BENTHIC HABITAT MAPPING AND CHARACTERIZATION

Background

Recent amendments to the Magnuson-Stevens Fishery Management and Conservation Act require the determination and characterization of essential fish habitats (EFH) and habitat areas of particular concern (HAPC) to improve management of living marine resources based on ecosystem principles. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, or growth to maturity. This includes benthic habitats, as well as the water column or oceanographic habitats required to sustain ecosystem function. According to Magnuson-Stevens, HAPC are a subset of EFH and include those areas that are essential to the life cycle of important coral reef species, based on meeting certain specific criteria. This section describes the CREI activities designed to determine, characterize, and map the benthic habitats of the U.S. Pacific Islands coral reef areas. The companion activities to characterize and monitor the oceanographic habitats are discussed in the oceanography section.

Goals and Objectives

As discussed above, knowledge of benthic habitat types and distributions is essential for effective management of marine ecosystems and the associated resources that could potentially be exploited. Due to the high diversity and complexity of coral reef ecosystems, accurate characterization and mapping of these areas are particularly important. For this reason, the CREI has designed and initiated a comprehensive benthic habitat mapping and characterization program utilizing primarily acoustic and visual technologies to complement and support the satellite and airborne mapping activities of NOS in the U.S. Pacific Islands coral reef areas. The goals of the benthic habitat mapping and characterization program of CREI are to:

- Develop effective tools to rapidly characterize and map benthic habitats of coral reef areas.
- Determine the spatial distributions, composition, extent and health of the benthic substrates.
- Determine and define the EFH and HAPC for the coral reef areas.
- Associate identified habitats with distributions of the biological components of the ecosystem, including fish, invertebrates, and algae.
- Determine depth or habitat-based boundaries to support MPAs and the WPRFMC Coral Reef Ecosystem FMP.
- Provide high-resolution *in-situ* data to assist NOS in ground-truthing remote sensing-based mapping data of shallow water areas.
- Examine changes over time of the distribution and health of selected habitats, particularly corals, algae, and sand.

Methods

Until very recently, maps of coral reef areas of the U.S. Pacific Islands were generally poor and little data existed to accurately describe the location, extent, and health of these coral reef ecosystems. On-going collaborative efforts led by

NOS have recently begun collecting aerial hyperspectral imagery and satellite-based multi-spectral imagery of shallow water reef areas (0-<30-m) of the U.S. Pacific Islands. While these products are critical to developing quality maps, high-resolution *in-situ* observations are needed to validate or ground-truth this imagery. Moreover, many essential coral reef habitat areas are too deep (>30-m) to be observed by these remote sensing technologies. Therefore, CREI scientists are leading the efforts in the U.S. Pacific Islands to provide the *in-situ* observations and high-resolution acoustic mapping products necessary to complete the habitat mapping and characterization over the full range of depths necessary to effectively manage these ecosystems. Tools and methods currently in use by CREI scientists include towed diver habitat/fish surveys, acoustic mapping and characterization, towed vehicle photography, and remote sensing.

Towed Diver Habitat/Fish Surveys

Towed diver surveys allow scientists to classify habitats and census marine resources at high resolution over extensive reef areas quickly (~3-km per dive). Paired towboards are equipped with downward-looking and forward-looking digital video cameras, precision temperature and depth recorders, and scaling lasers. In addition to the video records, the divers manually record visual observations of habitat complexity, percent cover of coral (live, dead, rubble, and carbonate pavement), algae (fleshy and coralline), sand (fine, medium, and coarse grain), and rock (cobble, boulder, and basalt pavement), dominant habitat structures, exploitable and other conspicuous macro invertebrates (lobsters, crown-of-thorns starfish, urchins, octopus, cucumbers, and giant clams), and marine debris. Innovative use of digital video combined with fixed distance lasers allow for accurate sizing of fish and corals. The CREI towed diver surveys are one of the primary tools used to ground-truth the remote sensing imagery. Towed diver habitat surveys are used primarily in shallow areas (0-20-m), but can be used to water depths of 30-m (Fig. 16).

