current status of the Hawaiian black coral fishery using both historical and new perspectives, as well as the impact of the alien snowflake coral (Carijoa riisei) on black coral beds.*

The Coral Reef Ecosystems Studies (CRES) program, sponsored by NOAA, solicits proposals for projects addressing the causes of regional declines in coral abundance and degradation of coral ecosystems. The intent of this program is to provide timely and high-quality scientific results for use in developing alternative management strategies to restore and protect coral reef ecosystems. During 2004-2006, CRES funded research in the Micronesia region of the Western Pacific. This project contributed 28 peer-reviewed publications, and built local capacity by supporting the graduate work of four students, three them native Pacific Islanders. The project also provided data support and educational outreach for watershed protection in Umatac Bay, Guam; established watershed and marine protected areas in the Enipein area Pohnpei, FSM; assessed coral reef damage cases in Hawai'i and Micronesia; and initiated a nine-month educational campaign for the Micronesian region. The CRES—Micronesia project also made significant contributions to policy and management in Palau. This project served as the basis for a local moratorium and pending national legislation related to the clearing and grading of mangroves that was having documented adverse impact on the near-shore coral reef ecosystems. This work is one notable example of how effective translation of research can inform policy development and implementation.

Palmyra Atoll Research Consortium Palmyra Atoll National Wildlife Refuge, Central Pacific Ocean

Representing one of the world's most pristine coral reefs, Palmyra Atoll has been described as "a crown jewel of the Central Pacific." Its diverse marine habitats feature steeply sloping coral reef walls, extensive and shallow-perimeter coral reef shelves, reef pools, sand flats, and protected lagoons. Palmyra's submerged coral reefs support three times the number of coral species found in the Caribbean and Hawai'i, and five times the coral species found in the Florida Keys.

Palmyra Atoll offers an extraordinary opportunity for scientific studies aimed at protecting coral reef ecosystems in the Pacific and around the world. Palmyra's location near the equator, its phenomenal biodiversity, and its history of minimal human impact make it an unparalleled laboratory to study vital issues affecting tropical island ecosystems, as well as global challenges such as climate change.

Recognizing these unique conditions, scientific researchers capitalized on coral reef study opportunities by forming the Palmyra Atoll Research Consortium (PARC) in July 2004. This partnership between the USFWS and The Nature Conservancy involves researchers from around the globe. With the recent addition of a privately funded $1.5 million research station, Palmyra has a new future as a world-class site for scientific study.

Working together with the USFWS, the Consortium has grouped its proposed studies under three themes: (1) biodiversity of Palmyra; (2) terrestrial/marine interface; and (3) marine biology, climate change, and biogeochemical structure. The largely pristine condition of Palmyra can provide insight about how unaltered ecosystems are structured, how they function, and how they can most effectively be preserved (Agardy, 2001). Research at Palmyra Atoll National Wildlife Refuge will help answer many questions about the ability of coral reef environments to survive into the future.

Research conducted at Palmyra Atoll National Wildlife Refuge can help answer important questions concerning the global health of coral reef ecosystems.

NASA's Airborne Remote Sensing of Coral Reefs for Ecosystems Research

NASA's suborbital assets have been used to fly over strategic coral reef sites to collect high-resolution imagery to support coral reef ecosystem biodiversity research. The goal of this research is to better understand how light scatters and reflects in shallow aquatic ecosystems—including coral reefs, seagrass beds, and mangrove stands—so current and future remote sensing sensors and data can be optimized for ecosystem research in the coastal zone. Further, there is a need to identify the spatial resolution detection limits of remote-sensing instruments for discriminating coral assemblages. The airborne sensors consist of a high-resolution digital camera system and the Airborne Visible Infrared Imaging Spectrometer (AVIRIS), a hyperspectral sensor. NASA's airborne platforms supporting these payloads include the ER-2 and Twin Otter aircraft.

NASA's airborne missions in 2004 included the Florida Keys following Hurricane Charley, and La Parguera and Mayaguez Bays in Puerto Rico as well as much of the north, south, and west coasts of Puerto Rico, and the north and south coasts of Vieques Island. Airborne missions in 2005 included Kāneʻohe Bay on Oʻahu, Hawai`i; Culebra Island, Puerto Rico; La Parguera, Puerto Rico; Buck Island and the northeast coast of St. Croix, USVI; the entire island of St. John, USVI; and Vieques Island. NASA, NOAA, DOI, and university scientists conducted field sampling coincident with the overflights for atmospheric correction and validation of the AVIRIS data. In addition, field spectra were collected underwater for water column characterization and developing spectral libraries of benthic types (coral, algae, and seagrass) to relate to the AVIRIS data for creating benthic habitat maps and analysis within and between habitat spectral variations. The expected outcomes of this research for coral reef ecosystems are improved

interpretation of coral reef habitat variability and biodiversity and enhanced benthic habitat classification algorithms. This effort also will contribute to studies of coastal relationships, including assessing coastal habitat composition and distribution, application of remote-sensing techniques to study land-sea interactions, and ridge-to-reef habitat assessments.

