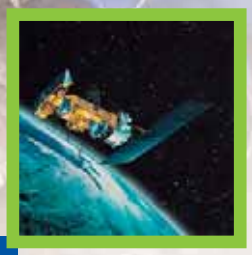
CHAPTER 1

Mapping U.S. Coral Reefs



GOAL: *Produce comprehensive digital maps of all shallow coral reef ecosystems in the United States and characterize priority moderate-depth reef systems by 2009.*

Rationale for Action

Accurate geo-referenced information on the location of specific natural resources and habitat types is important for effectively managing marine habitats. This need is particularly acute for coral reef ecosystems because the consequences of misinformed management decisions can have significant and lasting socioeconomic and ecological consequences. The USCRTF made mapping U.S. shallow-water reefs a high priority, with a goal of producing comprehensive, digital maps of all U.S. shallow-water coral reefs by 2009. However, many coral reef ecosystems in U.S. waters, particularly in the Pacific Ocean and moderate-depth water (30–200 meters), still need to be accurately mapped and characterized using modern techniques at a scale useful to managers and the public addressing conservation issues. Current, accurate, and consistent maps will greatly enhance

OBJECTIVES

OBJECTIVE 1: Develop high-resolution benthic maps of local and regional coral reef ecosystems using imagery from satellites and aircraft and *in situ* surveys. The mapping activities include MPAs, reefs at risk of degradation due to human activities, and other priority sites identified by the U.S. Islands representatives.

OBJECTIVE 2: Develop large-scale, low-resolution maps of broad coral reef ecosystems throughout U.S. waters using satellites and other remote sensing assets for use in characterizing habitats, designing monitoring programs, and planning such regional conservation measures as MPAs.

OBJECTIVE 3: Develop and adapt new technologies and data sources to increase mapping efficiency while maintaining accuracy; enhance coral reef ecosystem mapping, survey, and assessment capabilities; and, if possible, detect important ecological changes and trends.

OBJECTIVE 4: Characterize priority deep-water reefs (moderate-depth reefs, 30–200 meters) and associated habitats.

efforts to conserve and manage coral reef ecosystems throughout the United States.

Comprehensive maps and habitat assessments assist a variety of conservation measures, including:

- Creation of accurate baselines for long-term monitoring;
- Characterization of habitats for place-based conservation measures (e.g., marine protected areas [MPAs]); and
- Enhancement of scientific understanding of the large-scale oceanographic and ecological processes affecting the health of reef ecosystems.

Comprehensive maps can also be used to illustrate trends in coral reef health over time by providing a geo-referenced tool to track disease and invasive species and documenting loss of habitat and reef-dependent species.

The USCRTF has committed to the production of comprehensive digital maps of all U.S. shallow (less than 30 meters) coral reefs and to the characterization of priority moderate-depth reef systems by 2009. Coral reef mapping efforts are coordinated through the USCRTF Mapping and Information Synthesis Working Group, which consists of representatives from NOAA, the U.S. Geological Survey (USGS), the National Aeronautics and Space

Table 2. Status of Shallow-Water Coral Reef Ecosystem Mapping Activities in Tropical and Subtropical U.S. Waters[a]

	Total area mapped (km^2)[b]	Area mapped outside 10-fm depth curve (km^2)[b]	Area mapped inside 10-fm depth curve (km^2)[b]	Unmapped area inside 10-fm depth curve (km^2)[b]	Percentage of total estimated area mapped[c]
Puerto Rico	2,297	460	1,837	465	83
U.S. Virgin Islands	488	170	318	26	95
Southern Florida	0	0	0	0	–
Hawai'i (main islands)	812	131	681	551	60
Northwestern Hawaiian Islands	2,360	1,125	1,235	2,194	52
American Samoa	72	32	39	13	85
Guam	105	21	84	7	94
Northern Mariana Islands	204	93	111	12	94
U.S. Flag Islands (e.g., Palmyra, Navassa)	0	0	0	0	–
Republic of Palau	0	0	0	0	–
Federated States of Micronesia	0	0	0	0	–
Republic of the Marshall Islands	0	0	0	0	–
Total	6,338	2,032	4,305	3,268	66

[a] Mapping activity refers to the transformation of data or imagery into a shallow-water benthic habitat map depicting geomorphology, zonation, biological cover, and associated assessments of the thematic accuracy of the map.

[b] Depth-curve information derived from NOAA nautical charts. In clear water, seafloor features can be mapped in water up to 15 fm deep. Because of water quality, clouds, cloud shadows, and other factors, seafloor features in water less than 10 fm deep cannot always be mapped (10 fm is equivalent to 18.3 meters).