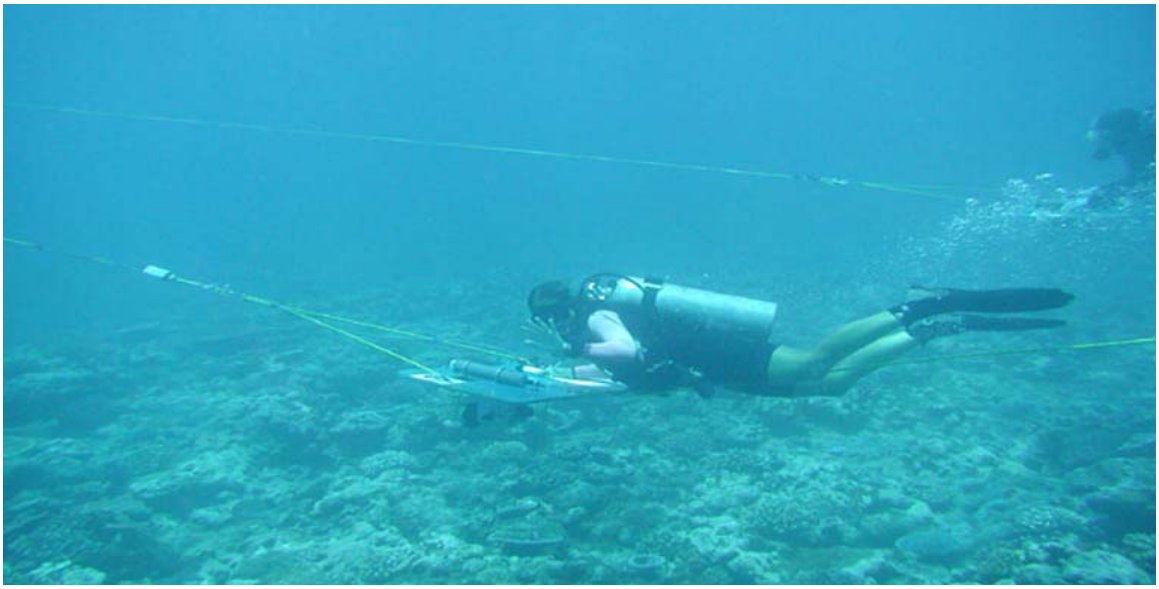

Fig. 16. CREI diver on towboard.

Acoustic Mapping and Characterization

Most areas in the U.S.-affiliated Pacific areas include out-of-date bathymetric data collected in the 1940's or earlier. Since towed diver habitat surveys and remote sensing imagery are useful only in relatively shallow water (~0-30-m) habitats, the primary use of acoustic data is in the 20-400-m depth range. In addition to bathymetry, acoustic techniques are under evaluation for their direct applicability to identification of the various coral reef habitats. Instruments currently being used for acoustic benthic habitat mapping include single-beam echo sounders and a Questar Tangent Corporation (QTC) bottom classification system, which collects and analyzes acoustic returns, and provides a framework for classifying the seabed into different regions based on their acoustic characteristics.

To date, CREI has been using ship-based, single-beam acoustic technology that provides a single, 10-degree beam-width sample per ping with very low resolution under the survey vessel. Multibeam mapping techniques provide scientists with much more accurate, comprehensive, and detailed information about the seafloor. Typically, multibeam echo sounders provide up to 150, one to two degree beam width, high-resolution samples per ping that are approximately perpendicular to the ship track. In 2001, CREI contracted for a commercial assessment of current multibeam capabilities as related to coral reef habitat mapping and characterization requirements. This assessment highlighted the requirement for a high-frequency, high resolution sonar that can operate in water depths from 1-400- m and is capable of imaging features as small as 1-3-m, the size of typical coral formations. Based on these results, compact 240-kHz multibeam sonar was identified and procured.

