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.

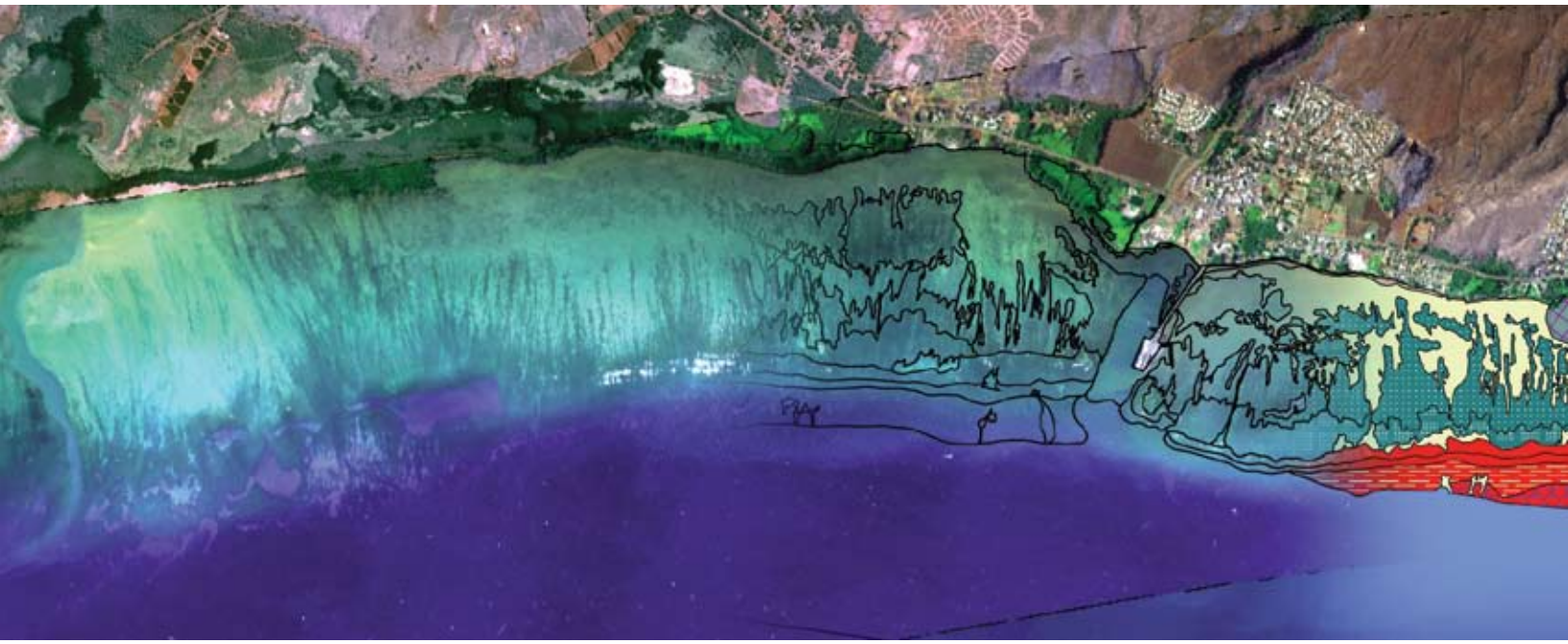
Current, accurate, and consistent maps greatly enhance efforts to preserve and manage coral reef ecosystems. With comprehensive maps and habitat assessments, coral reef managers can be more effective in designing and implementing a variety of conservation measures including:

Long-term monitoring programs with accurate baselines from which to track changes;

Place-based conservation measures such as marine protected areas (MPAs); and

Targeted research to better understand the oceanographic and ecological processes affecting coral reef ecosystem health.

The USCRTF has committed to produce comprehensive digital maps of all U.S. shallow-water (less than 30 meters) coral



reef habitats, and to characterize priority moderate-depth (30-200 meters) reef systems (USCRTF 2000). Coral reef mapping efforts are coordinated through the USCRTF Mapping and Information Synthesis Working Group, composed of representatives from the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), National Aeronautics and Space Administration (NASA), other federal and state agencies, and academic and non-governmental organizations (NGOs). Although six of the seven primary jurisdictions have been mapped as of 2007, the goal of mapping all U.S. shallow-water coral reef ecosystems by 2009 may not be attainable due to the large area and complexity presented by Florida's reef ecosystems.