[c] Percentage equals the area mapped divided by the sum of area mapped plus the unmapped area inside the 10-fm depth curve (10 fm = 18.3 m).

Administration (NASA), other federal and state agencies, and academic and nongovernmental organizations. Also, federal, state, and local agencies; universities; and the private sector continue to play an integral role in the production of both high- and low-resolution maps to meet management needs.

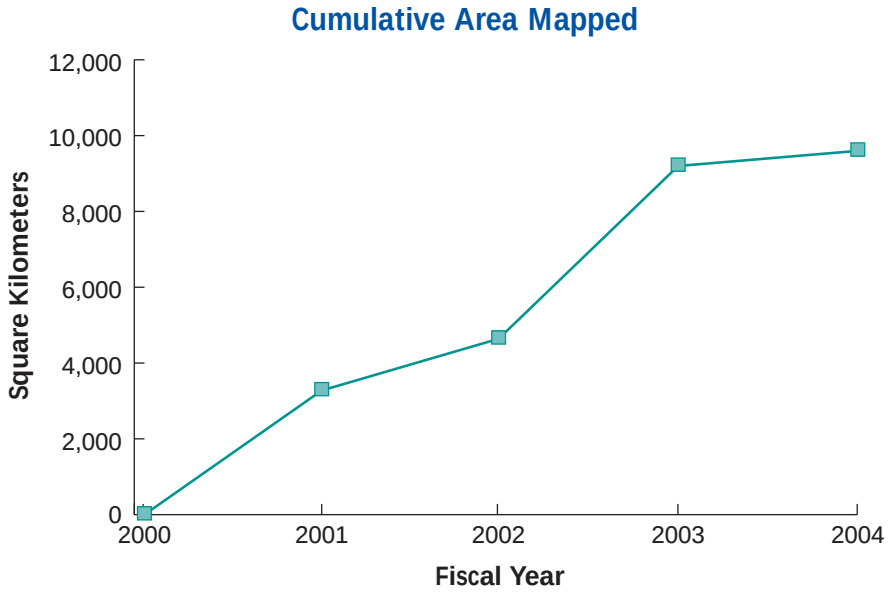
Summary of Implementation

The comprehensive mapping program led by NOAA has used aerial photography and satellite images to create accurate benthic habitat maps that characterize more than 66 percent of the habitats of U.S. coral reef ecosystems in water less than 30 meters deep (see table 2 and figure 1). For some areas, shoreline maps, in addition to fine-scale maps showing water depths (bathymetry), have been developed using light detection and ranging (LIDAR) technology.

As part of the mapping process, a habitat classification scheme is developed for each area, using similar classification schemes in different jurisdictions to allow for comparison. NOAA, in partnership with local management agencies and other partners, collects video imagery and diver ground-truthing of the shallow-water seafloor and uses them in the benthic habitat characterization process. For instance, scuba divers videotaped an estimated 8,000 linear kilometers of the seafloor around islands and atolls throughout the U.S. Pacific waters in 2002–2003. In southern Florida, more than 1,800 scuba dives have been performed along the reef tract. Examples of these classification schemes can be found online at *http://biogeo.nos.noaa.gov*.

Figure 1. Shallow-Water Coral Reef Area Mapped: 2000–2004

This graph shows the U.S. shallow-water coral reefs (less than 30 meters in depth) mapped since 2000. Currently, 9,598 square kilometers of U.S. coral reefs in shallow water have been mapped. Of this area, 6,338 square kilometers have been classified in habitat maps. The remainder is classified as unknown for various reasons.



Each map product is provided to the user community for evaluation and accuracy assessment. Independent contractors, such as the University of Hawai'i, evaluate the accuracy of the maps, while individuals from academia, state and territory management agencies, federal partners, and appropriate nongovernmental groups conduct user evaluations of the mapping products. Map products are generally 80 to 95 percent accurate, depending on the variety of benthic habitats found at each location.

In addition to efforts to map shallow-water coral ecosystems, NOAA, USGS, and academic partners are also mapping priority moderate-depth coral reef ecosystems identified by the fishery management councils as important habitat for many commercial reef fish species. Mapping moderate-depth reefs primarily involves using multibeam sonar technology in which sound waves emitted from a ship are reflected from the seafloor to provide information about the depth and character of the seafloor. A recent inventory indicates depth data have been collected for, at most, 20 percent of the moderate-depth areas in the U.S. Pacific waters, with emphasis on the Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (CNMI), and American Samoa (see table 3). Bathymetry data have also been collected around Florida in the U.S. Caribbean, but a similar inventory has not been completed for these regions. The collection of data for seafloor characterization requires ships capable of launching remotely operated vehicles (ROVs) and other advanced underwater technologies in combination with still and video imagery. Due to specialized equipment requirements, the extent of seafloor characterization at these depths lags far behind bathymetry data collection. NOAA and USGS have generated benthic habitat maps of portions of the West Florida Shelf, the NWHI, Moloka'i, and O'ahu. NOAA and USGS are also undertaking an inventory of the distribution and status of known deep-water coral (cold-water coral) ecosystems occurring throughout the U.S. economic exclusive zone.

