



## CRUISE REPORT<sup>1</sup>

**VESSEL:** *Hi'ialakai*, Cruise 08-04 (Fig. 1)

**CRUISE PERIOD:** May 2–29, 2008

**AREA OF OPERATION:** Necker Island, French Frigate Shoals (FFS), and Brooks Banks, Northwestern Hawaiian Islands, Papahānaumokuākea Marine National Monument (PMNM)

**TYPE OF OPERATION:** Personnel from the Coral Reef Ecosystem Division (CRED), Pacific Islands Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS), NOAA, the PMNM, and NOAA's Biogeography Branch conducted multibeam mapping, camera operations, and diving deployments to better characterize the benthic habitats around FFS and other banks of the PMNM. All activities described in this report were conducted from the NOAA Ship *Hi'ialakai* and are covered under PMNM Conservation and Management permit # PMNM-2008-011 and the *Hi'ialakai* ship permit # PMNM-2008-010.

**ITINERARY:**

2 May Friday. Start of cruise. Embarked Joyce Miller (Chief Scientist), Scott Ferguson (mapping), Frances Lichowski (mapping), Jonathan Weiss (mapping), John Rooney (mapping and diving), Kelly Grimshaw (diving and mapping), Max Sudnovsky (mapping and diving), Joe Chojnacki (Dive Master and mapping), Lisa Baldwin (mapping), Alisha Bare (mapping), Emily Donham (mapping), Charlie Menza (mapping), and Zach Heckt-Levitt (mapping). Departed NOAA pier facility at 1130 and shifted to fueling pier. Finished fueling and exited Pearl Harbor at ~ 1730. Conducted Conductivity, Temperature, Density (CTD) cast and multibeam patch test from 1800 to 2400.

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<sup>1</sup> PIFSC Cruise Report CR-08-008  
Issued 1 August 2008



- 3 May Saturday. Continued multibeam patch tests until ~ 0630. Anchored outside of Keehi Lagoon ~ 0730 and deployed divers to clean ship's hull. Weighed anchor and departed Oahu at ~ 1600. Transited to FFS.
- 4 May Sunday. Continued transit to FFS. At 1015, conducted safety drills. In the afternoon, operational meetings were held to discuss deck operations and diving protocols.
- 5 May Monday. Continued transit to FFS. At ~ 0530, conducted CTD cast. Conducted multibeam mapping south of Necker Island and continued multibeam survey west to FFS.
- 6 May Tuesday. Continued transit and multibeam mapping to FFS. At 0730, conducted boating safety meeting. At 0800, launched R/V *AHI*. At 0900, launched 19-ft Safeboat to recover R/V *AHI* due to engine problems that proved to be air in a fuel line. From 0800 to 1100 tested camera systems aboard ship. At ~ 1230, launched *AHI*. At ~ 1430, recovered *AHI* due to sonar processor failure. From 1230 to 1630 continued shipboard testing of camera systems. At 1815, conducted daily operations meeting. From 2000 to 2400 conducted camera tows.
- 7 May Wednesday. At 0100, conducted CTD and deep multibeam survey south of FFS. At 0800–1130, troubleshooting revealed that sonar processor malfunction was not repairable; efforts were begun to identify replacement unit. At 0900–1130, ship delivered seven fuel barrels to Tern Island for field camps. At 1200, diving safety drills were conducted. At 1400–2400, camera operations were underway.
- 8 May Thursday. At 0000–0400, continued camera operations. At 0400–1030, conducted multibeam survey to west and north of FFS. From 1030 to 2045 conducted camera operations on north bank of FFS. From 2045 to 2400 ship steamed north out of Special Preservation Area (SPA) to dump wet garbage and pump MSD system. Conducted CTD cast and gap filling multibeam survey as time allowed.
- 9 May Friday. From 0000 to 0730 pumping and multibeam survey continued. At 0730, conducted diving safety meeting. At 0800–1430, deployed *HI-2* for diving operations to test protocols for sediment classification. At 1330, conducted shallow CTD cast and commenced multibeam operations on south bank of FFS. At 1430, picked up *HI-2* with fuel system problems. From 1500 to 2400, conducted camera operations on south bank of FFS.
- 10 May Saturday. From 0000 to 0300, continued camera operations. At 0400, conducted CTD cast. From 0500 to 0900, conducted multibeam survey on east side of FFS. At 0900, stopped survey to begin transit to Oahu.

- 11 May Sunday. Continued transit to Oahu. At 0800–1100, slowed down/stopped to remove hawser from *Hi'ialakai* propellers.
- 12 May Monday. Continued transit to Oahu. At ~ 1530–1600, there was a generator failure. From 1800 to 2000 entered Pearl Harbor, exchanged *HI-2* for *HI-1*, picked up spares. At 2000, began transit back to FFS.
- 13 May Tuesday. Continued transit to FFS.
- 14 May Wednesday. Conducted CTD cast at 1100. Conducted deep multibeam survey from 1130 to 2400 between Necker and FFS.
- 15 May Thursday. From 0000 to 0600 continued deep multibeam survey on east flank of FFS. At 0730, a boat and dive operations meeting was held. At 0745, launched R/V *AHI* for survey of area south of Tern Island. At 0800, launched *HI-1* for dive operations south of Tern Island. Between 1630 and 1700 recovered R/V *AHI* and *HI-1*. Conducted camera operations on FFS Bank from 1800 to 2400..
- 16 May Friday. Continued camera operations from 0000 to 0600. At 0730, a boat operations meeting was held. At 0745, launched R/V *AHI* for multibeam survey operations on east flank of FFS. Conducted ship camera operations from 0900 to 1830 on east flank of FFS. At 1830, recovered R/V *AHI*. Conducted camera operations from 1930 to 2400 on east flank of FFS.
- 17 May Saturday. Continued camera operations from 0000 to 0600. Boat and dive safety meeting was held at 0730. Launched R/V *AHI* at 0745 for multibeam operations south of Tern Island. Launched *HI-1* at 0800 for dive operations on outer rim of SW FFS bank. From 0900 to 1600 safeboat was deployed for visits to Tern Island. USFWS staff went aboard *Hi'ialakai* for lunch. Recovered *HI-1* at 1630. Recovered *AHI* at 1645. At 1700, transited out of FFS SPA to dump tanks. Conducted CTD cast at 1830. At 1900, continued transit to dump tanks. Multibeam mapping done north and west of FFS during transit for dumping tanks.
- 18 May Sunday. From 0000 to 0600 continued multibeam mapping west of FFS. Boat and dive safety meeting was conducted at 0730. Launched R/V *AHI* at 0745 for multibeam operations south of Tern Island. Launched *HI-1* at 0800 for dive operations on south FFS bank. Conducted Tethered Optical Assessment Device (TOAD) troubleshooting on board *Hi'ialakai* at 0830. Deployed inflatable for Dive Master refresher dive at 1200. Recovered inflatable at 1600.

- Recovered *HI-1* at 1615. Recovered *AHI* at 1630. From 1700 to 2400 engaged camera operations on SW FFS bank.
- 19 May Monday. Continued camera operations from 0000 to 0600 on SW FFS bank. Boat safety meeting was held at 0730. Launched *AHI* at 0745. At 0800, recovered *AHI* with computer problems. Relaunched *AHI* at 0900 for mapping south of Tern Island. At 0930, engaged camera operations north of FFS. At 1730, recovered *AHI* north of FFS. Continued camera operations at 1800 north of FFS.
- 20 May Tuesday. From 0000 to 0500 continued camera operations north and west of FFS. Conducted CTD cast at 0600. Boat and diving safety meeting was held at 0730. Launched *AHI* at 0745. Launched *HI-1* at 0800 for dive operations. At 0815, recovered *AHI* with air conditioning problems. Relaunched *AHI* at 0900. At 1000, conducted troubleshooting of EM3002 sonar. At 1100, engaged in multibeam mapping on FFS. Exchanged diver and *HI-1* coxswain at 1200. Deployed *HI-5* from 1300 to 1600 for educational benthic habitat mapping operations. Recovered *HI-1* at 1515. Recovered *AHI* at 1630. At 1700, transited offshore for pumping. Conducted CTD cast at 1830. From 1830 to 2400 engaged in pumping and deepwater multibeam operations.
- 21 May Wednesday. From 0000 to 0500 conducted multibeam operations west of FFS and camera tows on Brooks Banks. Boat safety meeting was held at 0745. Launched *AHI* at 0800. Ship transited to N. FFS for camera tows. Recovered *AHI* at 0445. Conducted camera tows from 0530 to 2400 on SW FFS Bank.
- 22 May Thursday. Continued camera tows from 0000 to 0400. Boat and dive safety meeting was held at 0730. Launched *AHI* at 0745 for survey east of La Perouse Rock. Launched *HI-1* at 0755 for diving north of La Perouse Rock. Recovered *HI-1* at 1545. Recovered *AHI* at 1645. Transited for multibeam operations NW of FFS at 1700. Conducted CTD cast at 1830. Conducted deep multibeam survey from 1900 to 2400 NW of FFS.
- 23 May Friday. Continued multibeam survey from 0000 to 0500. Discussed launch conditions on bridge at 0730. Held boat safety meeting at 0745. Launched *AHI* at 0800 for multibeam survey on SE FFS bank. From 0900 to 1500 conducted camera operations on SE bank of FFS. Recovered R/V *AHI* at 1500. Camera operations were conducted from 1500 to 1700. At 1700, ran south of FFS SPA to pump MSD tanks. Engaged in CTD and multibeam operations from 2000 to 2400 east of FFS.