Accomplishments by Objective

Objective 1: *Develop high-resolution benthic (sea floor) maps of local and regional coral reef ecosystems using imagery from satellites and aircraft and in situ surveys, with particular emphasis on marine protected areas, reefs at risk of degradation due to human activities, and other priority sites identified by the U.S. islands representatives.*

Shallow-water Mapping

In nearshore areas, scientists primarily rely on visual interpretation of imagery from satellites or other sensors to delineate habitats and assign them to categories of geological structure and biological cover. This progression is depicted in Figure 1. Completed digital map products cover 6,340 square kilometers of U.S. shallow-water coral reef ecosystems and represent major milestones in achieving the USCRTF goal of mapping all U.S. shallow-water coral reef ecosystems.

Progress in U.S. States and Territories

Benthic habitat maps for Hawai'i, released in 2003, characterized about 60 percent of shallow-water habitats in the Main Hawaiian

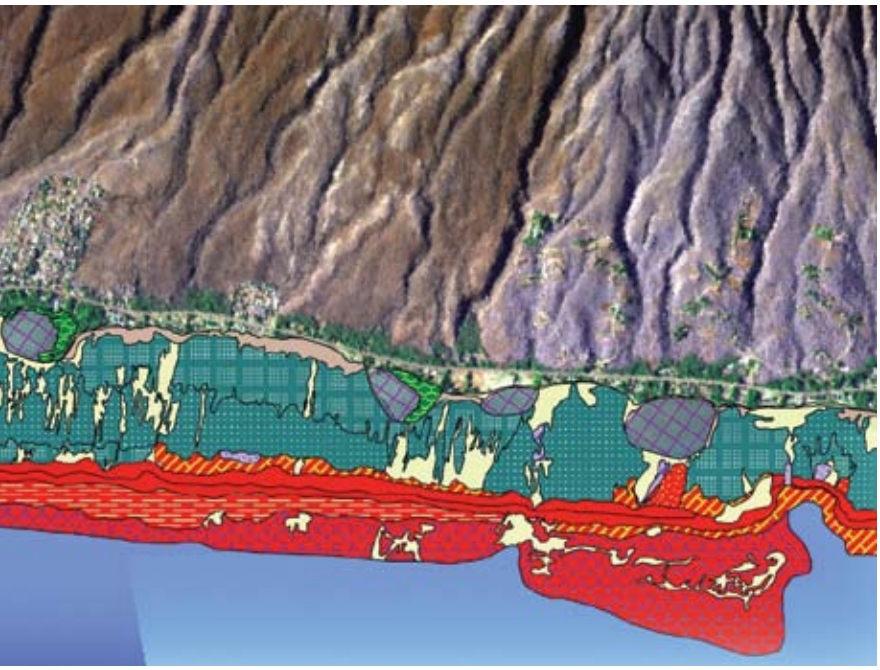


Figure 1: This image depicts the transition from georeferenced satellite imagery (left), to delineated habitat boundaries (center), to visual interpretation and classification of habitat types (right). The minimum mapping unit (mmu) or smallest feature delineated in the map, has an area of 1 acre (~4,000 square meters).

Islands, and a separate product characterized shallow-water habitats for most of the islands, banks, and atolls in the Northwestern Hawaiian Islands (NWHI). A project to re-map the main Hawaiian Islands, including the 40 percent not captured in the first effort, began in 2005 and was completed in October 2007. In 2004-2005, work focused on mapping American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), and Guam. Benthic habitat maps for those jurisdictions were released in 2005. Also in 2005, NOAA scientists purchased IKONOS satellite imagery depicting approximately 10,000 square kilometers of coastal southern Florida and developed a Mapping Implementation Plan in preparation for mapping this large area of shallow-water habitat over the next several years. In 2006, Florida project partners georeferenced the imagery acquired in 2005 and produced a common habitat classification scheme. Southern Florida reef ecosystems encompass an area of shallow water greater than all of the other mapped jurisdictions combined.

Partners in Florida, the National Coral Reef Institute (NCRI), the Florida Fish and Wildlife Conservation Commission (FWC), and the Florida Department of Environmental Protection (FDEP) completed development of benthic habitat maps for the nearshore, shallow (< 35m) areas of Broward and Palm Beach Counties in southeast Florida. Data collected using Laser Airborne Depth Sounder bathymetry, multi- and single-beam bathymetry, acoustic sea floor discrimination, ecological assessments, and groundtruthing were integrated to generate the first habitat maps ever produced for this region of Florida. Funding is needed to map adjacent areas of Martin and northern Miami-Dade Counties.