Towed Vehicle Photography

A prototype towed optical assessment device (TOAD) was developed and deployed in 2001-2002 to provide digital still photographs and video data in depths to 100 meters. The photographs and videos are being used to ground-truth acoustic data. The TOAD provides a steerable platform upon which high resolution digital still and video cameras, lights, and an altimeter are mounted.

Remote Sensing

Satellite and aerial remote sensing of coral reef habitats is a relatively new discipline. The immense size, remoteness, and isolation of most U.S. Pacific coral reefs make remote sensing technology an essential tool to monitor, map, and manage the shallow water components of these ecosystems. Two types of images being evaluated for use in coral reef remote sensing are 1) multi-spectral (IKONOS satellite) and 2) hyperspectral (NASA AVIRIS, NOAA and private aircraft). Experimental products are under development and production by NOAA, other agencies, and industry for use in benthic habitat mapping. *In-situ* observations made by divers during CREI cruises support this development by providing important ground-truth data to constrain the remotely sensed benthic habitat characterizations.

Data Analysis and Results

Since May 2001 most of the efforts of the benthic habitat mapping and characterization program have focused on system and program design, procurement, at-sea data collection, data processing, and preliminary analyses. Since analyses remain in their preliminary stages, existing products must be considered experimental until finalized and submitted for peer review. However, as can be seen from the following discussion, these preliminary data already provide valuable and insightful information to improve our understanding of coral reef habitats. Several presentations of these preliminary analyses have recently been given.

Since early 2000 cruises to the U.S. Line and Phoenix Islands (3), American Samoa (1), and the NWHI (3) (Fig. 17) have provided characterizations of the shallow (0-20-m) benthic habitats and near-shore oceanographic conditions; completed baseline ecological assessments of fish, corals, algae, and other invertebrate diversity and abundance in selected areas; and collected acoustic depth and bottom characterization and validation photographic data in water depths of 20-100-m. Table 9 summarizes cruises to date and benthic habitat data collected on each cruise.