- 24 May Saturday. Engaged in multibeam operations from 0000 to 2400 east of FFS. Weather too rough to launch *AHI* or *HI-1*.
- 25 May Sunday. Continued multibeam operations from 0000 to 0500. Held boat and dive safety meeting at 0730. Launched *AHI* at 0745 for multibeam survey north of La Perouse Rock. Launched *HI-1* at 0800 for dive operations. Recovered *HI-1* at 1600. Recovered *AHI* at 1730. Transited to Little Brooks Banks from 1730 to 2000 for camera operations. Engaged in camera operations from 2000 to 2400 on Brooks Banks.
- 26 May Monday. Continued camera operations from 0000 to 0200 on Brooks Banks. Transited to FFS from 0200 to 0700. Held boat safety meeting at 0730. Launched *AHI* at 0745 for multibeam mapping on FFS bank. Conducted camera operations on FFS bank from 0800 to 1530. Recovered *AHI* at 1630. At 1700, transited to area east of FFS for CTD and multibeam operations. Conducted CTD cast at 2000. From 2030 to 2200 engaged in multibeam gap fills. At 2200, began transit to Honolulu.
- 27 May Tuesday. Transit.
- 28 May Wednesday. Transit.
- 29 May Thursday. At 0730, arrived at Pearl Harbor buoy. At 0845, tied up at Pearl Harbor.

**OPERATIONAL SUMMARY:**

Detailed descriptions of multibeam, towed camera, and diving operations can be found in Appendices A, B, and C.

Table 1.--Summary of HI-08-04 Operations.

<b>Operation</b>	<b># Days</b>	<b># Nights</b>	<b># Deploy-ments</b>	<b>Statistics</b>
Multibeam – <i>Hi’ialakai</i>	6	11	n/a	3297 km <sup>2</sup>
Multibeam -- <i>AHI</i>	12	n/a	15 launches	145 km <sup>2</sup>
Camera Operations	4	8	35 tows	159.8 km, 100.3 hrs
Diving	7	n/a	28 dives; 84 person dives	17 plot surveys, 9 transects; 172 data points; 780 m transect distance
CTDs			37	22 shipboard; 15 <i>AHI</i>
Transit	8.5			
Tests/Pumping	1	4		

## MISSIONS:

1. *Conduct benthic habitat mapping of the reefs and submerged banks surrounding FFS, Pearl and Hermes Reef, and deeper bank areas (as time allows) using ship-based and launch-based multibeam sonars.* Because of time limitations (3 days delay of start of cruise and 4 days of additional transit to return to main Hawaiian Islands to replace sonar processor and exchange *HI-2* with *HI-1*), work was only conducted at FFS and surrounding banks, including Necker and the Brooks Banks. The objective of collecting additional multibeam data at these locations was successfully completed and ~ 3442 km<sup>2</sup> of multibeam data were collected during the cruise.
2. *Conduct optical validation surveys to increase the amount of photographic and video data available in order to better delineate the seabed and associated fauna at FFS and Pearl and Hermes Reef.* Optical data were collected at FFS and on the Brooks Banks with totals of 159.8 linear km and 100.3 h of excellent quality video data being collected. New equipment configurations were successfully used including a dedicated winch controlled by the scientific observer/operator, new lights, a Track Link system, and the Biogeography camera sled. The optical data will be used for habitat characterization and for alien species identification.
3. *Conduct diving operations in order to better constrain and understand existing multibeam and optical validation data. In specific, diving operations are designed to determine the depth of sand in specific areas and to better quantify existing backscatter values.* Diving operations were very successful in achieving the scientific objectives of the mission, and the 28 dives proved to be quite able to pinpoint areas of interest to test hypotheses about the nature of the seafloor. Techniques developed on this cruise are a most useful addition to benthic habitat mapping methodologies.
4. *Conduct shipboard CTDs at specific predetermined locations along the NWHI.* CTDs were conducted in support of multibeam operations at Necker Island, FFS, and Brooks Banks. Twenty-two CTD deployments occurred from the *Hi'ialakai* and 15 from the R/V *AHI*.
5. *Collect ADCP data during all transits.* ADCP data were collected continuously during HI-08-04.

## SCIENTIFIC PERSONNEL:

Joyce Miller, Chief Scientist, *AHI* Coxswain, Joint Institute for Marine and Atmospheric Research (JIMAR), University of Hawaii (UH), Coral Reef Ecosystem Division (CRED)

Scott Ferguson, *AHI* lead, *AHI* Coxswain, JIMAR, UH, CRED

John Rooney, Camera operations lead, working diver, JIMAR, UH, CRED

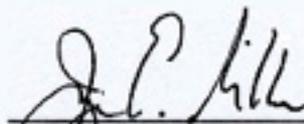
Charlie Menza, Nighttime camera operations lead, National Ocean Service (NOS),  
Biogeography

Jonathan Weiss, Shipboard multibeam lead, JIMAR, UH, CRED  
Frances Lichowski, *AHI* and coxswain trainee, JIMAR, UH, CRED  
Joe Chojnacki, Dive Master and diver, NOS, Papahānaumokuā Marine National  
Monument, Research Corporation of the University of Hawaii  
Kerry Grimshaw, Working diver, JIMAR, UH, CRED  
Alisha Bare, student trainee, JIMAR, UH, CRED  
Lisa Baldwin, student trainee, JIMAR, UH, CRED  
Zach Hecht-Leavitt, camera operations, NOS, Biogeography, Contractor  
Emily Donham, trainee, JIMAR, UH, CRED  
Max Sudnovsky, *AHI* Coxswain trainee, multibeam, Aquatic Farms, CRED  
James Bostick, Chamber operator, Dive Master, NOS, NDC

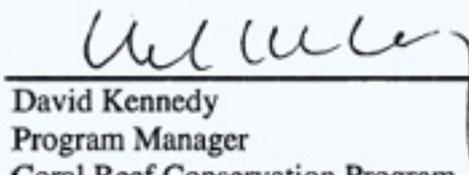
**DATA COLLECTED:**

EM300 Multibeam data  
EM3002 multibeam data (mostly replicates of 2005 data)  
Reson 8101 multibeam data  
Conductivity, temperature, density (CTD) data in support of multibeam mapping operations  
Acoustic Doppler Current Profiler data  
Video transects from TOAD camera system (both downward and forward looking)  
Still photographs from Biogeography camera system  
Sediment depth measurements  
Sediment photographs  
Sediment grain size data  
Still photographs from dive sites  
Diver observations of benthic habitats and bottom characteristics

Submitted by:

  
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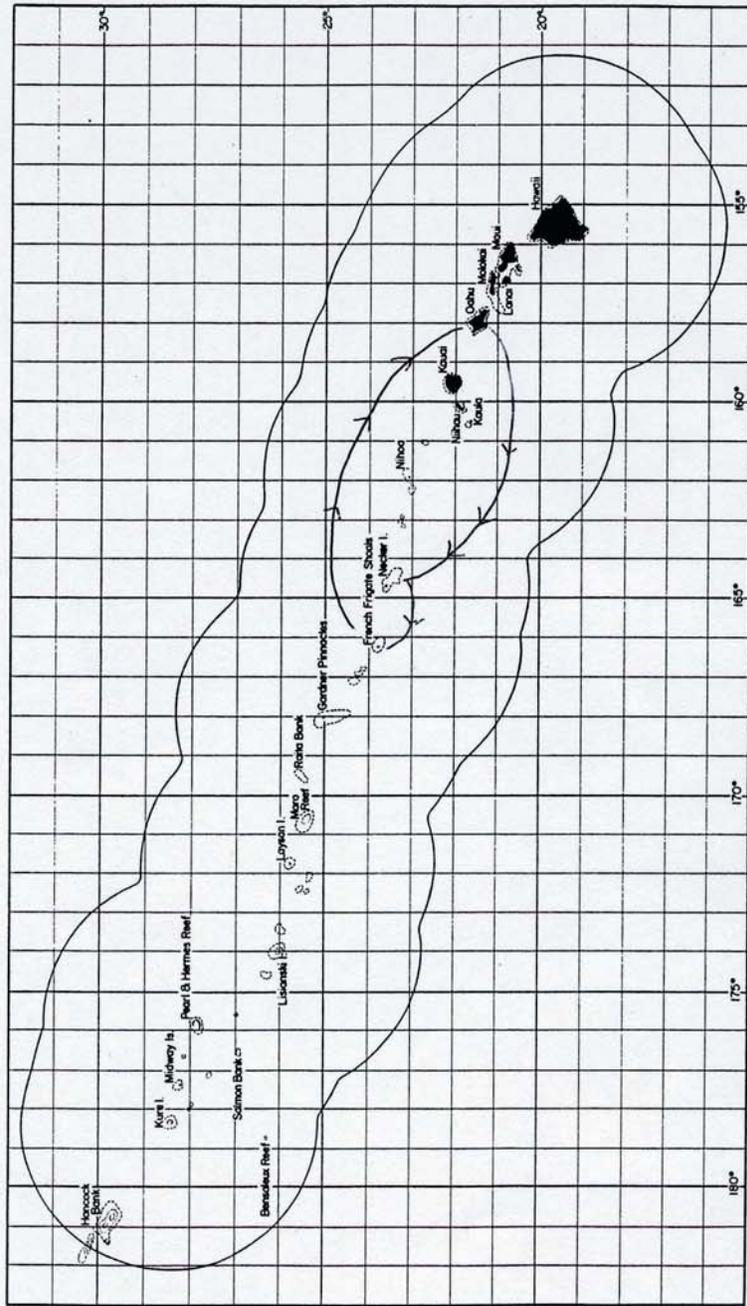


Figure 1.--Track of the NOAA Ship Hi'ialakai cruise HL-08-04, May 2-29, 2008.