At present, no shallow-water habitat mapping activities have been scheduled for the U.S. Flag Islands (including Navassa and the remote, uninhabited islands in the equatorial Pacific). These jurisdictions were not included in the original 2009 goal to map all U.S. shallow coral reef ecosystems.

High resolution Cirrus Digital Camera System (DCS) image of Buck Island, St. Croix, USVI flown by NASA in December 2005.

Proposals to expand the U.S. Navy anchorage areas available at Saipan and Apra Harbor are being considered by the U.S. Department of Defense (DoD). To support planning, several large-scale studies are in progress. DoD teamed with NOAA to collect high-resolution bathymetric mapping with video transects to use in ground-truthing the bathymetric map and will be converted into a three-dimensional habitat map. In the anchorage at Saipan, sediment, current, and wave activity were modeled, and the models will be used to predict the sediment plumes resulting from potential future activities. (For more information on this project, see page 95 and 101.)

Progress in the Pacific Freely Associated States

Since 2004, NOAA scientists have continued to make progress in mapping the Pacific Freely Associated States (FAS), including the Republic of Palau, the Federated States of Micronesia (FSM), and the Republic of the Marshall Islands (RMI). In 2004, FAS governments – with input from key federal, national, state, university, and other organizations – identified geographic priorities for mapping, inventoried mapping activities completed to date, and communicated management needs and other map-product requirements. This information was used to draft a Freely Associated States Shallow-water Coral Ecosystem Mapping Implementation Plan, which was released in 2005. Using satellite imagery purchased in 2004 and 2006, benthic habitat maps covering nearly 1,500 square kilometers of coral reef ecosystems in Palau were generated and released in August 2007. Project details are available online at: http://ccma.nos.noaa.gov/ecosystems/coralreef/palau_fas_mapping.html.

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 regional conservation measures such as marine protected areas.*

Millennium Coral Reef Maps

In a NASA-sponsored partnership between remote sensing scientists, international agencies, and NGOs, new efforts are being made to (1) develop low-resolution reef maps encompassing all tropical oceans to provide a foundation for more detailed future investigation, (2) assemble key baseline remote sensing data needed for future research in coral reef environments, and (3) partner with international organizations to use remote sensing data for applied science problems and improved coral reef management. This partnership developed the first uniform global maps of shallow coral reef geomorphology—Millennium Coral Reef Maps—which cover a vast area and include over 80 percent of the Earth's shallow tropical coral reefs. The project differs from other coral ecosystem mapping efforts in both resolution and geographic focus. The Millennium maps are based on Landsat imagery (a low-resolution satellite source with a pixel size of 30 square meters) and focus on geomorphologic structure in non-U.S. territories, whereas the NOAA maps use imagery with a finer resolution (1- to 4-meter pixels) and provide information on reef zonation, underlying structural characteristics, and biological cover for reef areas in the U.S. territories and Palau. Thanks to close communication among the participants, project scientists were able to minimize geographic overlap and avoid duplication of effort, and as a result, the projects and products complement each other well.

The Millennium Coral Reef Maps are being used by scientists, operational agencies, and various non-governmental entities in the United States and around the world at regional and local scales to:

Study sensitivity of tropical islands to climate change and sea-level rise;

Assess coral reef fisheries of the Pacific islands;

Design large-scale monitoring and conservation actions (MPA implementation);

Assess biodiversity in the Indo-Pacific (i.e., the role of reef diversity and island types in structuring biodiversity);

