R/V Kilo Moana cruise KM0206

to the

Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve

October 22 to November 16, 2002

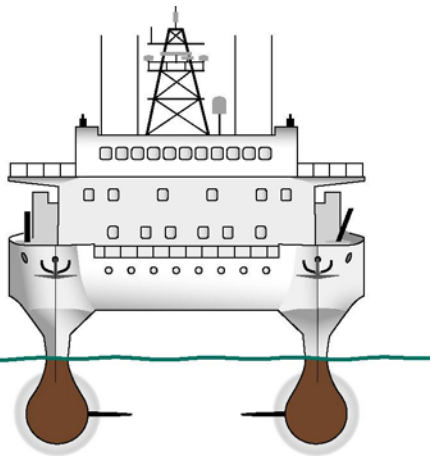
DATA PROCESSING EXCERPTS

from the cruise report currently in preparation

DRAFT

March 2003

R/V Kilo Moana
university of hawai'i



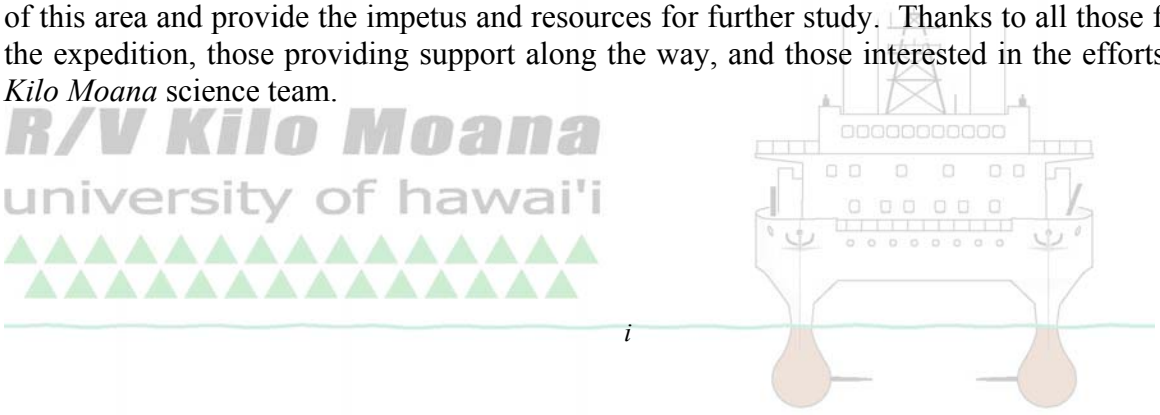
Expedition Summary and Accomplishments

The *Kilo Moana* cruise KM0206 to the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NWHICRER) took place from October 22 to November 16, 2002. To summarize the expedition, nearly complete coverage of the 100-fm contours was gained at all sites. The 25-fm surveys were slightly less complete, owing to often more elusive terrain, a narrow swath width in such shallow water, and maneuvering away from the contour for vessel safety. The 25-fm surveys were usually only attempted during daylight, in good weather, and preferably in well charted areas or with additional bathymetric soundings from the National Marine Fisheries Service (NMFS) or Hawaii Undersea Research Laboratory (HURL) ships. The final line mileage, including dedicated surveys and transits, was 4691 nm (pre-survey cruise plan expected 4065 nm) with a mapped area estimate of 11,186 square nautical miles (nm). Thus, an additional 15% of work was accomplished thanks to mostly good weather, conservative planning, and excellent ship handling. Coupled with surveying done on the HURL ship R/V *Ka`imikai-o-Kanaloa* (*KoK*) on the previous Northwestern Hawaiian Islands (NWHI) cruise, the 100 fathom contour ("blue" zone on nautical charts) was mapped at least at every location from the Nihoa Island to the unnamed bank northwest of Lisianski Island.

In addition to collecting new data, the collaborative nature of numerous NOAA line offices onshore as funders and planners, and onboard as the mix of cruise participants, led to the sharing of existing data and incorporation with the new bathymetry. The pre-existing single beam NMFS data, which had been collected in 10-100 m water depths in all major reserve areas except Nihoa, were used to define and layout the 25-fm route saving valuable survey time. The single beam bathymetric data also provided depth information in areas shallower than 45 m that were not surveyed during the *Kilo Moana* cruise and was combined with multibeam data in the gridded data products. *SeaBeam* multibeam swath data, provided by HURL from their swath system on the R/V *Ka`imikai-o-Kanaloa*, were also incorporated into the data set. In addition, the NMFS single beam and HURL *SeaBeam* data were provided to NOS along with the *Kilo Moana* data and will be used to update existing nautical charts in areas not surveyed during this field program.