## Appendix A: Multibeam

### A.1 Benthic Habitat Mapping Methods

*(Joyce Miller, Jonathan Weiss, Scott Ferguson, Jeremy Taylor, Frances Lichowski, Max Sudnovsky)*

#### *System Descriptions*

Multibeam mapping capability for cruise HI-08-04 included two shipboard multibeam sonars (Kongsberg Simrad EM300 and EM3002D) and the Reson 8101ER multibeam sonar (AHI-08-04) aboard the 8-m launch R/V *Acoustic Habitat Investigator (AHI)*. Table A1-1 provides an overview of the three multibeam sonars and their capabilities.

Table A1-1.--Sonar System Capabilities.

<b>Sonar</b>	<b>Vessel</b>	<b>Freq. (kHz)</b>	<b>Depth range (m)</b>	<b>Beam size (deg)</b>	<b>Number of beams</b>
EM300	<i>Hi'ialakai</i>	30	30-3000	1 ½ x 1 ½	135
EM3002D	<i>Hi'ialakai</i>	300	2-150	1 x 1	320-508
Reson 8101ER	<i>AHI</i>	240	2-250	1 ½ x 1 ½	101

In addition to the multibeam sonars, each vessel is equipped with an Applanix Position Orientation Sensor for Marine Vessels (POS/MV) vertical reference system, which provides timing, position, velocity pitch, roll, heave, and heading information for correction of motion in the multibeam data. Two conductivity-temperature-depth (CTD) sensors were used to provide sound velocity profiles (SVPs) that are critical for proper correction of sound velocity errors associated with multibeam data. A Sea-Bird Electronics (SBE) 11 is used aboard the *Hi'ialakai* and an SBE 19 is used aboard the R/V *AHI*. The SBE 19 was calibrated by Jeremy Taylor and Jonathan Weiss at the start of the cruise by attaching it to the shipboard SBE 11 while performing a cast and comparing the resulting data from the two instruments.

#### *Methods for Acquisition and Post Processing*

Prior to the cruise, preexisting multibeam bathymetric data were assembled to prevent re-surveying of previously mapped portions of the seafloor. These data included: (1) grids of multibeam bathymetric data from previous CRED cruises to the Northwestern Hawaiian Islands and, in particular, data collected in UTM Zone 03 N during cruises HI0501, AHI0501, HI0503, HI0612, and AHI0612; (2) seafloor depths derived from IKONOS satellite imagery of the FFS bank top; (3) recently collected NOAA R/V *Ka'imikai-o-Kanaloa (KOK)* multibeam bathymetric data from the FFS area provided in netCDF grid format by Dr. John Smith (Hawaii Undersea Research Laboratory); (4) recently collected UH R/V *Kilo Moana* multibeam data around Kauai; and (5) one swath of multibeam data collected during cruise AVON01MV on Necker Ridge downloaded from NGDC. In addition to the multibeam data, predicted tides for stations 1611400 Nawiliwili, 1619910 Midway, and 1617433 Kawaihae, and tide zones corrections (provided by NOAA Center for Operational Oceanographic Products and Services) were integrated into the ISS-2000 software during the first part of the

cruise. CRED towboard tracks at FFS were provided by Ben Richards (CRED) and integrated into the real-time acquisition systems as a track file, which was then loaded onto both the shipboard and R/V *AHI* acquisition computers. Existing multibeam and backscatter data grids, TOAD, and towboard data from 2000 to 2006 cruises were assembled and integrated into ArcGIS 9.2.

All sensors on both vessels were interfaced to the SAIC ISS-2000 data acquisition and survey control system, which provide survey planning and data acquisition capabilities. The ISS-2000 survey system enables seamless sharing of data between the two vessels. The Generic Sensor Format (GSF), which is implemented in the ISS-2000 system, allows logging of multibeam data from a variety of multibeam sonars into a single, standardized format; the GSF also provides integrated metadata within the real-time multibeam files. In addition, the ISS-2000 creates digital message logs that allow full traceability of software and real-time events.

During system configuration, all vessel offsets are entered into either the Position Orientation Sensor for Marine Vessels, the sonar, or into the ISS-2000. Survey plans consisting of coverage grids with preexisting data, coverage grids generated in real time during acquisition, survey plans, track lines, etc., are loaded into the real-time system on both vessels prior to data acquisition.

SVPs are taken at the beginning of each 12-h period of surveying on the ship and each 8-h day of surveying on the *AHI*. Standardized survey procedures, including a 2-min warm-up on deck and a 2-min surface equilibration, are used on every cast. After the sound velocity cast is done, the data are downloaded with VelocWin software on the ship and with the SeaBird software on the launch. Sound velocity profiles are loaded using the ISS-2000 and applied in real-time to the data. A real-time probe is used on the ship to monitor the surface sound velocity (SSV); if a difference between the SSV and the SVP at the surface is greater than 3 m/sec, an alarm is generated. The sonar on the *AHI* is less susceptible to SSV errors, and the daily casts are generally sufficient to correct for sound velocity. In all cases, the data are carefully monitored for sound velocity artifacts using the real-time displays, and additional SVPs are performed whenever possible and if necessary. Predicted tide files that can be used throughout 2008 were prepared before the cruise and were applied to the multibeam data in real time. HI-08-04 multibeam data were logged to two disks simultaneously in real time. The ISS-2000 auto archive program, which copies the data to a third archive disk (HII1) was run as needed during post processing. The AHI-08-04 data set was logged on the real-time computer, and the data were manually copied to an external hard drive on a daily basis and then manually copied to HII1 on board the ship. The program xfer, which invokes auto archive, was used to copy the *AHI* data from HII1 to the Pacific Islands Benthic Habitat Mapping Center (PIBHMC) data server (AHI10), and data processing and manipulation were performed on this final copy of the data. The SABER data processing package, which provides full multibeam processing capability, was used to manually edit the multibeam data on a GSF file by file basis, to plot tracklines, to post-apply SVP and tide data when necessary, and to create gridded data sets using the Pure File Magic (PFM) format. PFM is a data storage and display format developed by the U.S. Naval Oceanographic Office (NAVOCEANO) and licensed to SAIC for use in SABER. PFM creation is an area-based editing approach that

facilitates the removal of outliers where files overlap. PFM layers are created with previously acquired new data, and edits made to a PFM are unloaded to the GSF files on a daily basis. CUBE (Calculating Uncertainty in a Bathymetric Editor) surfaces were created as a part of the PFMs for the newly acquired data. The CUBE algorithm performs a statistical analysis of the data and populates a bathymetric surface with the statistically 'best' guess. Tape backups of all processed data were made once a week. Finalized gridded data sets that combine all of the CRED data from the area will be prepared and distributed via the PIBHMC Web site at [www.soest.hawaii.edu/pibhmc](http://www.soest.hawaii.edu/pibhmc). These data will be converted to ASCII files for conversion to Arc raster grids and added to the Geographic Information Systems product archive.

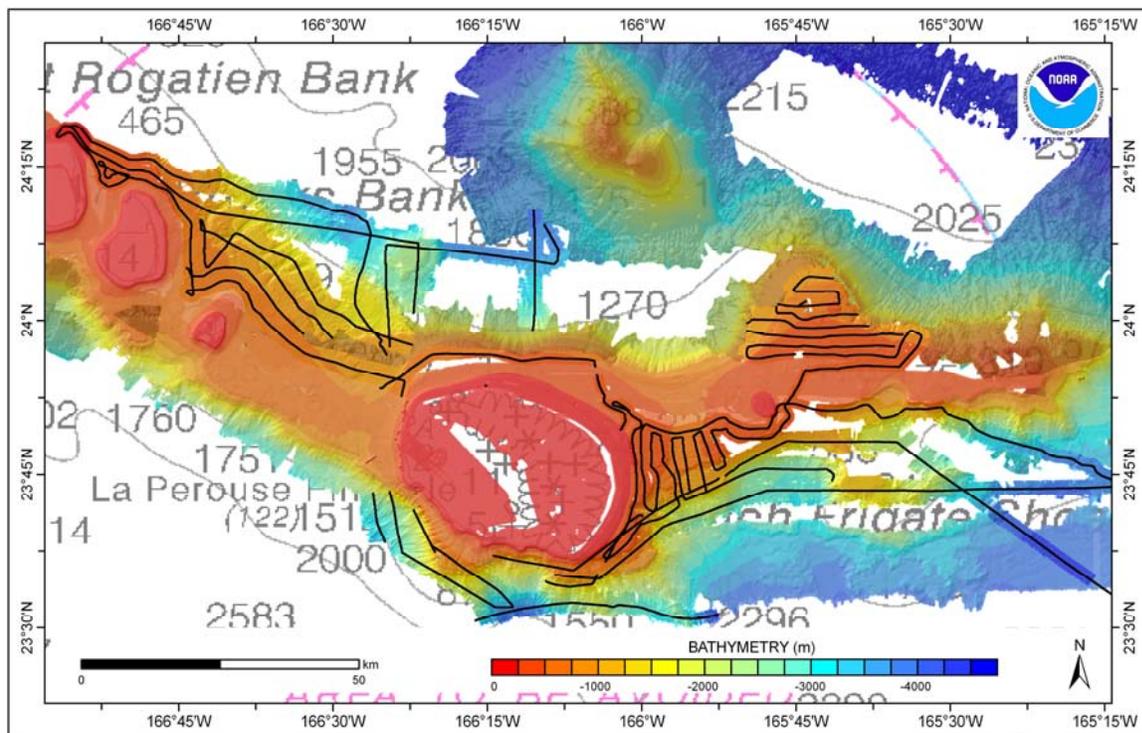
#### *Confirmation Patch Test*

Confirmation patch tests for the NOAA Ship *Hi'ialakai* multibeam sonars (Simrad EM300 and EM3002d) were conducted on May 2–3, 2008 immediately after departing Pearl Harbor. The tests were performed to validate the 2007 calibration results. The sonar system bias parameters were NOT reset to values of zero prior to the calibrations. Determined biases were not significant, and existing values were left in both of the Simrad sonars. The patch tests were a useful exercise for determining the accuracy of previously entered offsets. They also gave NOAA officers a chance to run survey lines for the first time in over a year and afforded the science team the opportunity to test the sonar and data acquisition and processing systems. Everything appeared to be working well, but during subsequent HI-08-04 operations some errors were detected in the EM3002D data due to apparent electrical problems with the sonar; upon inspection of the EM3002D patch test data, it was apparent that these problems had also been present at the time of the patch test runs. More detailed descriptions of the patch tests and results are included in a report that is included in the NOAA Ship *Hi'ialakai* Patch Test notebook, which is a cumulative report that is located in the multibeam survey office.

