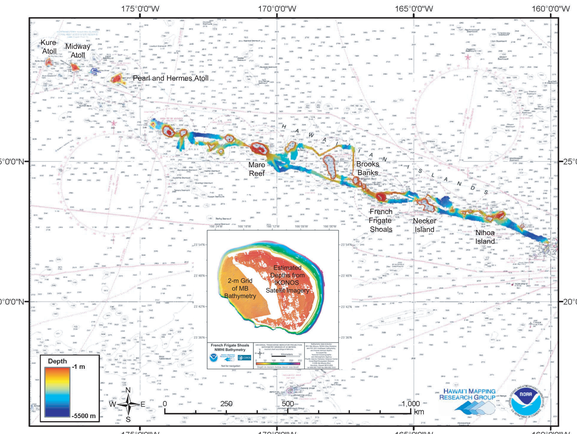
NOAA Seafloor Mapping and Characterization in the Hawaiian Archipelago

Joyce Miller, Jonathan Weiss, Emily Lundblad, Jeremey Jones, Scott Ferguson, John Rooney, Joe Chojnacki: JIMAR/NOAA Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division & SOEST/Pacific Islands Benthic Habitat Mapping Center;
Susan Vogt, NOAA/National Marine Sanctuaries Program; Robert O'Conner, NOAA Pacific Islands Regional Office

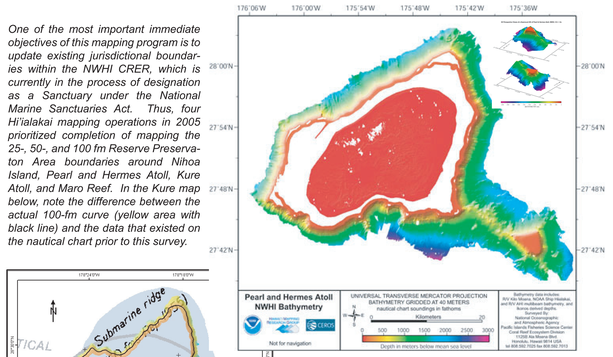
Northwestern Hawaiian Islands



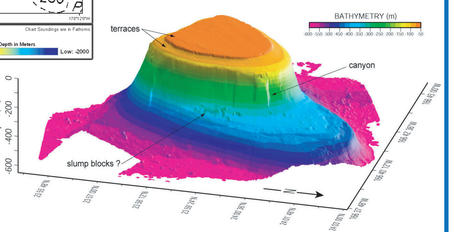
The Northwestern Hawaiian Islands (NWHI) stretch almost 2000 km from Nihoa Island to Kure Atoll. The multi-beam bathymetry data shown here were collected on six mapping cruises between 2002 and 2005. As part of this work an on-going synthesis effort is underway to constantly update and make available to the public accurate and up-to-date bathymetric grids. All NWHI bathymetric grids shown here are available for download at http://www.soest.hawaii.edu/pibhmc.

Since 2002 NOAA has implemented a major mapping program in the Hawaiian Archipelago in support of NOAA's Coral Reef Conservation Program (CRCP), NOAA Fisheries, and the National Marine Sanctuaries Program (NMSP). Major goals of this work are to conduct benthic habitat mapping using seafloor bathymetry, acoustic backscatter, and optical data; to develop methods for determination of seafloor substrate type and habitat for priority areas in moderate depth (20-500 m) submarine environments; to provide information for determination of Essential Fish Habitat (EFH); and to accurately map the NWHI Coral Reef Ecosystem Reserve (CRER) and other priority NMSP areas. To accomplish these goals the *Hi'ialakai* was outfitted with two sonar systems that provide multibeam data in water depths between 20 and 5000 m. The R/V *AHI*, a 25-ft survey launch also equipped with multibeam sonar, is deployed from the *Hi'ialakai* or independently from shore, to map near-shore regions.