More information is available online at: http://earthscience.arc.nasa.gov/sge/coral-health/.

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

The National Sea Grant College Program works with local communities to understand and prepare for the effects of coastal hazards, including hurricanes, climate change, and other factors affecting the health of coral reefs. Through integrated research, outreach, and education efforts—particularly in Hawai'i, Florida, and Puerto Rico—Sea Grant is working with local communities and decision makers to build capacity and understanding of ecosystem-scale threats. In addition, as part of the 2006 work plan for the Sub-committee for Integrated Management of Ocean Resources (SIMOR), Sea Grant is facilitating interagency Regional Research and Information Plans to identify the top-priority areas to build research and outreach capacity.

In American Samoa, disease surveys were initiated in 2004 at seven sites around Tutuila to document the baseline levels of disease in the major genera of corals and coralline algae. The same seven sites were resurveyed in January 2005 to look for seasonal differences in disease levels. From these surveys, 15 coral disease states and two crustose coralline algae diseases were described. A member of the NOAA-funded Coral Reef Monitoring Team was trained to continue disease monitoring in the territory.

Objective 3: *Develop and transfer technologies for faster and more accurate mapping, assessment, monitoring, and restoration.*

Targeted Research: Water Temperature Fluctuation, Coral Bleaching, and Reef Resilience

DoD funded a multi-phase research project to develop new technology for monitoring coral reef health, focusing on how warm temperatures cause coral bleaching at the biochemical level. Objectives of this project included:

> *Developing advanced techniques to quickly and non-destructively assess the viability and health of coral reef communities, with capabilities to identify and quantify natural and anthropogenic stresses;*
>
> *Developing prototypes of Fast Repetition Rate Fluorosensors for permanent underwater monitoring stations and ROVs or Diver Propulsion Vehicles; and*
>
> *Collecting a library of baseline data on physiological, biophysical, bio-optical, and genetic diversity of coral reef ecosystems near DoD installations.*

Laboratory work was completed to develop a baseline for measuring the impact of two common natural stresses (elevated temperature and excess light) on the photosynthetic activity and fluorescence of selected coral species. Field trips were then completed in both the Caribbean and Indo-Pacific regions to validate the process. The results showed that Fast Repetition Rate Fluorosensors can detect physiological changes resulting from heat and light stress in target coral species. The researchers are expanding the baseline data set to evaluate

Dr Curt Storlazzi from USGS measuring water quality in Hanalei Bay, Kauai.

a wider range of species and a range of anthropogenic stresses.

The U.S. Environmental Protection Agency (EPA) has developed laboratory and field tools to quantify exposure and response of coral reefs to elevated temperature and ultraviolet (UV) radiation. Interactive effects have been demonstrated on both intact corals and their photosynthetic algae. A new technique based on remotely sensed ocean color was used to map UV exposure of coral reefs during different seasons and locations in the Florida Keys where greater UV protection was linked to healthier coral condition. Exposure and condition measurements from the Florida Keys are being examined through geospatial analysis to determine the regions, reefs, and species most vulnerable to future declines.

In American Samoa, the National Park of American Samoa and the University of Hawai‘i worked with the Governor’s Coral Reef Advisory Group (CRAG) to build a field research station in the Manu‘a Islands. The field station offers advantageous conditions for scientific research not common elsewhere in the U.S. system including diverse Indo-Pacific coral reefs with over 200 species of corals and relatively few impacts due to other anthropogenic factors. CRAG has coordinated and/or provided partial funding for several coral studies in American Samoa, including temperature tolerance of corals, bleaching and disease susceptibility due to land-based nutrient enrichment, nearshore settlement patterns of coral larvae, genetic variation among corals in differing habitats, and UV tolerance. One such study, a three-year effort led by the University of Hawai‘i, will address some of the key scientific questions about coral bleaching. EPA completed a hypothesis-driven monitoring project to assess the relative effects of temperature, water quality, and protected area status on coral bleaching and recovery. The project findings, available in

fall 2007, address coral reef management in the context of climate variability. A USGS project assessed the potential for coral adaptation and the physiological resilience of corals to high temperatures in American Samoa's lagoon pools. This research will provide an understanding of the sensitivity and adaptability of coral reef ecosystems to environmental changes and provide insight into which coral reefs are most important to protect from disruptive human activities, informing future site-specific protection efforts.