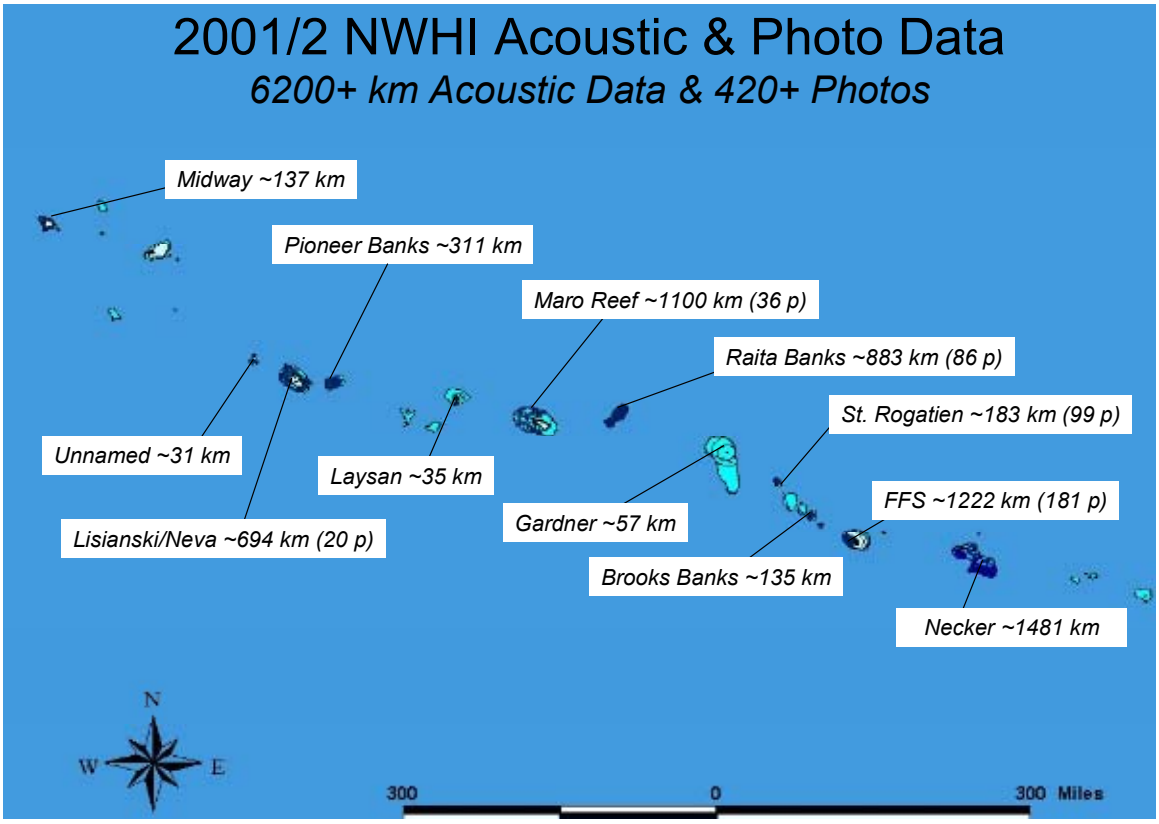

Fig. 17. Location of 2001/2002 NWHI acoustic survey areas with depth and bottom classification data. The number of still photographs is indicated in parentheses.

Table 9. Benthic Habitat Data Collected on CREI Cruises – 2000 to 2002.

Cruise	Dates	Areas	#Tows	Bottom* Class (km)	Photos**
TC-00-01	Mar/Apr 00	Line/Phoenix	36	N/A	N/A
TC-00-11	Sep/Oct 00	NWHI	104	N/A	N/A
TC-01-01	Jan/Feb 01	Line/Phoenix	31	N/A	N/A
TC-01-10/11	Sep/Nov 01	NWHI	33	6269	420
TC-02-01	Jan/Mar 02	L/P/Am Samoa	102	1600	653
Total			**306**	**7869**	**1173**

* Linear kilometers of bottom classification data
** TOAD photos usable for bottom identification

Towed diver habitat surveys have provided basic *in-situ* information for habitat characterization, estimating abundance of coral, algal, and other bottom cover over broad areas, ground-truthing satellite, and aerial imagery (Fig. 18).