One of the most important immediate objectives of this mapping program is to update existing jurisdictional boundaries within the NWHI CRER, which is currently in the process of designation as a Sanctuary under the National Marine Sanctuaries Act. Thus, four Hi'ialakai mapping operations in 2005 prioritized completion of mapping the 25-, 50-, and 100 fm Reserve Preservaton Area boundaries around Nihoa Island, Pearl and Hermes Atoll, Kure Atoll, and Maro Reef. In the Kure map below, note the difference between the actual 100-fm curve (yellow area with black line) and the data that existed on the nautical chart prior to this survey.



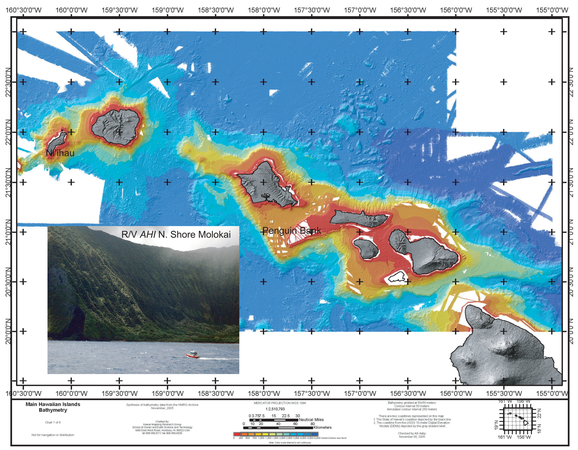
At Pearl and Hermes Atoll (above), in addition to mapping the 100-fm boundary, a survey was done of a seamount to the southeast of the atoll. This seamount, previously depicted as a single 40-fm sounding on the nautical chart, has been documented as a foraging ground for the endangered Hawaiian monkseal by NOAA Fisheries scientists. Two three-dimension representations of the seamount are shown in the upper right corner of the figure. The summit of this unnamed, flat-toped seamount is at 107 meters, while at Brooks Banks (figure below) the summit of a similar flat-topped seamount was mapped at 60 m. This type of information is critical in analysis of previous stands of the sea and climate change.



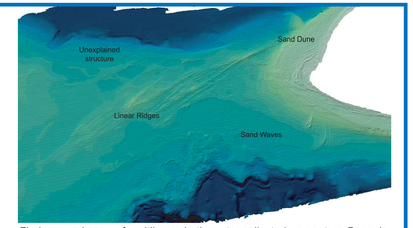
Data collected at Brooks Bank reveal a double terrace at the summit, canyons on the slope, and extensive evidence of mass wasting at the base of the seamount. This detailed morphological data is invaluable for interpretaton of the geological and ecological history of the NWHI

3D Perspective view of Brooks Bank, NWHI looking from 045 degrees. VE = 2x.

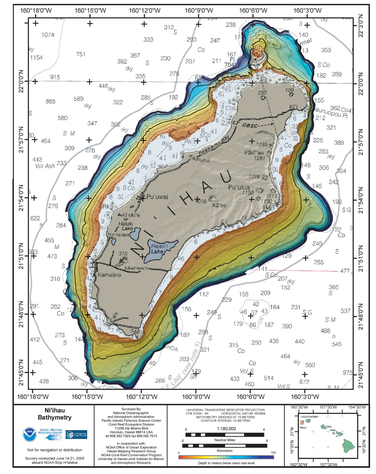
Main Hawaiian Islands



University of Hawaii School of Ocean and Earth Science and Technology (SOEST) scientists, under the direction of Dr. Brian Taylor, have been collecting and integrating multibeam data in the Main Hawaiian Islands (MHI) for many years. Numerous UH investigators, including Dr. Taylor, Dr. Chris Kelley, Dr. John Smith, and Dr. Bruce Appelgate have contributed significant amounts of multibeam data and have kindly permitted us to use this figure of their on-going MHI bathymetric synthesis. In 2004 NOAA and UH/JIMAR/SOEST formed the Pacific Islands Benthic Habitat Mapping Center under a grant from the National Defense Center of Excellence in Ocean Research (CEROS). PIBHMC was formed to combine expertise at SOEST with that of NOAA scientists in collecting and analyzing acoustic and optical data. With the addition of the *AHI* and the *Hi'ialakai* to the research fleet, NOAA joined the MHI mapping effort by surveying the shallow waters around Ni'ihau, Penguin Bank (west of Molokai), the north shore of Molokai, and small shallow areas near Maui & Oahu in 2005. These surveys were planned and executed in response to the needs of managers from the Hawaii Division of Land and Natural Resources (DLNR), the Western Pacific Fisheries Management Council, and the NOAA NMSP Humpback Whale Sanctuary. In April 2006 a follow-up NOAA survey is planned at Penguin Bank to complete the survey of one of the last major unmapped areas in the MHI.