Rising ocean temperatures threaten all U.S. coral reefs with coral bleaching. The widely distributed and isolated locations of many coral reefs preclude us from using instruments to monitoring conditions on all U.S. coral reefs. Since 1998 NOAA has used polar-orbiting satellites to monitor the thermal bleaching stress that leads to coral reef bleaching. Research into the relationship between thermal stress and bleaching resulted in operational products that NOAA provides via the internet. These include night-time only sea surface temperatures and anomalies, and two products targeted directly at coral bleaching: the Coral Reef HotSpot anomaly product (became operational in 2002), the Degree Heating Week accumulated heat stress product and Virtual Stations webpage (became operational in 2003), and the Satellite Bleaching Alert e-mail system (became operational in 2005). Starting in 2006, NOAA began making gridded data products in HDF and Google Earth formats available as well. This suite of remarkably accurate tools for monitoring potential coral bleaching events has been highly used by researchers and managers alike. NOAA supports these coral bleaching products on a 24-hour, seven-day operational basis. These products proved invaluable to researchers and managers who were able to mobilize resources to assess the record-breaking 2005 Caribbean bleaching event, and alerted monitoring teams of the 2002 and 2004 bleaching events in the remote Northwestern Hawaiian Islands. Further research has focused on refining these products to improve their ability to predict coral bleaching events.

Ocean acidification, caused by increasing levels of atmospheric carbon dioxide (CO_2), can impact coral reef ecosystems by slowing the rate at which corals build and maintain their skeletons, thereby reducing their resiliency. Several USCRTF member agencies are conducting research on impacts of increasing atmospheric CO_2 levels on coral reefs. In collaboration with researchers at the University of Hawai'i, USGS completed a long-term, small-scale controlled investigation of the effects of ocean acidification on coral reef organisms. These studies indicate that projected increases in the partial pressure of CO_2 (pCO_2) in the oceans resulting from anthropogenic burning of fossil fuels could have severe impacts on coral reef ecosystems with critical levels being surpassed by 2100 (Yates & Halley 2006). Other studies examining the community-scale impact suggest net-reef calcification could decline to approximately one-half to two-thirds of preindustrial rates by the year 2100 (Langdon and Atkinson, 2005). There is also concern that the recruitment and growth of encrusting coralline algae, which are very important occupiers of hard substratum on reefs across the globe, could also see a severe reduction.

NOAA data products from three in situ monitoring stations within the Integrated Coral Observing Network provide near real-time (hourly) data in the waters near Lee Stocking Island (LSI), Bahamas; St. Croix, USVI; and La Parguera, Puerto Rico. At the LSI station, the installation of a Pulse Amplitude Modulating fluorometer and a pCO_2 sensor to calculate CO_2 have improved the understanding of the impacts of increased

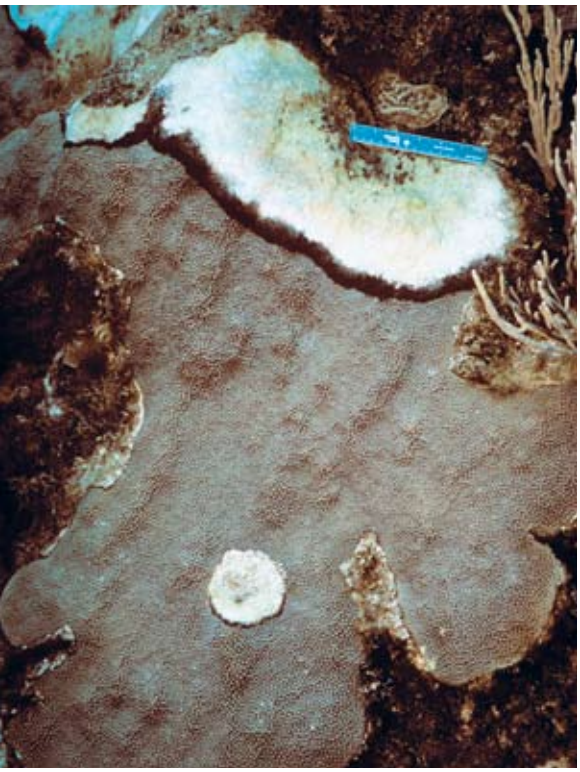
Integrated Coral Observing Network (ICON) Stations are near real-time monitoring stations with an emphasis on data processing for the development of ecological forecasting models. The instruments provide unique in situ information that will aid in improving NOAA's forecasting capabilities (e.g. coral bleaching and climate change).

temperature and light on corals and the effects of ocean acidification on coral growth rates, respectively. In the future, researchers plan to deploy similar instruments in Jamaica, Little Cayman, Antigua, and elsewhere in the Caribbean.