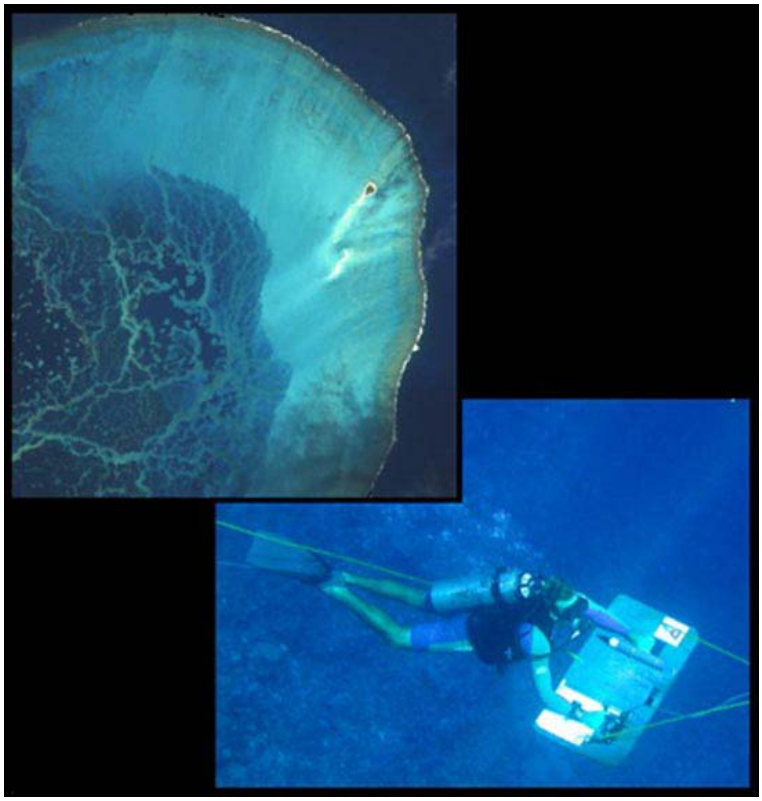

Fig. 18. Towed diver surveys provide basic *in-situ* information for groundtruthing satellite images.

Post-cruise in-depth analysis of video and sample data at CREI and at collaborative institutions including the UH, Oceanic Institute, Bishop Museum, and USFWS provides more accurate and statistical estimates of species occurrence and diversity and distribution of bottom types. Using sophisticated visual imaging software, CREI scientists systematically analyze frames of video and generate quantitative descriptions of abundance and percent cover of coral, algae, sand, rock, and other substrate components. Quantitative analyses of 35 towed-diver digital video habitat tapes have been completed, providing data for habitat characterization used in numerous presentations and reports (Fig. 19).

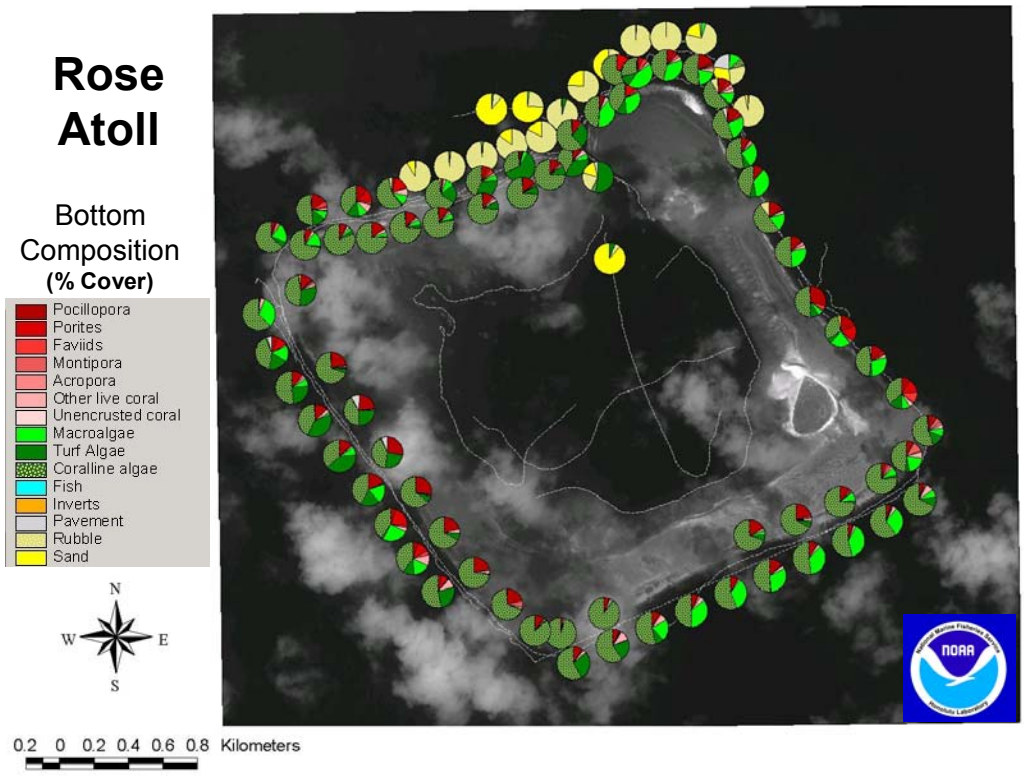

Fig. 19. Rose Atoll – Habitat complexity and substrate composition from towed diver habitat/fish surveys overlaid on IKONOS image (courtesy of Space Imaging).