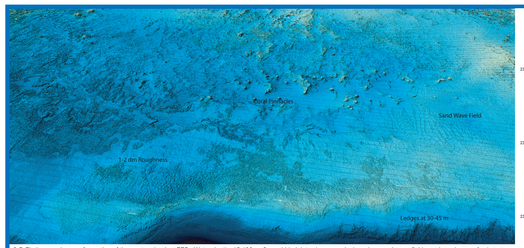


Fledermaus image of multibeam bathymetry collected on eastern Penguin Bank, which was previously considered to be "featureless", reveals sand waves, a 2 1/2 km x 40 m high sand dune, linear ridges, and complex structures on the bank edges.



Bathymetry in 15-100 m depths around Ni'ihau were collected at the request of Hawaii DLNR. These data were supplied to DLNR within one week of cruise completion and are being used by this and other agencies to evaluate fishing and other management issues.

NOAA began systematic mapping in the Hawaiian Archipelago in late 2002, when UH's R/V Kilo Moana surveyed over 38,000 sq. km. in the NWHI in support of defining boundaries for the CRER. The *Kilo Moana* has two Kongsberg/Simrad multibeams: EM1002 (100 kHz) and EM120 (12 kHz). In 2003 the R/V *AHI* (Acoustic Habitat Investigator) began survey work in Hawaii, the Commonwealth of the Northern Mariana Islands, and Guam using a Reson 8101ER (240 kHz) multibeam. The NOAA Ship *Hi'ialakai* was outfitted with two multibeams, Kongsberg EM300 (30 kHz) and EM3002 (300 kHz), and began multibeam surveying in Hawaii in early 2005. In 2005 the *AHI* and the *Hi'ialakai* surveyed over 2800 sq. km. in the Hawaiian Archipelago. In addition to multi-beam bathymetry, all sonars on the three vessels produce acoustic backscatter data, which aids in seafloor characterization.

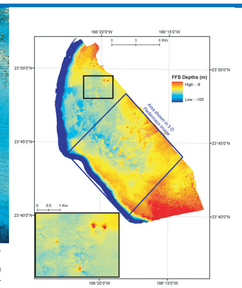


3-D Fledermaus image of a portion of the western bank at FFS. Water depths 15-100m. 2-m gridded data shows coral pinnacles, sand wave fields, and roughness of substrate.

French Frigate Shoals (FFS) was chosen as the first NWHI CRER site for detailed multibeam survey because it is an ecologically important area. FFS is thought to be a genetic gateway to the NWHI from islands that lie south of the archipelago, and critically endangered monk seals, threatened green sea turtles, and millions of seabirds nest there. A permanent USFWS field station at FFS enables scientists to continuously monitor this fragile ecosystem.

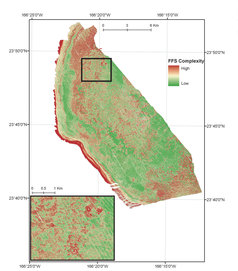
Multibeam data were collected in 2002 and 2005 on the western bank and perimeter of FFS. In 2002 the *Kilo Moana* surveyed on the perimeter of the bank at the 25- and 100-fm isobaths using Simrad EM1002 and EM120 sonars. In 2005 the western bank was mapped at higher resolution with the *AHI*'s Reson 8101ER and the *Hi'ialakai*'s EM3002D sonars in water depths ranging from 15 to 200 m. These high resolution data were then gridded using a 2-m grid cell size.