Work conducted by the NASA Interdisciplinary Study Coral Reef Assessment using NASA's Earth Observing System platforms and numerical models brings together the expertise of numerical modelers and remote sensing specialists to examine larval connectivity, coral bleaching, and sediment dispersal in three large coral reef systems, including the Mesoamerican Barrier Reef System, the Great Barrier Reef, and reefs and lagoons of New Caledonia. Recent work includes reef connectivity modeling using Sea-viewing Wide Field-of-View Sensor (SeaWiFS) and Landsat data for the Mesoamerican Barrier Reef System. Modelers addressed both normal and hurricane conditions (Tang et al. 2006, Sheng et al. in press). For the Great Barrier Reef, Landsat data are used to improve understanding of the shallow bathymetry around and on top of reefs. For New Caledonia, in situ optical data and MODIS and Landsat images are used to refine and validate sediment concentrations modeled in the water column.

Research Efforts in Coral Disease

Disease is one of the most significant and growing biological threats to tropical coral reefs around the globe. Although a low level of disease is normal, the abundance and spread of coral disease is escalating, susceptible species are increasing in number, and mortality is escalating beyond the level expected for healthy populations. In addition, observation effort has increased in the past decade. Between 1972, when coral disease was first discovered, and 1999, a total of 2000



left image: Black band disease on a colony of mountainous star coral (Montastraea faveolata)

right image: Close-up of black band disease on starlet coral (Siderastrea siderea)

disease observations were published. Between 2000 and 2005, there were 6000 new records of disease. Since 1999, the number of coral genera reported with disease increased by 25 percent (39 total), the number of affected species increased by 45 percent (148 total), and the number of countries with reports of disease increased by 17 percent (63 total). Over the past decade, the number of named diseases increased from less than 10 to about 65, and most have not been adequately characterized. Given the increased observation effort, the actual rate of increase in coral disease is uncertain. However, coral disease is clearly an important issue for coral conservation.

The Coral Disease and Health Consortium (CDHC) was created in 2002, in response to the USCRTF *National Action Plan*, to provide coastal and ocean managers with scientific understanding and tools to help address coral health issues and mitigate degradation. The CDHC is a network of field and laboratory scientists, coral reef managers, and agency representatives devoted to understanding coral health and disease. It is cross-disciplinary, highly collaborative, and completely voluntary. Over 100 partners—including EPA, DOI, NOAA, other federal agencies, academia, non-profit organizations, and industry—contribute their time and expertise to this endeavor.

The causes of coral disease are not straightforward. Available evidence shows that biological (e.g., bacterial pathogens) and non-biological agents (e.g., land-based pollution) acting separately or in combination, are compromising coral health. Responding to this threat requires improved scientific understanding and tools to: (1) detect and assess trends in coral diseases; (2) determine the causes and consequences of increased disease incidence and spread; and (3) identify and test management options to mitigate the effect of disease on coral reef ecosystems.

Due to the complexity of the problem, limited knowledge of disease etiologies, and lack of existing options to manage and/or mitigate diseases, a triage plan of action has

been undertaken to (1) build a unified coral community with a solid foundation for cross-disciplinary research (e.g., training workshops, advanced education and professional development opportunities, and information dissemination strategies); (2) conduct strategic laboratory and field-based research; and (3) develop, implement, and test management strategies. During 2003-2006, the CDHC core team implemented a series of strategic objectives focused these three elements. Each objective is geared to improve our ability to forecast, characterize, understand, and mitigate coral diseases.

Efforts to build capacity in the coral disease and health community have included continued development of standardized nomenclature and procedures to allow comparison of information and sharing of tools between the scientists, coral reef stakeholders, and resource managers. *A Strategic Plan of Action, Coral Health and Disease in the Pacific: Vision for Action,* was developed during a CDHC workshop to help combat a possible health crisis for Pacific coral reefs. The express purpose of this workshop and action plan is to organize and coordinate U.S. scientific resources to focus on coral health issues in the Pacific. Response protocols for disease outbreak and response investigation were developed using an Incident Command Structure, which included the concepts, procedures, techniques for conducting an investigation. In addition, the community has collaborated with the CDHC to initiate regional Outbreak Response Team training efforts intended to build local capacity for responding to coral disease outbreaks.