While acoustic technologies for bathymetric charting and mapping are well established, they are only now being implemented, modified, and evaluated to determine their applicability to benthic habitat characterization of coral reefs. In order to begin providing accurate and detailed base maps for all types of habitats, analyses are underway to determine the best and most applicable tools and products for benthic habitat mapping and characterization in water depths ranging from 10-100 m. Promising analysis tools for the acoustic data, which are currently under development by CREI scientists, include along-track acoustic variability, spatial acoustic variability, and rugosity (Fig. 20). Such statistical parameters can be displayed draped over the bathymetric base maps calculated from our acoustic depth data using the ArcView GIS. These preliminary 2D- and

3D-visualization products already provide scientists with useful tools for understanding the benthic habitat (Fig. 21).

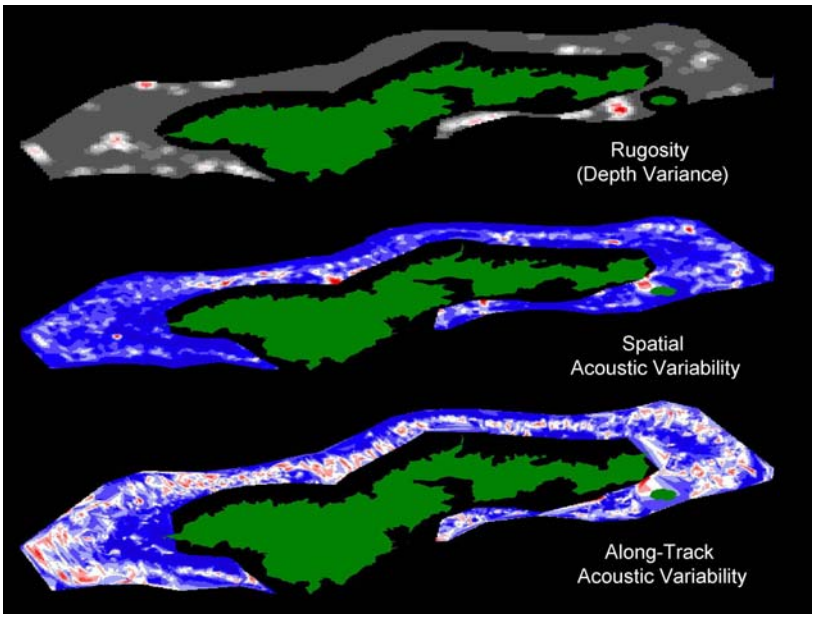

Fig. 20. Comparison of acoustic variability and rugosity around Tutuila Island, American Samoa. Rugosity was calculated using a method described by Ardron (2002). The acoustic variability of the QTC bottom classes, which is calculated using principle components analysis, was evaluated both along-track and spatially using tools created in ArcView GIS.