#### *Necker Ridge Survey*

During the initial transit to FFS, a few hours of multibeam bathymetric data were collected south of Necker Island to better define the structure of the Necker Ridge, a northwest trending, linear bathymetric high (Fig. A1-1). We collected data directly over the northern portion of the ridge as it approaches the Necker Island bank. These data will be provided to the National Geophysical Data Center (NGDC) and will be used as base level data for Exclusive Economic Zone (EEZ) boundary definitions in the NWHI. After the Necker Ridge survey, additional data were collected around the bank edge south of and to the east of Necker Island. Data were collected in similar locations during our transit to pick up equipment in Honolulu. Figure A1-1 shows the new data around Necker Island and one swath of data from the AVON01MV research cruise downloaded from the NGDC Web site.





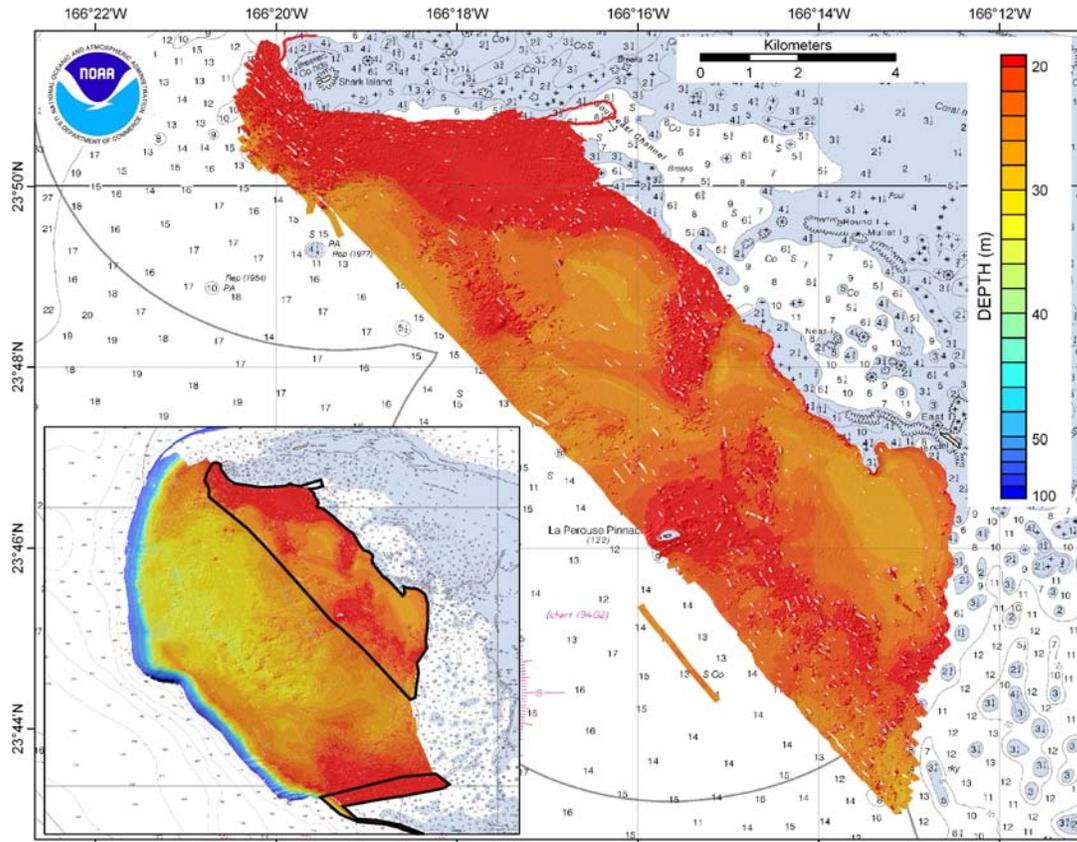
**Figure A1-2.**--Deep water multibeam bathymetric data around FFS include R/V *Kilo Moana* data (KM0206) collected in 2002, NOAA Ship *Hi'ialakai* Simrad EM300 and EM3002d data collected in 2005 and 2008, R/V *AHI* data collected in 2005 and 2008, and R/V *KOK* data collected in 2007. The black line indicates the deep water multibeam data that were collected during HI-08-04.

#### *Shallow Water Mapping at FFS*

A primary mission of HI-08-04 was to conduct benthic habitat mapping on portions of the bank top at FFS in locations where we were unable to map in 2005, where water depths are too shallow for the *Hi'ialakai* to map safely, and beyond the depth limit of the IKONOS derived depths. Figure A1-3 shows the AHI-08-04 bank top bathymetry. The high resolution data resolve the complex nature of the coral reef ecosystem at FFS, which includes patch and linear reefs, pinnacles, pavement, and sand fields. Nearly all of the bank top that could safely be mapped by the R/V *AHI* was completed during AHI-08-04 except for a small portion near the southern edge of the bank. Calm weather permitted the *AHI* to collect data outside of the fringing reef on the east, northeast, and north sides of FFS. These data provide a bathymetric base layer in the location of CRED towboard tracks. Previously, very little overlap existed between the multibeam data and the towboard tracks. CRED scientists plan to use these overlapping data sets to correlate fish abundances with measures of bathymetric variance such as slope and rugosity.

A few swaths of Simrad EM3002d multibeam data were collected during HI-08-04 on portions of the FFS bank top that had previously been mapped in 2005. These data were collected when time permitted to investigate whether or not significant changes in backscatter character had occurred since the earlier data were collected. The EM3002d mapping focused

primarily on locations where diver-based ground-truth data were collected during HI-08-04. The backscatter imagery from these data will be processed in the coming months and incorporated into the ongoing effort to create accurate benthic habitat maps for all of the CRED study sites and the FFS bank top in particular. These data will aid our study of the effect of substrate type on backscatter intensity.



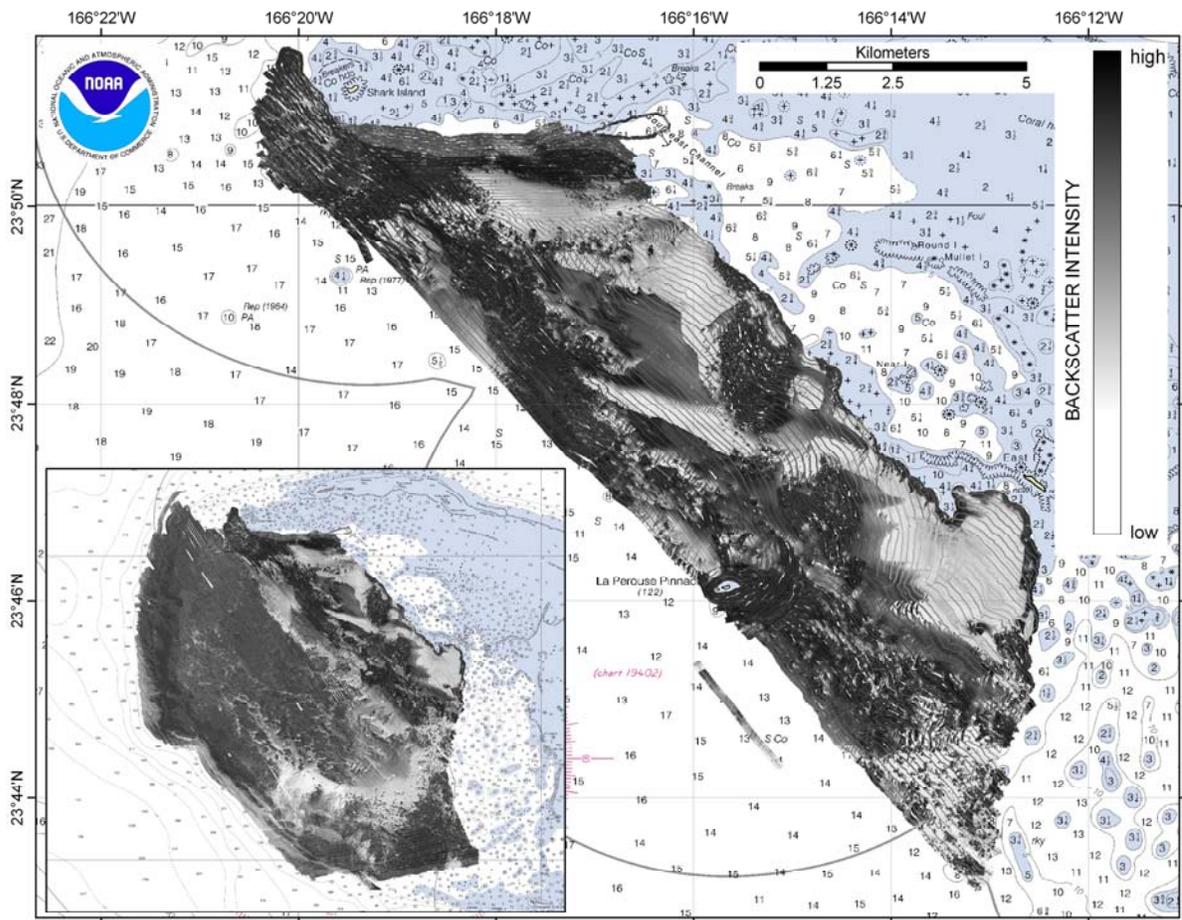
**Figure A1-3.**--Shallow water multibeam bathymetric data collected at FFS aboard the R/V *AHI* during cruise HI-08-04. The inset map shows all of the bank top data including the 2005 data with the HI-08-04 data outlined in black. The larger map shows the new data on shallow portions of the bank ranging from 10 to 30 m below sea level. Note that the data set approaches as close to the shoal areas as possible as shown on the chart. The few lines collected during HI-08-04 on the outer edge of the bank top are not shown in these maps but overlap with CRED towboard tracks.