The bathymetry of the western bank reveals dozens of pinnacles, extensive sand wave fields in several areas, and spur and groove formations on the northwest tip. While the bathymetric map (above right) provides a significant amount of information, a three-dimensional image (above) generated with Fledermaus software aids in interpretation of the bathymetry. Sand waves at the lower right of the above image are less than 0.5 m in height; coral pinnacles in the center of the image are 7-15 m in height and ~150 m in diameter and were, in general, undetected by previous single-beam surveys; small-scale roughness in the foreground is 1-2 decimeters; and a consistent drop-off is seen around the bank at 30-45 m depths, indicating a previous sea-level stand.



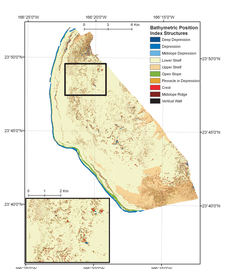
A number of products are derived from the multibeam depth data shown above, including slope, complexity, and bathymetric position index/feature identification maps. These derived products all aid in interpretation of bathymetric data, as steps toward the seafloor characterization and benthic habitat mapping.

A bathymetric complexity map was generated from the 2-m gridded depth data, following the method described in "A GIS Recipe for Determining Benthic Complexity: An Indicator of Species Richness, Ardron, J. Marine Geography, 2002. Using ArcGIS an exaggerated (5x) slope map was first generated. The second derivative (slope of the exaggerated slope) was then calculated, resulting in this complexity map (right).



Physical complexity has proven to be very useful as an indicator of distinctive heterogeneous habitats that are often assocatied with species richness. On the western bank of FFS, high complexity is associated with pinnacles, steep slopes, spur-and-groove formations, and with areas showing small scale roughness shown in the 3-D image, while lower complexity is most often associated with sandy areas.

Another promising habitat classification method is described in "A Benthic Terraine Classification Scheme for American Samoa", Lundblad, et al., Marine Geodesy, 2006, in press.

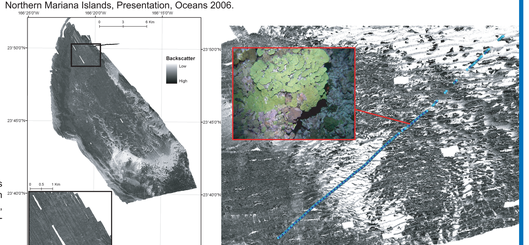


This bathymetric position index map, which was created using Lundblad et al's terraine classification method, helps to identify the occurrence of features, such as the distinctive coral pinnacles, that are important habitats for a variety of species.

Seafloor Characterization and Benthic Habitat Mapping

All multibeam sonars being used in this project produce backscatter information in addition to the depth data. In the figure below, processed backscatter data from the Reson 8101ER and the EM3002D sonars are shown. These data were processed using software recently developed by the Hawaii Mapping Research Group to handle multibeam backscatter data from the 8101ER, EM300 and EM3002D sonars. Major questions still under investigation are how to merge data from three sonars at different frequencies (30, 240, and 300 kHz) and to produce estimates of seafloor types using backscatter values. Backscatter processing and results at FFS are discussed in Weiss et al, Seafloor Characterization using High Resolution Multibeam Bathymetry and Backscatter at FFS, NWHI, presentation, Oceans 2006.

The Reson 8101ER and EM3002D backscatter data are of excellent quality and, when combined with numerous video and photographic images, can be interpreted to produce seafloor characterization and benthic habitat maps. CRED has collected over 4000 video and photo segments in the NWHI since 2001. The optical data at FFS facilitates interpretation of high and low backscatter areas and their association with specific habitat types. As high resolution multibeam grids become available, the bathymetry, backscatter, and optical data can then be combined to provide a variety of products that are useful for resource managers and scientists. Techniques for creation of benthic habitat maps are discussed in Rooney et al, Benthic Habitat Mapping to Meet Management Needs: A Case Study from Saipan, Commonwealth of the Northern Mariana Islands, Presentation, Oceans 2006.



For information, contact Joyce.Miller@noaa.gov