Additional efforts to better address coral disease have included research activities in both the field and laboratory setting. Laboratory research has used and developed tools and methodologies for diagnosis and assessment including DNA tests for surveillance of known pathogens and the development and sequencing of coral DNA libraries for use as a resource to identify coral genes and their role in health and disease. To date, over 15,000 DNA (specifically 16S rDNA) sequences submitted to public databases are pointing to key differences between healthy and diseased corals. The diagnoses of the cellular physiology response to environmental and toxicological stressors are being investigated to develop health assessment criteria.

Field activities include directed monitoring and investigation focused on the ESA-listed coral species, *Acropora palmata.* These activities have provided information in the prevalence estimates for various diseases affecting this species, and on patterns of disease outbreak following hurricane impacts in the Florida Keys (in particular in 2005) and at Navassa Island.

There has also been a focus on establishing disease incidence and baseline information for the following key locations:

Guam, the Commonwealth of the Northern Mariana Islands, Wake Atoll, and the Main Hawaiian Islands;

Maui: island-wide survey to determine the extent and possible causes of coral lesions;

Northwestern Hawaiian Islands: permanent transects for monitoring reef health; and

Puerto Rico: baseline assessment of the temporal variability of coral diseases including subsequent disease incidence due in part to the impact of the 2005 Caribbean-wide bleaching episode.

The first known occurrence of a disease outbreak (similar to white plague) was observed at the FGBNMS in February, 2005. The CDHC partnered with the FGBNMS to coordinate a rapid response to characterize the event and collect samples for laboratory analysis. Disease outbreaks are of major concern for the FGBNMS, because of their recent emergence on these reefs; an unusually high prevalence and rapid spread observed among colonies during winter and spring when most diseases in other locations are in remission; elevated rates of tissue loss in areas with high coral cover; and the greatest extent of mortality observed among the largest and most abundant reef-building coral taxa *(Montastraea spp.)*. Since May 2005, NOAA has conducted seasonal monitoring of diseases to begin characterizing patterns of spread and impacts of disease.

Coral Reef Biological Criteria and Bioassessment

EPA is providing technical and regulatory guidance for states and territories on the development and implementation of bioassessment procedures and their application in establishing biological criteria (biocriteria) for the protection of coral reefs. Under the authority of the Clean Water Act, U.S. jurisdictions can assess coral reef condition to determine whether reefs are meeting resource expectations or whether they are impaired by human activity. Several regulatory options fall under the Clean Water Act, but they must be supported through scientifically valid bioassessment programs employing biological indicators to distinguish human disturbances from natural fluctuations in reef condition.

Among the most promising and comprehensive regulatory options for protection of coral reefs are water-quality standards based on biocriteria. Narrative or quantitative thresholds are established to describe levels of expected coral reef condition for different designated waterbody uses. If reefs do not meet these expectations, the water body is listed as impaired and corrective action is implemented in the water body and watershed. EPA has formed a Coral Reef Biocriteria Working Group, composed of staff from several EPA Offices and Regions, to support development and implementation of coral reef biocriteria. The Working Group held an open workshop in conjunction with the May 2006 USCRTF meeting in Washington, D.C., and is completing technical guidance for a standard, rapid bioassessment of stony corals (publication anticipated in 2007). EPA is working directly with jurisdictions to support development of biocriteria in the USVI, American Samoa, CNMI, Florida, and Hawai‘i.

Research to develop defensible indicators and valid monitoring programs has been undertaken by EPA and USVI. In 2006, targeted surveys were performed in St. Croix to examine the potential of stony coral indicators in a biocriteria monitoring program. Transfer of the rapid bioassessment protocol to USVI resource managers was very successful, indicators demonstrated adequate power to detect change, and several indicators showed high sensitivity to human disturbances. A 2007 survey will employ a probability-based sampling design, and its results will inform the development of a balanced, long-term monitoring program designed to support status, trend, and targeted sampling for local and regional needs.