#### *Backscatter Imagery Processing for Ground-truth Site Selection*

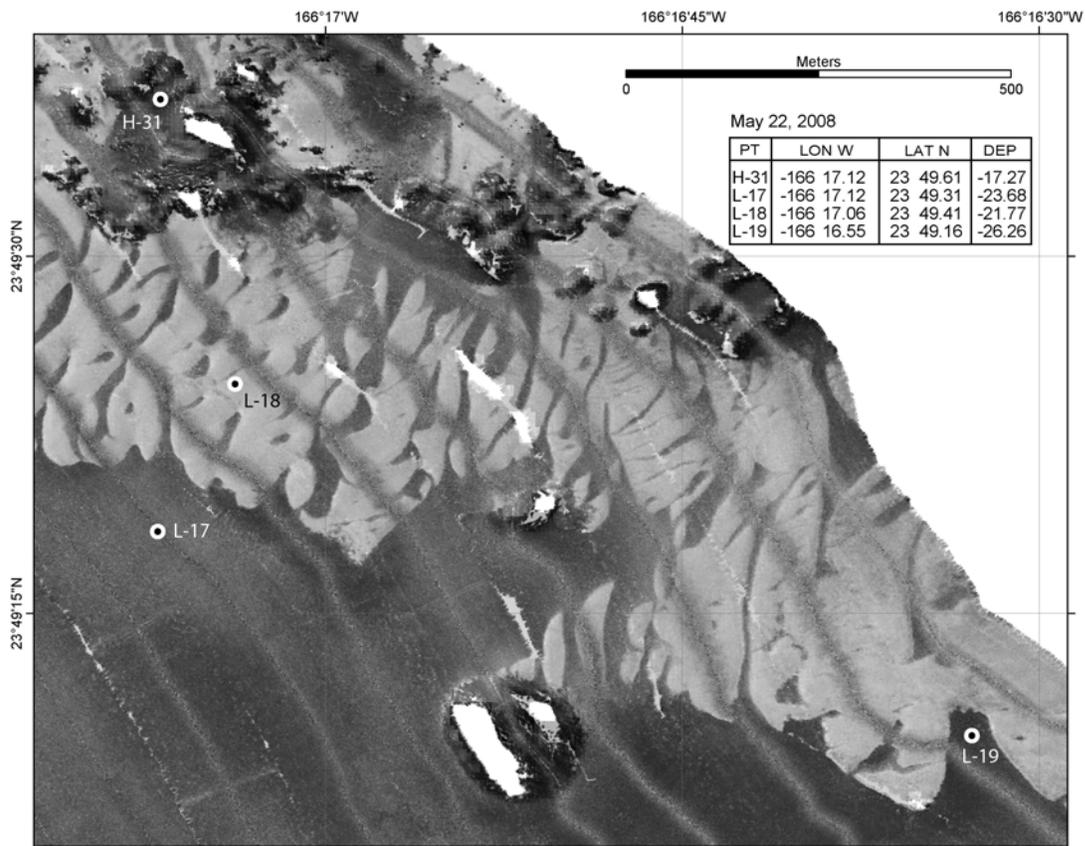
A primary mission of HI-08-04 was to conduct diving operations and obtain ground-truth information at previously determined locations of interest on the FFS bank top. The motivation was to answer some long standing questions regarding variations in backscatter intensity and to validate hard and soft substrate maps. For example, a number of different backscatter intensities all represent seafloor classified as soft or sand bottom. The divers investigated the causes of the variations by taking sediment grain size and sediment thickness

measurements, photographs, etc. across acoustic boundaries and at preselected point locations in the center of acoustically homogeneous areas.

During cruise planning CRED and Papahānaumokuākea Marine National Monument scientists realized that, in addition to collecting ground-truth data at previously mapped locations, diving operations would have to be performed on newly mapped sites to ensure that changes in the seabed morphology and composition since 2005 would not influence all of the conclusions we hope to draw from the ground-truth data. Therefore, the backscatter data collected aboard the R/V *AHI* were preliminarily processed at night using LINUX computers on the *Hi'ialakai* and used for dive planning the following day. Software developed in-house at the University of Hawaii by the Hawaii Mapping Research Group (HMRG) was used to convert the GSF data into a file format compatible with the software. The data were split into 5-min segments, despeckle and demicrostripe filters were applied, an angle varying gain correction was applied, a gray map was generated, and GeoTIFF mosaics were created. The GeoTIFF files were imported into ArcGIS, preliminarily analyzed, and used to determine dive sites. Figure A1-4 shows the backscatter imagery collected and processed during HI-08-04. In addition to increasing the bank top coverage, the data revealed a number of very sharp acoustic boundaries in areas with sand or soft seafloor that were excellent sites for ground-truth data collection. Flame-like features and sand waves were also mapped and indicate the presence of strong seabed currents. A number of hard bottom areas and transition zones between areas of varying backscatter intensity were also excellent locations for ground-truth data collection. Figure A1-5 shows a portion of the AHI-08-04 backscatter data and planned dive points. Maps like these were created on a semi-daily basis, printed on waterproof paper and taken into the field by the divers; these maps greatly aided the ground-truth operation.



**Figure A1-4.**---Backscatter data collected aboard R/V *AHI* during AHI-08-04 and preliminarily processed on board the *Hi'ialakai* for dive planning purposes. The inset map shows the entire bank top backscatter data set including EM3002d and Reson 8101 data collected in 2005. All backscatter data are gridded at a 1-m resolution.



**Figure A1-5.**--R/V *AHI* multibeam backscatter data were processed the night after acquisition and used to choose dive sites for ground-truth operations. In this example, dive sites are on a presumed hard bottom substrate (H-31), and a variety of presumed soft bottom substrates (L17, L18, and L-19). Maps like this one were provided to the divers the night before planned operations and proved useful for locating themselves on the substrates of interest. Note the variety of patterns and substrates of varying acoustic intensity that were mapped in this relatively small area. Darker shades of gray indicate higher backscatter values, whereas lighter shades of gray indicate lower backscatter values.

## Appendix B. Towed-Camera Operations

### Introduction

From May 7 to May 26, 2008 towed underwater cameras were used at FFS and the Brooks Banks in the Northwestern Hawaiian Islands to collect in situ benthic imagery. The cameras were deployed from the NOAA Ship *Hi'ialakai* and collected over 100 h of video data. Table 1 provides tow summary statistics.

Table 1.--Tow summary statistics at FFS and Brooks Banks, Northwestern Hawaiian Islands.

Location	No. of tows	Total length (km)	Total bottom time (hrs)	Depth range (m)
French Frigate Shoals	31	153.3	96.2	20–225
Middle Brooks Bank	2	1.7	1.51	27–43
West Brooks Bank	1	3.7	1.66	22–48
Baby Brooks Bank	1	1.1	1.01	51–53
Totals	35	159.8	100.3	20–225

Locations of previous tows (only available for FFS) and tow tracks from this cruise for FFS and for each of the Brooks Banks can be seen in Figures 1–4.

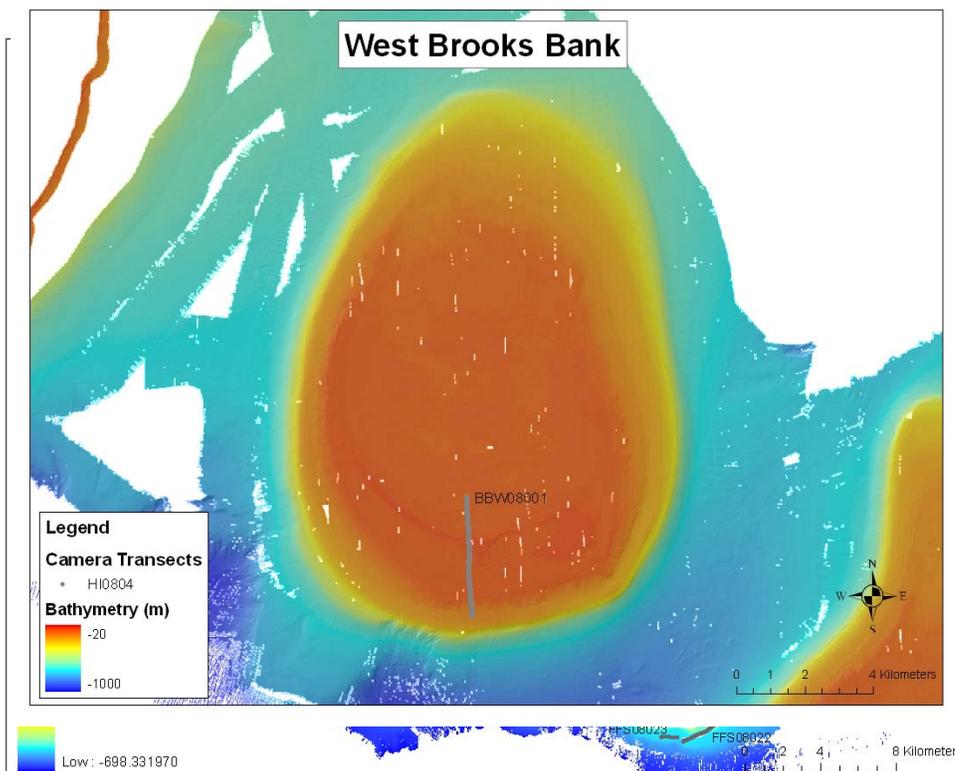


Figure 1.--Location of tows at FFS.