The shallow-water benthic habitat maps and their associated imagery and metadata are available to researchers and management agencies on CD–ROM and on the Internet at *http://biogeo.nos.noaa.gov* and *http://www.coris.noaa.gov*. These products are being used in a variety of ways to support coral reef management. For example, completed map atlases for Puerto Rico are helping researchers and resource managers study habitat suitability and MPA placement in southwestern Puerto Rico. Map atlases for the U.S. Virgin Islands (USVI) are being used to assess the impact of an expansion of the

Table 3. Status of Pacific Moderate-Depth Data Collection Efforts Using Ship-Based Technologies

	Area where bathymetry data have been collected (km^2)[a]	Potential coral ecosystem area inside 10-fm depth curve (km^2)[b]	Potential coral ecosystem area inside 100-fm depth curve (km^2)[b]
Hawai'i (main islands)	0	1,231	6,666
Northwestern Hawaiian Islands	70,019	1,595	13,771
American Samoa	271	55	464
Guam	26	108	276
Northern Mariana Islands	218	124	476
U.S. Pacific Flag Islands	0	252	436

[a] Multibeam data provide important information about seafloor features. These data, in combination with such optical information as video or other imagery are used to develop benthic habitat maps.

[b] Depth-curve information derived from NOAA nautical charts. Estimated coral ecosystem area for the Republic of Palau, the Federated States of Micronesia, and the Republic of the Marshall Islands derived from Landsat satellite imagery.

Buck Island Reef National Monument, assess the creation of the Virgin Islands Coral Reef National Monument and the Salt River National Park in St. Croix, and characterize the status of coral ecosystems and associated fisheries in the Virgin Islands National Park in St. John.

The map atlas covering 60 percent of the Main Hawaiian Islands is being used to assess the spatial characteristics and location of Marine Life Conservation Districts in Hawai'i and identify gaps in coral reef management areas. Moreover, USGS is using satellite imagery to map and study transport patterns of sediment in reef systems of some Hawaiian islands and to study potential impacts of these sediments on coral reef health.

Highlights of Task Force Member Activities

OBJECTIVES 1 & 2: Develop high-resolution benthic maps of local and regional coral reef ecosystems using imagery from satellites and aircraft and *in situ* surveys. The mapping activities include MPAs, reefs at risk of degradation due to human activities, and other priority sites identified by the U.S. Islands representatives. Develop large-scale, low-resolution maps of broad coral reef ecosystems throughout U.S. waters using satellites and other remote sensing assets for use in characterizing habitats, designing monitoring programs, and planning such regional conservation measures as MPAs.

Draft NWHI Atlas Is New Tool for Managers

In 2003, NOAA released the *Atlas of the Shallow-Water Benthic Habitats of the Northwestern Hawaiian Islands—Draft,* which provided baseline information on the locations and distributions of approximately 2,365 square kilometers of shallow-water reefs and other seabed features of the NWHI. The atlas is an integral tool in designing further research and management plans. The atlas and associated satellite imagery are being used to track marine debris deposition and removal, develop research mission plans, track the distribution of and gaps in tow-board data collection activities, monitor the impact of recent coral bleaching events, and provide an archive for future research and related activities. The benthic habitat maps and satellite imagery are being used to track and monitor the distribution and habitat use patterns of such protected species as the endangered Hawaiian monk seal and threatened sea turtles.

Map products depict water depths and seafloor features in nearshore areas around the island of Ofu in American Samoa. Black areas indicate data "holidays" or areas for which no information was collected.

Revolutionary Map Helps Understanding of Global Coral Distribution

Through the joint efforts of NASA and NOAA, the first global map of tropical shallow water was created from nearly 44,000 SeaWiFS (Sea-viewing Wide Field-of-View Sensor) scenes. NOAA continues to work with the United Nations Environment Programme—World Conservation Monitoring

Centre to use these data to improve the ReefBase database of coral reefs. The maps are now available from the ReefBase website at *http://www.reefbase.org* and have been used to better understand the spatial distribution of coral reef ecosystems around the globe. These maps routinely appear in publications depicting the global distribution of coral ecosystems.