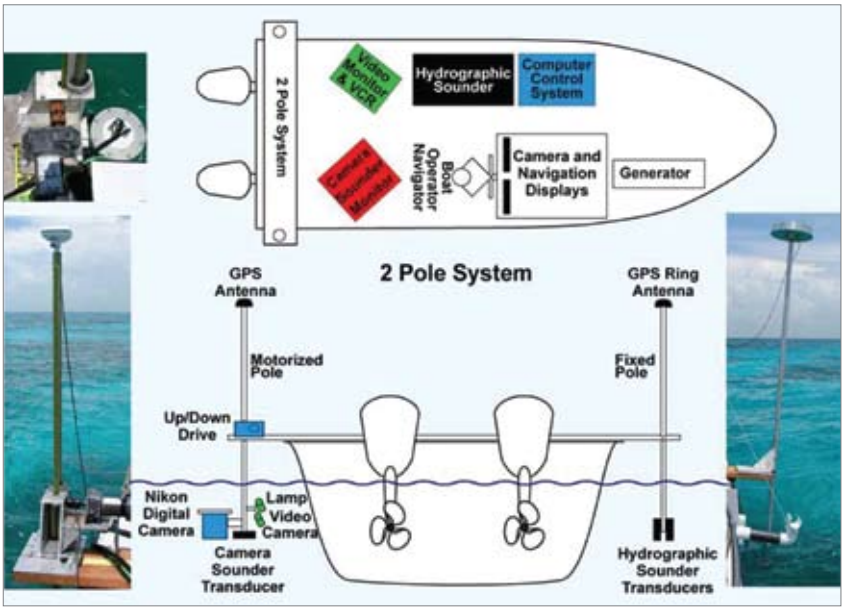
Determine genetic connectivity of fish populations in the Caribbean;

Detect reef fish spawning sites; and

Strengthen the case for classifying certain reef areas as United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites.

Since September 2006, the Millennium Coral Reef Maps and metadata have served as the primary layer of the WorldFish Center's ReefBase on-line Global Information System (GIS) (http://www.reefbase.org/), which provides access to both the source imagery and the classified maps in the form of GIS layers. More information on the Millennium Coral Reef Maps is available online at: http://imars.marine.usf.edu/corals/.

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.*



Schematic depicting USGS Along Track Reef Imaging System (ATRIS)

The National Coral Reef Institute, in partnership with NOAA, made progress in benthic habitat mapping research by creating and refining a Hybrid Mapping Tool (HMT). This new tool combines automated and visual techniques to expedite the accurate delineation and classification of habitats from satellite imagery.

The USGS developed the Along-Track Reef Imaging System (ATRIS), which provides resource managers with highly detailed and accurately geolocated benthic-substrate observations for monitoring and mapping coral reef ecosystems. ATRIS is a boat-based sensor package that allows rapid mapping of shallow-water (<10 meters) benthic environments. ATRIS combines high-resolution bathymetry, underwater color digital photography, underwater video, vessel-heave compensation, and differential Global Positioning System (GPS) data to provide photographic and video transects of the sea floor keyed to precise geographic locations and water depths. This tool provides a ground-truthing capability for constructing and validating remote sensing maps of coral reef habitats and submarine topography. ATRIS has been used to collect shallow-water observations for several areas in the Florida Keys and Dry Tortugas National Park, and these observations will provide valuable information for mapping in this area.

DoD funded a research project using advanced video technology mounted on a remotely operated vehicle (ROV) to map and inventory coral reefs. DoD sponsored researchers from the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) to conduct initial research into establishing a method for processing the digital data collected and using it to create and interpret mosaic images of coral reef habitats. This method has been tested in collaboration with NOAA for use in reef damage assessment and surveys of endangered species, hurricane impacts, and deep reefs.