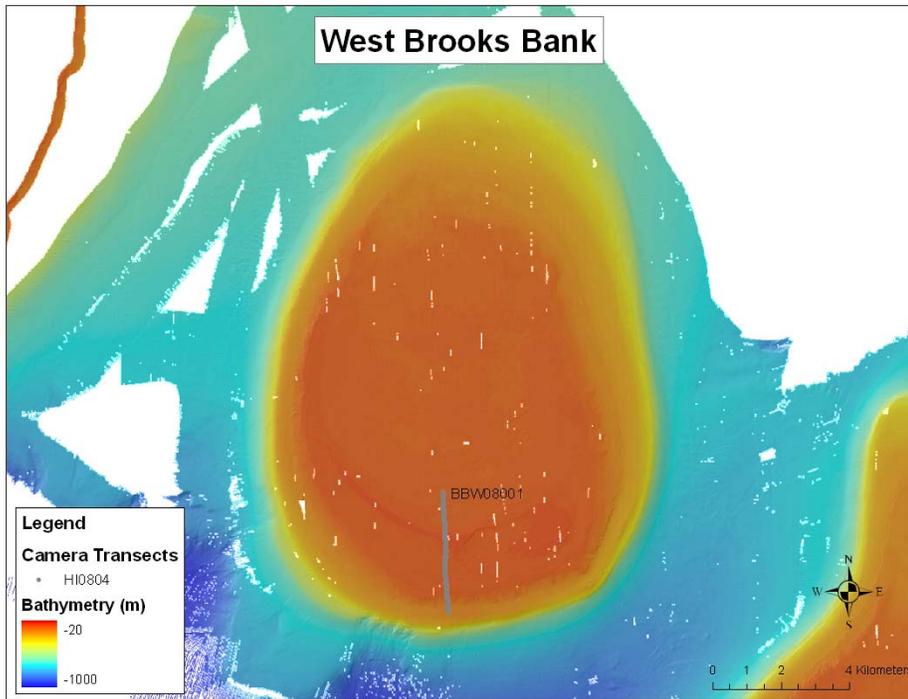


Figure 2.--Location of tow at West Brooks Bank.

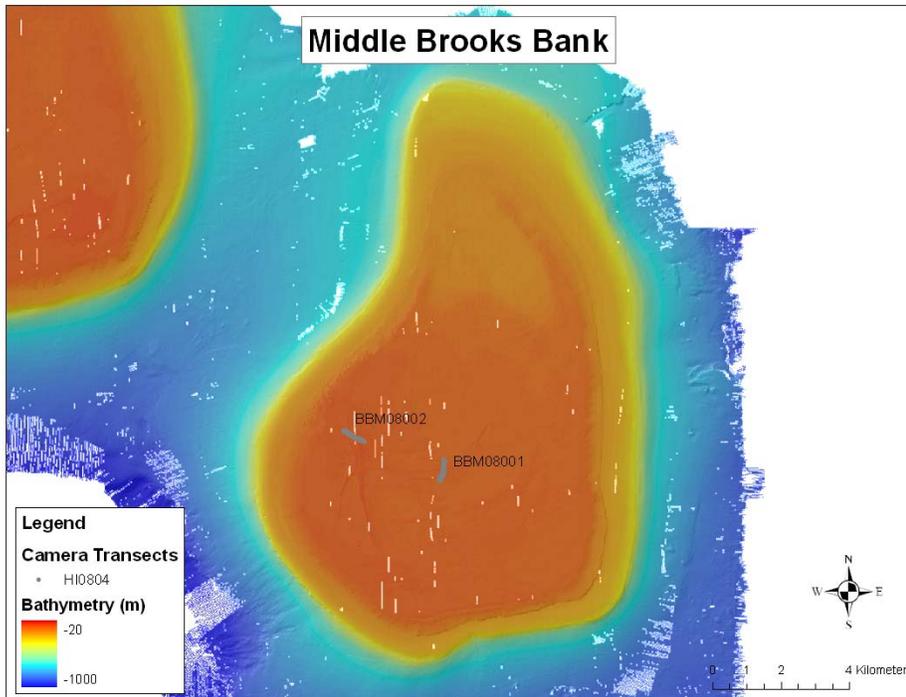


Figure 3.--Location of tows at Middle Brooks Bank.

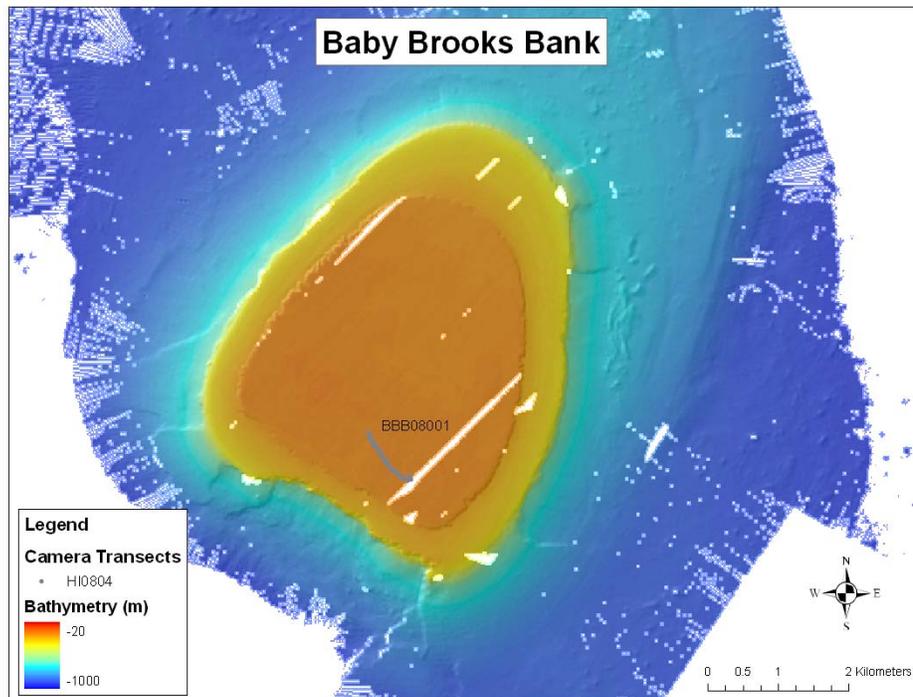


Figure 4.--Location of tow at East (Baby) Brooks Bank.

### Methods

Two different camera systems were used to collect video data. The majority of data were collected using the Coral Reef Ecosystem Division's (CRED; NOAA/NMFS/PIFSC) TOAD camera system and the remainder by the Biogeography Branch's NOAA/NOS/NCCOS/CCMA) drop camera system. Table 2 summarizes tow statistics for each of the camera systems. The CRED camera was used for the majority of tows because in its current iteration it features both a forward-looking, obstacle-avoidance camera and a downward-looking camera for recording seafloor data. The Biogeography Branch's system includes only a single camera aimed straight down. The forward-pointing video camera allowed camera operators to detect and avoid obstacles which, in turn, allowed the camera to be positioned closer to the bottom and gather more detailed benthic data. Both camera systems provided detailed video of the substrate and benthos from approximately 1 m above the seafloor. High wattage (> 300 W) lights were used both during the day and night to illuminate the seafloor and draw out colors.

Table 2.--Tow statistics for the CRED and Biogeography Branch camera systems.

Location	No. of tows	Total length (km)	Total bottom time (hrs)	Depth range (m)
TOAD camera system	28	119.2	65.7	20–225
Drop camera	7	40.6	34.7	20–125
Totals	35	159.8	100.3	20–225

One significant difference between the towed camera system configurations used during HI-08-04 and those used on previous cruises is that both systems used on this cruise included their own dedicated winch. Each winch had a remote controller, although the cable for the Biogeography Branch's controller was too short to reach into the *Hi'ialakai's* drylab where the video monitors and other equipment were set up. The remote TOAD winch controller enabled the person sitting at the video monitor to adjust the altitude of the camera sled above the seafloor. The use of a dedicated winch and remote controller has three important consequences for camera sled operations. First, the quality of the imagery is improved because the operator is able to adjust the sleds altitude almost instantaneously as opposed to relaying commands by radio to a winch operator. This keeps the camera closer to the seafloor and also saves time when ledges and overhangs are observed, thus requiring a quick raising of the sled to avoid possible fouling. A forward-looking camera was also added to the system to facilitate earlier warning of obstacles upon which the sled might get fouled. These equipment changes have significantly improved the safety of camera sled operations. A third advantage of this configuration is that the ship's force personnel requirements are reduced when supporting camera sled operations. Two scientists were utilized to deploy and recover the sleds for the duration of the cruise. One operated the winch and the other maintained control of the sled, while the bridge watchstander operated the J-frame. This approach was used safely and effectively throughout the cruise. The final change in equipment configuration that should be mentioned was the addition of a dedicated topside video camera to monitor the towed camera winches. This camera, provided by CRED and compatible with the existing *Hi'ialakai* topside camera system, enabled both camera operators and bridge watchstanders to monitor the winch and the fore-aft angle of the sled's umbilical cable. This capability enabled the winch to be monitored without requiring deck department personnel to be stationed at the winch on a full-time basis.