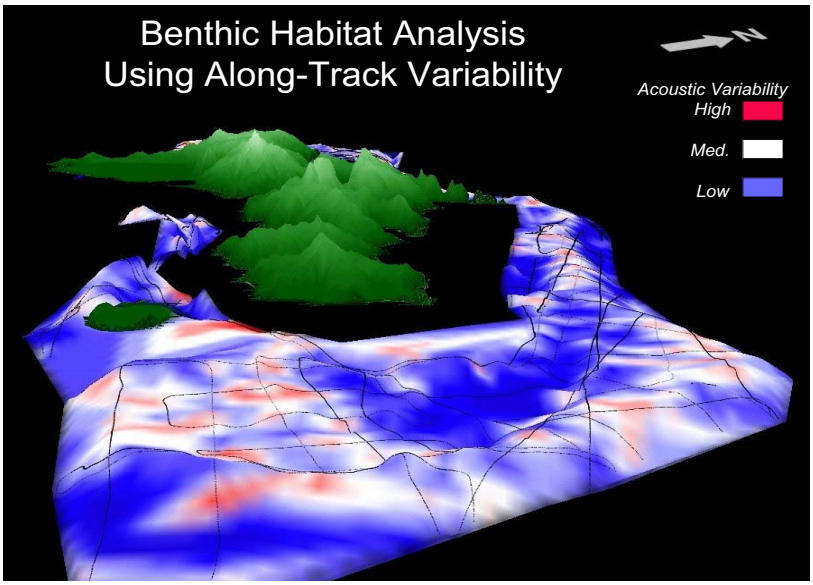

Fig. 21. ArcView 3D Image of along-track acoustic variability for Tutuila, American Samoa. Nearest neighbor interpolation of variability of QTC principle component acoustic classes draped over bottom topography. Actual survey lines shown in black. Land surfaces (green) created from USGS 10-m DEM with 3X vertical exaggeration. Below sea level represented with 10X vertical exaggeration.

CREI is working with our NOAA colleagues to develop data management protocols and guidance for all coral reef ecosystem related data. In addition to assisting with the development of the NOAA Coral Reef Information System (CoRIS), CREI scientists and data management specialists are working to provide data, publications, and other products to the NOAA CoRIS team. A dedicated CREI data management position has recently been established and filled to coordinate CREI data management efforts.

Future Plans

Scheduled Field Work

In the next year, CREI has a 30-day cruise in the NWHI before the NOAA ship *Townsend Cromwell* is retired in October 2002. Following that, 105 sea days are scheduled aboard the NOAA ship *Oscar Elton Sette* between July and October 2003. Studies of benthic habitat, associated reef organism distribution and abundance, and oceanography will be incorporated into all of these cruises. In addition, CREI scientists will participate in a NWHI multibeam survey in October and November 2002, sponsored by NOS and the Office of Ocean Exploration (OE), aboard the UH's new research vessel *Kilo Moana*. During this cruise, critical fisheries management boundaries required by the proposed Coral Reef Ecosystem FMP and NWHI Coral Reef Ecosystem Reserve will be mapped. CREI is providing base-maps of existing data as well as bottom classification instrumentation and software to complement the planned single and multibeam mapping activities. This cruise includes scientists from NOS, NMFS and Ocean Exploration, UH and UH/NOAA Hawaii Undersea Research Laboratory (HURL), providing another example of multi-agency cooperation in coral reef activities.

Analyses and Publication

Another significant part of the work to be done in the upcoming months is to continue with analysis of the recently collected benthic habitat data from the NWHI, American Samoa, and the U.S. Line and Phoenix Islands. CREI scientists, in collaboration with our partners, will continue detailed and quantitative analyses of video and photographic data and evaluating acoustic bottom classification data. Collated metadata will be incorporated into the CoRIS database and products will be distributed on the CREI and CoRIS web sites. Scientific papers will be prepared for peer reviewed publication and presentation at scientific and resource management meetings.

Multibeam Mapping System

As mentioned, one of the principal CREI goals is the development of an acoustic benthic habitat characterization system capable of performing high-resolution mapping in coral reef habitats. Acoustic mapping provides a very effective means for extending habitat characterization to deeper areas that are not suited to observations by divers or by satellite. However, acoustic bottom characterization cannot be conducted in isolation. If acoustic characterization is