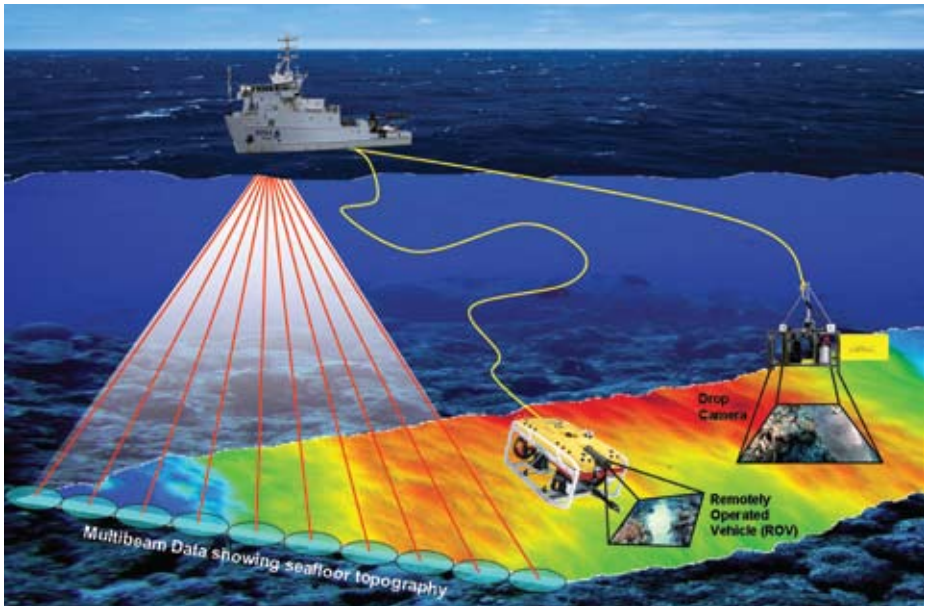


Figure 2: Multibeam data collection and ground truthing diagram. A multibeam echosounder (MBES) is used to collect bathymetric and backscatter information. A remotely operated vehicle (ROV) or drop camera is used to capture underwater imagery of seafloor habitats.

In 2006, NOAA scientists collaborated with the Canadian firm, Shark Marine Technologies, on the design of a custom underwater camera device and GPS unit for deployment in water depths up to 1,000 meters, for visually groundtruthing acoustic multibeam and backscatter data. The collection of georeferenced imagery in moderate to deep water enables scientists to begin to generate simplified habitat maps from acoustic technologies. The new camera device was used on cruises in 2007 and will be used in future cruises. Images collected on underwater transects during research cruises to Puerto Rico and the U.S. Virgin Islands (USVI) can be accessed via the Benthic Habitat Viewer at: http://www8.nos.noaa.gov/bhv/bhvMapBrowser.aspx.

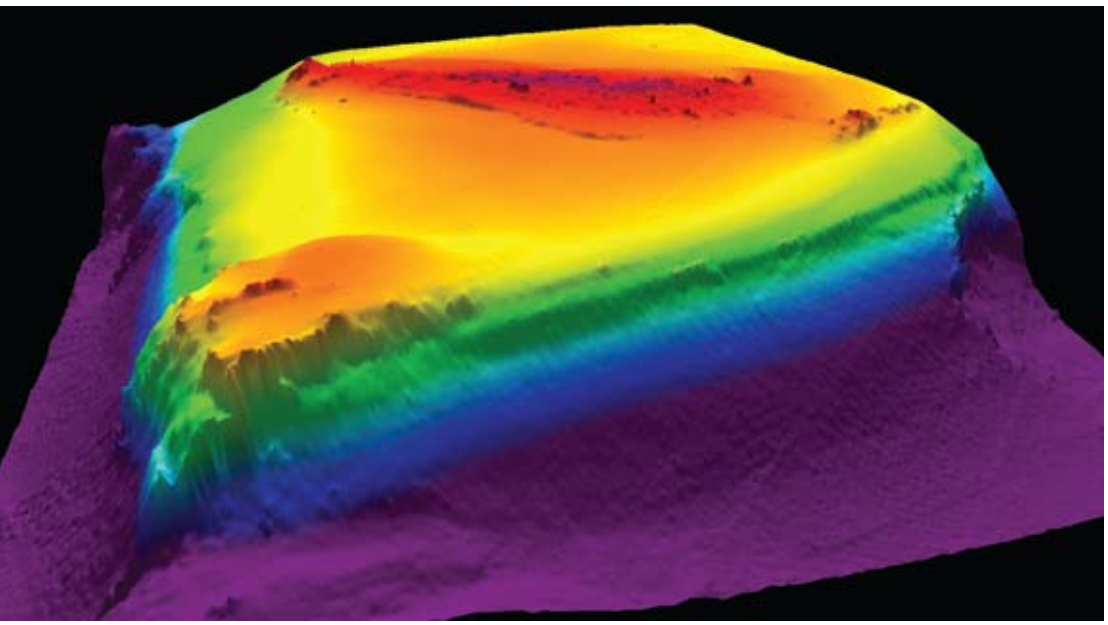
Objective 4: *Characterize priority deep-water reefs (moderate-depth reefs, 30-200 meters) and associated habitats.*

Mid-Water Depth Acoustic Mapping

Mapping using acoustic data collection techniques has progressed significantly, yielding detailed information about sea-floor topography and bottom imagery in moderate-depth habitats (30-200 meters) in U.S. coral reef jurisdictions. In areas too deep or turbid for visual interpretation techniques, scientists primarily use acoustic technologies (i.e., multibeam sounders and side-scan sonar) to collect high-detail information about the topography of the sea floor (Figure 2). Acoustic technologies can help determine basic substrate characteristics, but provide less detailed habitat information than the visual techniques.