Both camera systems utilized an ultrashort baseline (USBL) navigation system to keep track of the towed camera position in relation to the *Hi'ialakai*. The USBL system was integrated with the ship's differential geographic positioning system to determine the towed camera's geographic position within approximately +/- 15 m. Subsequent analyses will refine the total horizontal positional accuracy of these data. In conjunction with a time overlay on the video, geographic position of the camera systems will be used to define the spatial position of benthic features observed in the video.

Tows varied in distance from less than 1 km (e.g., FFS08014) to over 18 km (e.g., FFS08026). One camera system at a time was deployed from the *Hi'ialakai's* starboard J-frame. Generally, tows were conducted in a drift mode, with tow speed and direction resulting only from the prevailing winds and currents. Occasionally, light turns ahead or astern were applied to adjust tow speed or direction.

## **Objectives**

Towed camera data have been collected at FFS in previous years. Consequently, a major objective was to gather data from locations and habitats not covered by existing data and over as large a spatial extent as possible. The primary objective of collecting in situ video data is to groundtruth remotely sensed multibeam data. Together, interpreted video and multibeam data can be used to produce benthic habitat maps. For this purpose, video data will be

visually interpreted every 30 s to record benthic components, such as type of substrate (mud, sand, rubble, boulder, etc.), living cover (scleractinian corals, macroalgae, coralline algae), coral genera, and coral morphology. Two downward pointing parallel lasers set 10 cm apart provide scaling.

A secondary objective of the seafloor videography is to assess the feasibility of detecting marine invasive species. Video data will be observed for 12 different invasive species known to exist in the Northwestern Hawaiian Islands or found in the main Hawaiian Islands and considered a significant threat to the ecosystem. Table 3 lists the invasive species to be identified. Preliminary observations detected large schools of *Lutjanus kasmira* within FFS' lagoon and Brooks Banks.

Table 3.--List of invasive species in the Northwestern Hawaiian Islands or found in the main Hawaiian Islands and of particular concern.

Species
<i>Lutjanus fulvus</i>
<i>Lutjanus kasmira</i>
<i>Cephalopholis argus</i>
<i>Pennaria disticha</i>
<i>Balanus reticulatus</i>
<i>Diadumene lineata</i>
<i>Carijoa riisei</i>
<i>Hypnea musciformis</i>
<i>Acanthophora spicifera</i>
<i>Amathia distans</i>
<i>Schizoporella errata</i>
<i>Balanus venustus</i>
<i>Chthamalus proteus</i>

## Results

### French Frigate Shoals

The majority of tows (31 of 35) were completed at FFS (Fig. 1). Targeted areas included the western and central portions of the lagoon and along the insular slope seaward of the atoll rim on the eastern and northern sides of the atoll. Ship constraints precluded tows in areas shallower than 20 m and within 1 nmi of land. The outer insular shelf around FFS, from the northeastern corner moving clockwise around to the southern side of the island had only previously been imaged with two short tows on the southeastern side. Favorable wind and sea conditions enabled us to conduct tows along most of this area. Generally the ship stayed at least a mile offshore for safety reasons.

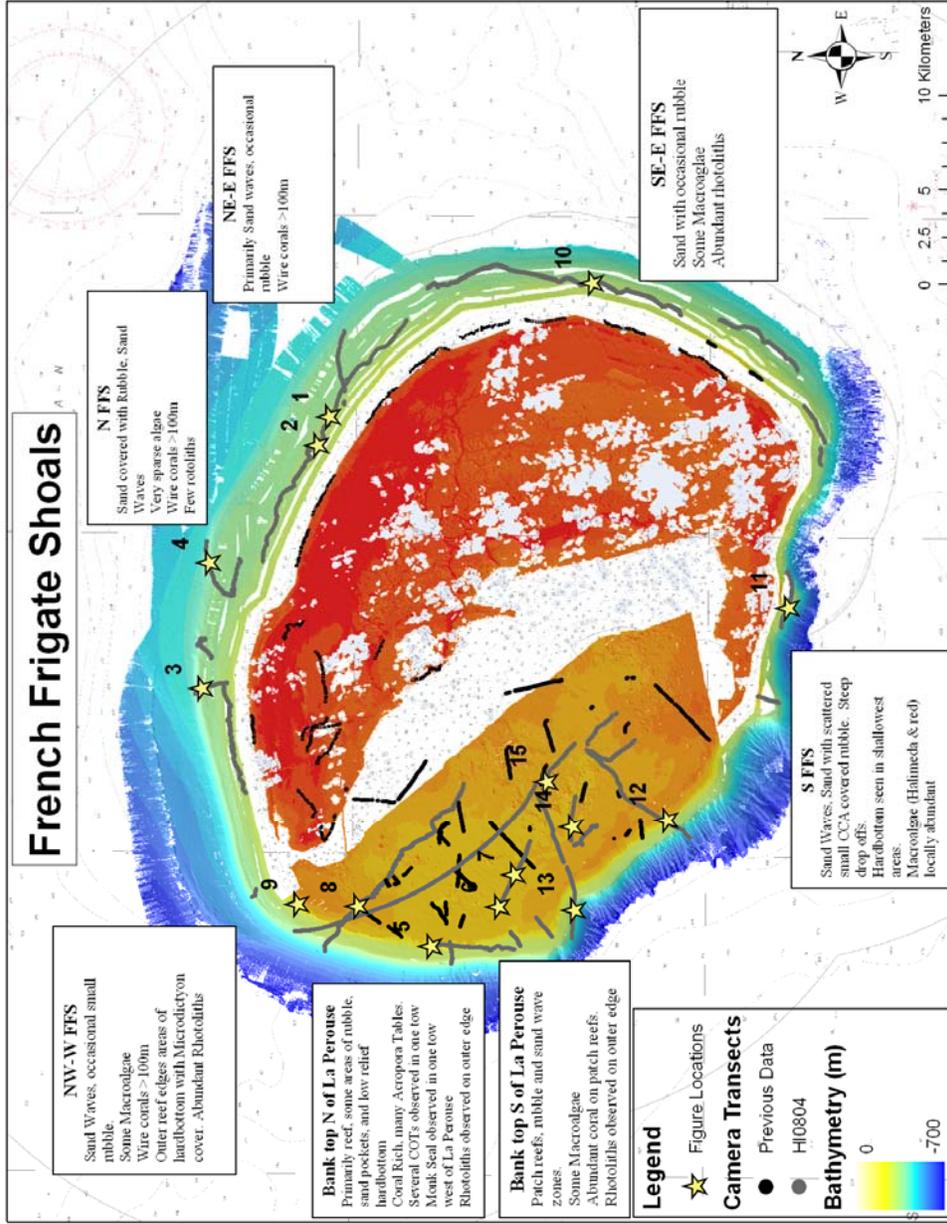


Figure 6.-- Preliminary observations of benthic characteristics from different regions of FFS. Numbered stars indicate the location where video framegrabs, shown in subsequent figures, were taken.



Framegrab 1: Sea urchin aggregation on sand.



Framegrab 4: Sea Urchin on scattered rubble in sand.



Framegrab 2: Sand waves with rubble.



Framegrab 5: Rhodolith "mobile coralline algae" bed.



Framegrab 3: Wire coral in unconsolidated habitat.



Framegrab 6: Coralline algae and *porites compressa*.

Figure 7.--Video framegrabs from FFS. Framegrab numbers correspond to numbered stars in Figure 6.



Framegrab 7: Hawaiian monk seal, *Monachus schauinslandi*, used camera light to spot prey at night.



Framegrab 10: Unidentified macroalgae on sand.



Framegrab 8: *Porites lobata* and *Acropora* sp.



Framegrab 11: *Halimeda incrassata* on sand.



Framegrab 9: Sea star on pavement and rubble.



Framegrab 12: Slipper lobsters on sand.

Figure 8.--Additional video framegrabs from FFS. Framegrab numbers correspond to numbered stars in Figure 6.

In this depth realm the substrate was predominantly sand (Fig. 5) with some gravel and rhodoliths (round nodules of encrusting coralline algae). This area is inhabited by several species of urchins, scattered macroalgae, and at depths of approximately 120 m, wire corals are common (Figs. 7 and 8). Only approximately, the southwestern third of the lagoon is navigable by vessels as large as the *Hi'ialakai*. However, the center of the northern portion of the area of the lagoon where we could survey is characterized by high percentages of coral cover, interspersed with occasional patches of sand, rubble, or low relief hard bottom (Figs. 7–9). Large table coral colonies of *Acropora* are common. The outer edge of the lagoon appears to be a drowned atoll rim. Much of that features low relief hard pavement thickly colonized with *Microdictyon* algae. Moving downslope and outside the atoll from there, rhodoliths are common and eventually give way to sandy substrate. The southern half of the lagoonal area that we were able to optically survey generally has less live coral than the northern portion, with more areas covered with sand and rubble. Patch reefs with significant living scleractinian coral cover are common, however.

### **Brooks Banks**

Four tows were also completed at Brooks Banks, including Middle Brooks Bank (Fig. 2), West Brooks Bank (Fig. 3), and East (Baby) Brooks Bank (Fig. 4). Collectively, a total of 6.5 linear km of seafloor were covered in, including 4.2 h of video, over the Brooks Banks. Table 1 provides summary statistics of tows for each of the banks, separately. Tows at Brooks Banks were a secondary objective and were completed during occasions when the ship made forays away from the immediate vicinity of FFS.