to support satellite and *in-situ* visual observations and extend them into deeper waters, it is important for acoustic mapping surveys to be designed to overlap with satellite and *in-situ* surveys, which are usually in depths of less than 20 m; thus survey overlap would necessarily be in depths less than 20 m. Furthermore, because of the hazards of navigating large research vessels near poorly charted Pacific reefs, ship-based surveys could not be conducted in many critical coral reef areas of the U.S. Pacific Islands where steep fore reef slopes prevent larger vessels from safely operating in water depths shallower than 100 m. Shallow water surveys represent a critical component of the EFH that CREI needs to characterize and monitor. In order to avoid limiting the utility of the CREI multibeam acoustic mapping system for habitat mapping and characterization of the coral reef ecosystems of the U.S. Pacific Islands, a survey launch capable of operating from either the NOAA ship *Oscar Elton Sette* or NOAA ship *Vindicator* is being procured. This boat will be a foam-collared rigid aluminum hulled boat that is capable of operations in the routinely rough tradewind waters of the central and western Pacific. The hull is being modified to include a fairing for the multibeam sonar and to accommodate other critical survey electronics (Fig. 22). Multibeam acquisition, processing, and classification software has also been added to CREI's habitat mapping toolkit (Fig. 23). After installation and testing, several surveys of reef habitats within the MHI are planned for early summer 2003, prior to operational deployment to the NWHI, Guam, and CNMI on the *Oscar Elton Sette* in July 2003.

Fig. 22. Survey launch for multibeam operations.

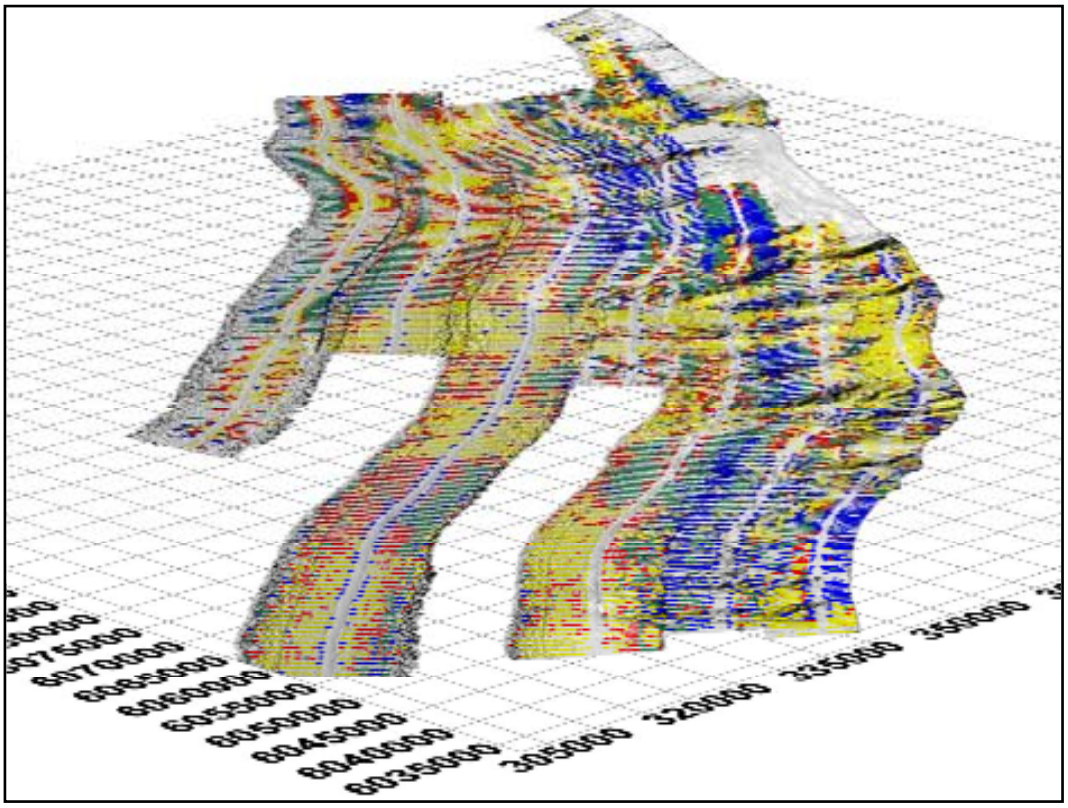

Fig. 23. Example of multibeam bottom classification results courtesy of Quester Tangent Corporation. The data were collected and are owned by the Irish Geological Survey. The colors are classes of sediment and bedrock generated by QTC MULTIVIEW analyzing the raw multibeam backscatter data.