Progress in the Atlantic/Caribbean

The NOAA Ship *Nancy Foster*—which operates most often in coastal areas of the Atlantic, Caribbean, and Gulf of Mexico—was



This image provides the first depiction of detailed seafloor topography of Bajo de Cico Bank(oriented northeast) located on the insular platform off the west coast of Puerto Rico as a result of NOAA ship-based multibeam mapping acitvities. The color-shaded visualization shows depth transitions from coral reef (red, 22 meters) to the precipitous Bank edge (purple, 250 meters). Seasonally closed to fishing, Bajo de Cico is a documented spawning aggregation site for Red Hind (/Epinephelus guttalus/).

outfitted with a multibeam sounding device in 2004. Since then, 1,623 square kilometers of sea-floor topography has been mapped using the device. In the USVI and Puerto Rico, survey cruises yielded over 261 square kilometers of new bathymetric and acoustic backscatter information for several project areas that support coral reefs and associated habitats, including National Park Service monuments and marine protected areas in St. Croix and St. John, USVI. In Puerto Rico, detailed bathymetry up to 300 meters deep confirms the presence of coral reefs in waters up to 50 meters deep at the Bajo de Cico and Abrir La Sierra reefs. Preliminary results suggest this reef extends to 90 meters. In 2006, 102 square kilometers of shelf area around Navassa Island were surveyed, at depths between 11 and 1000 meters.

Efforts have also focused on acoustic surveys of MPAs at Madison-Swanson and Steamboat Lumps off Florida's west coast. Building on over 560 square kilometers of multibeam data collected in these areas during 2001-2004, project activities in 2005 and 2006 added nearly 700 square kilometers of bathymetric and backscatter data in areas adjacent to the MPAs These areas are believed to encompass habitats used by grouper species with economic value as migration pathways and spawning aggregation sites. Also in the Gulf of Mexico, extensive side-scan sonar surveys of McGrail Bank and Sonnier Bank have been completed, and habitat characterization efforts are underway. In addition, the entire Florida Middle Ground Habitat Area of Particular Concern has been surveyed using acoustic multibeam techniques.

Progress in the Pacific and Pacific Remote Island Areas

Pacific Island progress in 2004-2006 built on advances reported in 2002-2003, and included efforts to validate acoustic bathymetry and

backscatter information through the use of optical devices and towed diver surveys. Primary accomplishments include multiple data collection cruises to the NWHI, yielding approximately 2,900 square kilometers of multibeam bathymetric data; and collaboration with academic partners to create virtually seamless bathymetric maps of all islands in the Territory of American Samoa covering 1,013 square kilometers of sea floor between 20 and 3,000 meters. Bathymetric surveys in American Samoa documented an extensive relic barrier reef structure around Tutuila and located several shallow submerged offshore banks, with optical validation data from towed camera sleds confirming the presence of high coral cover on these structures. Also, a seamount a few kilometers northwest of the island of Ta‘u was found to be capped with high coral cover, despite its depth of more than 35 meters. These previously unknown reefs will be the focus of greater mapping and monitoring efforts in the future, and possible enhanced consideration by managers.

Multibeam data collected during a cruise to the Mariana Archipelago in 2003 yielded information on over 244 square kilometers of the 14 islands and 12 banks comprising Guam and the CNMI; data collected during a May 2007 cruise will provide additional bathymetric information for the archipelago. In 2004, the survey effort in CNMI was expanded to include a more detailed survey of the Garapan Anchorage near Saipan Harbor. During the project, DoD teamed with NOAA to collect high-resolution bathymetric data and video transects to validate the multibeam data and develop a three-dimensional habitat map. The information generated by the project will be considered as DoD evaluates a possible expansion of U.S. Navy anchorage areas in Saipan and at Apra Harbor, Guam, while trying to minimize impacts to sensitive reef ecosystems.

Elsewhere in the Pacific, a spring 2006 cruise permitted scientists to complete bathymetric surveys of Howland, Baker, and Jarvis Islands in the Pacific Remote Island National Wildlife Refuges (20-2,500 meters) and achieve 85 percent completion of surveys in mid-water depths for Johnston, Kingman, and Palmyra Atoll National Wildlife Refuges. More information and data products for U.S. archipelagos in the Pacific is available online at: http://www.soest.hawaii.edu/pibhmc/.