The Brooks Banks are the southeastern three of a series of five flat-topped banks that form a southeast to northwest trending line that is approximately 100 km long and starts 37 km northwest of FFS. St. Rogatien Bank and a smaller bank located farther northwest that is unnamed on nautical charts but is often referred to as St. Rogatien West, are the northwesternmost banks in this line. West and Middle Brooks Banks have a minimum depth of approximately 25 m and 30 m, respectively, and their bank tops feature arcuate structures that appear to be indicative of a lower stand of sea level. The structures are hypothesized to be the fossilized remnants of a fringing reef or possibly beachrock ridges. Whatever their origin, today they provide three-dimensional structures that serve as habitats for a range of sessile benthic species, including numerous scleractinian coral colonies, as well as reef fish and other mobile species (Figs. 9 and 10). Except for these elevated hardbottom structures, the bank tops appear to be surfaced with sandy areas, rhodoliths, and patches of exposed low relief rock with a scattering of scleractinian corals and macroalgae (Fig. 5).

East or Baby Brooks Bank is the deepest of the Brooks Banks, with a minimum depth of approximately 55 m. The one short camera tow on the bank top showed a sand and gravel covered surface with frequent evidence of bioturbation. Bivalves and other mollusk shells were common, as were anemones and shrimp. On patches of rocky substrate, occasional colonies of *Porites lobata* and *Pocillopora meandrina* were observed.



Figure 13: Shark basking in the warm glow of HMI light.



Figure 16: Transition from sand to rhotoliths. Sea anemone in middle right side of photograph.



Figure 14: *Caranx ignobilis* or "ulua" is a common TOAD companion on French Frigate Shoals.



Figure 17: Exposed pavement with thin veneer of sand.



Figure 15: *Porites lobata* and *p. compressa*, common corals seen among patch reefs.



Figure 18: Thick mat of *microdictyon* sp.

Figure 9.--Additional video framegrabs from FFS as well as several from the Brooks Banks. Framegrab numbers correspond to numbered stars in Figures 6 and 10.

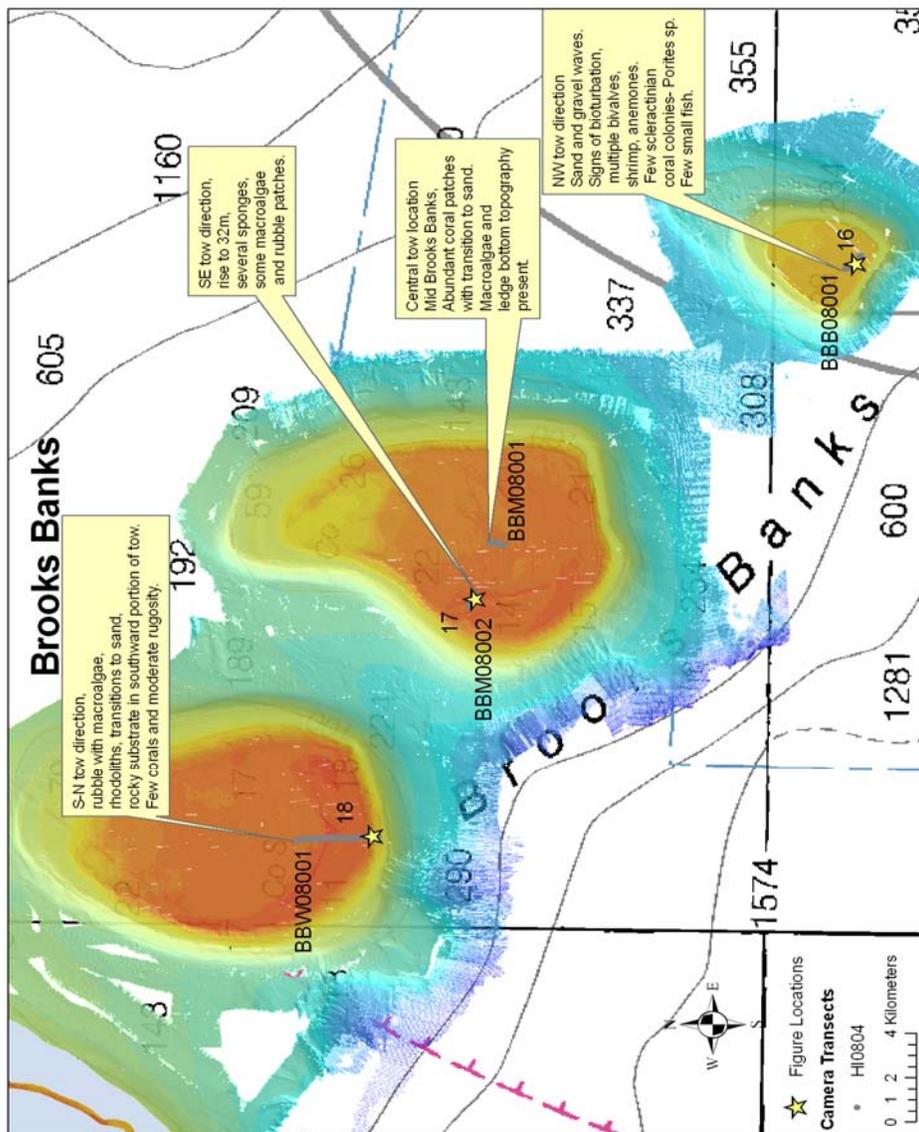


Figure 10.-- Preliminary observations of benthic characteristics from different regions of the Brooks Banks. Numbered stars indicate the location where video framegrabs, shown in subsequent figures, were taken.

## Appendix C: Diver Ground-truth Surveys

**Participants:** (*Joe Chojnacki (lead), Kerry Grimshaw, John Rooney, Max Sudnovsky, ship's divers*)

Total person dives:	84
Unique dive sites:	26
Plot surveys:	17
Transect surveys:	9
Total data points taken:	172
Total transect distance:	780 m

### Purpose

Diver ground-truth surveys were conducted on this cruise in order to better understand the multibeam backscatter data so that it can be used with more confidence in the development of benthic habitat maps. The aim of the diver ground-truth surveys was to provide a means of validation or disproof of substrate types predicted by interpreting the backscatter data, as well as to investigate specific features visible in the backscatter data.

### Methods

In total, the team dove in 26 unique sites, using two different methodologies. Each methodology involved measuring several parameters at multiple points. At each point, we recorded depth of water column, substrate type, living cover, sediment grain size, sediment sorting, and sediment thickness. We also took a photo of each point roughly 1 m above the bottom as well as a macro photo of sediment (where present) next to a grain-size scale card.

For the 17 plot array dives, we set up one center point and four points 5 m away in the four cardinal directions. (Four premeasured lengths of 200-lb test monofilament fishing line clipped in to a center weight were used to accurately measure 5 m from the center point. Underwater compasses were used to determine the cardinal directions.) The measurements from these 5 points were later averaged to produce one set of measurements known to be representative of a given area. These dives were designed to take accurate measurements of specific targeted acoustic bottom types.

For the 9 transect array dives, we established a start point and a direction of travel. After taking measurements at the start point we moved 10 m in our direction of travel and took another measurement. (Two of the previously described 5-m monofilament lengths were attached end to end to create a static 10-m line. Underwater compasses were used to maintain a constant direction of travel.) We continued sampling at 10-m intervals along the direction of travel until our air reserves forced us to end our dive or until it became clear that the bottom type was no longer changing. These dives were designed to measure the characteristics of substrate transition zones observed in the backscatter data.

## **Results**

Initial analysis of the SCUBA-based ground-truth data indicates that the methods described above are valuable approaches for aiding in producing benthic habitat maps and, in particular, for determining the effects of sediment grain size variations on multibeam backscatter intensity.

Generally, high and low backscatter intensity seafloor corresponds to hard and soft bottom substrates, respectively. This difference is often used to create cut-off values for bottom type determinations. However, extreme variations in backscatter intensity in areas known to be soft bottom and our preliminary SCUBA-based ground-truth data suggest that the acoustic return generated by sediment is highly variable and seems to be controlled by sediment grain size. Fine grain sediment absorbs more acoustic energy than coarse grain sediment, and coarse grain sediment can appear acoustically similar to hard substrates. Using cut-off backscatter intensity values to differentiate between hard and soft substrates oversimplifies the backscatter signal on shallow bank tops such as FFS. Furthermore, dive transects across distinct backscatter intensity boundaries with no significant topographic or sediment thickness changes support the notion that sediment grain size may be the controlling factor in determining the acoustic response of sediments at FFS.

The effects of sediment depth were not immediately clear because the grain size effect was so prominent and because it was difficult to find locations where backscatter intensity transitions could be related to thickening sediment wedges.

## **Conclusions and Recommendations**

Dive transects across sediment dunes revealed a consistent pattern of fine sediment overlaying coarse sediment. The interface between the sediment types was often very distinct, indicating very little mixing of the two sediment types. This possibly suggests a static layer of coarse-grained sediment overlain by a mobile fine-grained sediment veneer. These dunes could be evidence of continuous offshore transport of bioeroded reef structure. Judging from the loose sediment that we observed being transported during our dives, we believe these dunes are currently mobile. In order to understand the patterns of sediment transport, a dominant influence on coral habitat availability, future repeated multibeam surveys are recommended as part of a study.

Preliminary results suggest that a combination of multibeam backscatter and bathymetric data derivatives are necessary to create accurate benthic habitat maps in the NWHI. For example, slope and/or bathymetric variance can be used to differentiate between low and high backscatter intensity areas because low slope, low variability, high intensity seafloor probably indicates soft bottom whereas high slope, high variability, high intensity seafloor probably indicates hard bottom. Additionally, the SCUBA-based ground-truth data have helped answer some of the longstanding questions about the backscatter data and also help validate derived layers such as the FFS hard and soft substrate map currently being used by Northwestern Hawaiian Islands Papahānaumokuākea Marine National Monument managers to choose long-term monitoring sites. Similar ground-truth data should be collected in locations where similar substrate maps are required.