The American Samoa EPA coral reef monitoring program is conducting a long-term investigation to detect change over time resulting from land-based, human disturbance. This effort started in 2003 when six watershed-based survey sites were established around

Figure 4: Approximate range of Acropora spp. (highlighted in pink), including the Gulf of Mexico, Atlantic Ocean and Caribbean Sea. The highlighted areas are not specific locations of the corals but rather reflect general distribution. (Map created by J. Moore, NOAA Fisheries Service, with data from ESRI)

Tutuila Island (Houk et al. 2005), and was expanded in 2005 with the investigation of five addition sites (Houk, 2005). The relationships between watershed volume, human population density, and coral reef communities are examined within distinct settings to determine which ecological measures are most responsive to proxies of pollution. The findings form the basis for the development of four biological measures for health assessment and are used as biocriteria to evaluate water quality.

Endangered Species Act Listing of *Acropora (cervicornis, palmata)* as Threatened Background Synopsis

Acropora species are the most abundant group of corals in the world and once represented the most dominant reef-building species throughout the western Atlantic Ocean. They are found on shallow-water reefs, live in high-energy zones with increased wave action, and are in water temperatures from 66 to 86 °F. They have high relative growth rates for corals and exhibit branching morphologies providing important habitat for other reef organisms; no other Caribbean reef-building coral species are able to fulfill these ecosystem functions, which may be compromised at the current reduced abundance. Monitoring efforts by USGS, NOAA, NPS, and other partners have documented population losses of 80 to 98 percent of elkhorn coral *(Acropora palmata)* and staghorn coral *(A. cervicornis)* from a 1970 baseline throughout the Caribbean region.

Status

In March 2004, the Center for Biological Diversity petitioned NOAA to list elkhorn *(Acropora palmata)*, staghorn *(A. cervicornis)*, and fused-staghorn *(A. prolifera)* corals under the Endangered Species Act (ESA). In June 2004, NOAA found "listing these species may

Acropora species exhibit branching morphologies.

be warranted" and initiated a formal review of their biological status. The Atlantic *Acropora* Biological Review Team (BRT) was formed to compile and analyze the best scientific and commercial information on these species' life histories, abundances and distributions, and long-term changes. The members of the BRT included experts in the fields of coral biology and ecology, coral monitoring and restoration, climate, water quality, and coral taxonomy, as well as regional experts in coral abundance/distribution throughout the Caribbean Sea and state and federal resource managers. The comprehensive, peer-reviewed status review report developed by the BRT incorporated and summarized the best available data as of March 2005. Based on the findings of the report, NOAA determined "elkhorn and staghorn corals warrant listing" as threatened species under the ESA; this determination did not include fused-staghorn corals. NOAA finalized the ESA listing of elkhorn and staghorn corals as threatened on May 4, 2006.

Update and On-going Activities

NOAA worked to create an ESA 4(d) rule detailing prohibitions necessary and advisable to provide for the conservation of elkhorn and staghorn corals. The establishment of the 4(d) rule will help NOAA ensure that activities—such as water resources development projects involving dredging and in-water construction—avoid or minimize impacts to threatened coral species through the ESA consultation requirements.

NOAA is also in the process of designating critical habitat in the U.S. Caribbean and Florida where these species are found (see Figure 4 for a general distribution of these coral species). Maps showing known occurrences and habitat characteristics of elkhorn and staghorn corals in Puerto Rico, USVI, and Florida have been created to aid in critical habitat designation. The designation of critical habitat will aid in the recovery of listed coral species by protecting habitat essential for the conservation of the species. (As of publication date, the critical habitat designation is open for public comment through May 6, 2008.)

An interagency data-gathering effort between NOAA and the USGS is under way to obtain GIS and remote sensing data (e.g., benthic habitat data, water depth, water temperature, and presence/absence data for *Acropora* species colonies) to aid in the identification and mapping of areas qualifying as critical habitat for listed corals.

NOAA biologists, along with partners at the University of Miami/RSMAS, recently published: Demographic monitoring protocols for threatened Caribbean *Acropora* species corals. This manual is available online at: http://www.sefsc.noaa.gov/PDFdocs/Acropora Manual-Electronic.pdf. This manual provides standardized techniques for monitoring these threatened coral species throughout their range.

NOAA, USGS, and other partners are undertaking on-going targeted demographic monitoring in several U.S. locations to document current trends in *Acropora* species abundance and condition. For example, in 2005 after the March 2005 status review was published, substantial additional losses occurred of monitored *Acropora palmata* populations in the USVI due to bleaching and in the Florida Keys due to hurricanes and associated disease impacts. Monitored populations have also displayed very low rates of recruitment. This information will be used in developing of demographic models to define and assess recovery targets.