Data Provide Key Component of Southeast Florida Maps

The National Coral Reef Institute has produced detailed bathymetric data for a portion of southeast Florida reefs (up to 30.5 meters in depth) to serve as the base map for overlaying the results of biological and geological inventories, assessments, and monitoring. The maps integrate several available datasets, including aerial photography, LIDAR, and multibeam sonar, and will provide Florida with critical information to help it manage sensitive coral reef areas.

OBJECTIVE 3: Develop and adapt new technologies and data sources to increase mapping efficiency while maintaining accuracy; enhance coral reef ecosystem mapping, survey, and assessment capabilities; and, if possible, detect important ecological changes and trends.

New Airborne LIDAR Significantly Improves Capabilities

In September 2003, USGS tested a new underwater video system designed for rapid ground-truthing of habitat maps derived from remote sensing data. Using this new technology, USGS created fine-scale preliminary topographic maps for coral reefs in Biscayne National Park and portions of the northern Florida Keys. USGS scientists in collaboration with NASA are also mapping coral reef ecosystems using the Experimental Advanced Airborne Research LIDAR (EAARL). EAARL is a new airborne LIDAR that provides unprecedented capabilities to survey coral reefs in water 10 meters or less in depth, nearshore benthic habitats, coastal vegetation, and sandy beaches.

New Index Provides Critical Habitat Information

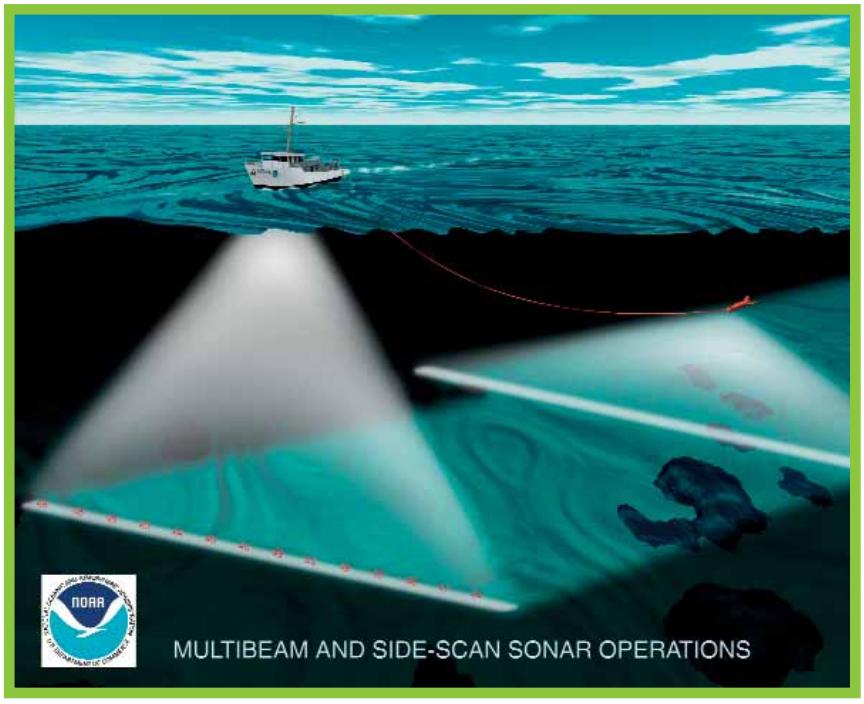
NOAA has established an Acoustic Complexity Index for identifying essential fish habitats. When areas of Florida's reef tract were mapped using an advanced seabed classification system, results showed that areas with a moderate to high abundance of grouper were acoustically complex (i.e., they returned highly variable acoustic waveforms over short spatial scales). Few to no grouper were found in areas with low acoustic complexity; however, grouper were found in greater numbers in areas with high acoustic complexity. This "Acoustic Complexity Index" will help identify essential grouper habitats that need to be protected and conserved to address overfishing.

OBJECTIVE 4: Characterize priority deep-water reefs (moderate-depth reefs, 30–200 meters) and associated habitats.

Discovery in Florida Leads to New Conservation

During a recent USGS/NOAA/University of South Florida multibeam cruise, scientists discovered and mapped approximately 16 square kilometers covered with 50 to 90 percent live coral in 70 to 80 meters of water on Pulley Ridge, an area on the southwest Florida shelf. Such extensive coral cover at these depths is unprecedented for hermatypic (reef-building) coral growth. (In comparison, Florida's shallow reefs typically have less than 10 percent live coral.) These moderate-depth corals may be key habitats for certain commercial fisheries and may seed the shallower reefs in the Florida

Keys. Sixty-six fish species have been identified, including deep-water and commercial species and those typical of shallow-water coral reefs. DNA testing is underway to determine the relationship between these moderate-depth corals and shallower corals of the Florida Keys. Initial results were presented to the Gulf of Mexico Fishery Management Council during July 2003. As a result, the 4,828-square-kilometer study area encompassing Pulley Ridge is being considered for designation as a fisheries Habitat Area of Particular Concern.



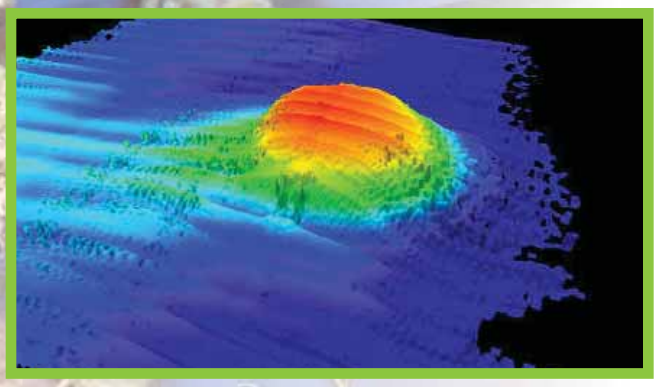
Several acoustic-based instruments mounted on NOAA vessels collect information about nearshore seafloor features and habitats.

Study Offers New Information on Biology and Habitat in USVI Waters

In March 2004, the National Park Service (NPS), NOAA, USGS, the USVI, and non-governmental organizations conducted moderate-depth biological and bathymetric characterizations of the Coral Reef National Monuments at Buck Island, St. Croix, and off the south shore of St. John. The study used ship-based multibeam and backscatter (a mapping technique that analyzes the strength of the echo once a sound wave hits a bottom surface) sonar technologies to identify benthic habitats. The associated biological resources were characterized using scuba-based visual census techniques and by trapping reef fish. The biological resource information will be combined with the seafloor characterization data to better understand the habitat use patterns and requirements of fish and other organisms found in these areas. A better understanding of these relationships will improve management and conservation efforts.

Cruise of the NWHI Contributes to Atlas

NOAA and its partners, including Hawai'i and the U.S. Fish and Wildlife Service (USFWS), have released a plan to comprehensively map the moderate-depth coral reef ecosystems of the U.S. Pacific Ocean starting with the NWHI. In 2002, a 25-day cruise mapped critical boundaries in the area. Data collected were incorporated into the *Bathymetric Atlas of the Northwestern Hawaiian Islands: A Planning Document for Benthic Habitat Mapping* and are available online at *http://crei.nmfs.hawaii.edu/BathyAtlas*. Additional seafloor characterization imagery will be collected using various technologies, such as drop cameras, towed video cameras, ROVs, and other advanced underwater technologies. The data and additional imagery will be combined to create habitat maps that will then be used in coral reef fishery management plans.



A previously uncharted seafloor feature within the Midshelf Reef complex south of St. John, USVI was detected by a multibeam sonar instrument during a collaborative mapping expedition in early 2004.

Future Challenges

Shallow-water benthic habitat mapping. Over the next several years, USCRTF agencies plan to complete shallow-water maps of coral reef ecosystems in the United States, its territories and flag islands, and, possibly, the Freely Associated States (i.e., the Republic of Palau, the Republic of the Marshall Islands, and the Federated States of Micronesia) in the Pacific. Final benthic habitat maps for American Samoa, Guam, and the CNMI were completed in 2004. The Main Hawaiian Islands mapping project produced draft maps of 60 percent of nearshore areas in 2003 and is expected to produce more complete draft habitat maps in 2006. In 2004, NOAA and its partners initiated a project to remap the coral reef ecosystems of southern Florida. The original maps were compiled using imagery collected in 1991–1992 and contain significant gaps. In 2005, NOAA and its partners plan to create a mapping implementation plan for southern Florida. In addition, a mapping effort may be initiated in the Freely Associated States. NOAA and its partners plan to map 40 percent of Palau and create a mapping implementation plan for the other Freely Associated States in 2005, contingent on funding.

Moderate-depth coral reef ecosystem mapping. The USCRTF has also set the goal of characterizing priority U.S. moderate-depth coral reef ecosystems by 2009. Mapping these ecosystems, especially those in remote locations, poses future challenges. New techniques will need to be developed to combine the moderate-depth bathymetry with moderate-depth seafloor characterization data to produce maps. The development of new technologies may help close gaps and provide managers with current, integrated data. At present, NOAA and its partners are working to map the moderate-depth reefs in the USVI National Monuments.