An educational public outreach component was added to the cruise with background information being prepared months in advance, live interviews done prior to and during the cruise, and web log updates posted weekly as the ship made its way up and down the island chain.

All in all, this cruise was a success on a number of levels as the same data will be applied to several different causes including scientific research and technique development, living resource and sanctuary management, and nautical charting and navigation. Finally, it is hoped that the fascinating seafloor data generated on this cruise, though not completely covering the underwater world of the Northwestern Hawaiian Islands by any means, will heighten the interest of this area and provide the impetus and resources for further study. Thanks to all those funding the expedition, those providing support along the way, and those interested in the efforts of the *Kilo Moana* science team.



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Debra Gall – Chief Steward
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Randy Rabago – Messman

Acknowledgements. This oceanographic research cruise was funded by several NOAA/NOS offices including the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (now part of the National Marine Sanctuaries Program, NMSP), the Office for Ocean Exploration, the Coral Reef Program, and additional funds from the NMSP. CDR Paul Moen of NOS served as the project PI in charge of rallying the funding groups and serving as the liaison with the University of Hawaii. The great success of this expedition is equally shared with the captain and crew of *Kilo Moana*, especially the bridge crew, for a difficult and tedious job well done. It was a pleasure to sail and do science on such a finely maintained vessel with an equally competent and friendly crew and, of course, the always important outstandingly fine dining. In addition, we thank the University of Hawaii Marine Center, Research Computing Facility, Shipboard Technical Assistance Group, and Hawaii Mapping Research Group for putting the ship and systems together and rigging up for this specific expedition. This cruise report was authored from contributions by all science and technical team members. It was compiled and formatted by J.R. Smith and V. Rectenwald. It contains a large amount of background material on various cruise related subjects in order to appeal to an audience of diverse specialties. Additional clarification of biological issues and technical systems were provided by Dr. Chris Kelley of HURL, Dr. Bruce Appelgate of HMRG, and Steve Poulos of STAG. Additional cruise information, including background material, photographs, images, and logs can be accessed via the NOAA Ocean Explorer web site at:

http://www.oceanexplorer.noaa.gov/explorations/02hawaii/welcome.html

Disclaimer. The descriptions and data included in this report are the result of onboard discussion, data processing, and analysis amongst the cruise participants and have neither been reviewed nor approved by the NOAA Marine Charting Division or any of the marine reserve offices. The prudent mariner and fisherman will consult the latest official nautical charts and adhere to official publications of usage rules for these areas. The text, maps, and data contained in this report or accompanying it are for the purposes of aiding those in the marine reserve offices who will determine revised boundaries and management policies, those in the Marine Charting Division who will evaluate and post-process the data and eventually incorporate it into a revised set of nautical charts, and those doing additional scientific research in the NWHICRER. The items included in or with this report are not intended for navigational purposes or to guide any fishing ventures or other reserve uses.

Mission Plan for the R/V Kilo Moana Cruise to the NWHICRER

The second phase of the 2002 NWHI expeditions was carried out aboard the new University of Hawaii SWATH ship R/V *Kilo Moana* that just recently arrived in Honolulu after a long transit from Jacksonville, Florida where it was built. The mission for this 25-day cruise to the NWHI differed greatly from the sampling and *in situ* observations carried out during first phase aboard the HURL ship R/V *KoK*. Although some seafloor mapping occurred on the *KoK* cruise, the entire *Kilo Moana* cruise was devoted to this activity using new and very sophisticated sonar systems. The goals were to identify and accurately position specific water depth "isolines" (i.e., contour lines of the same depth) around atolls and islets as well as determine the geographic center of submerged banks.

The NWHICRER contains 15 smaller protected areas called Reserve Preservation Areas (RPA's) discussed in detail in the previous section (Figs 4–7). Their outer boundaries and rules regarding bottomfishing are presently based on isolines (atolls and islets) or their geographic center (submerged banks). The outside boundary for all the atoll and islet RPA's is presently the 100-fathom isoline. The minimum isoline for bottomfishing varies between 25, 50, or 100 fathoms, depending on location. The outside boundary for submerged bank RPA's is 12 miles from its geographic center.

The task for the participants of the *Kilo Moana* cruise was to map as many of the islets, atolls, and banks as possible during the time allotted. The cruise plan projected the surveying of a dozen such features and covered all those of interest to the NWHICRER managers. These included, from the southeastern end to the farthest northwest point, East and West Nihoa, Necker Island, French Frigate Shoals, Middle and Northwest Brooks Banks, St. Rogatien Bank, Gardner Pinnacles, Maro Reef, Laysan Island, Pioneer Bank, and Lisianski Island. This plan took the ship about two-thirds of the way up the NWHI chain, or nearly 1000 nm from the starting point in Honolulu.

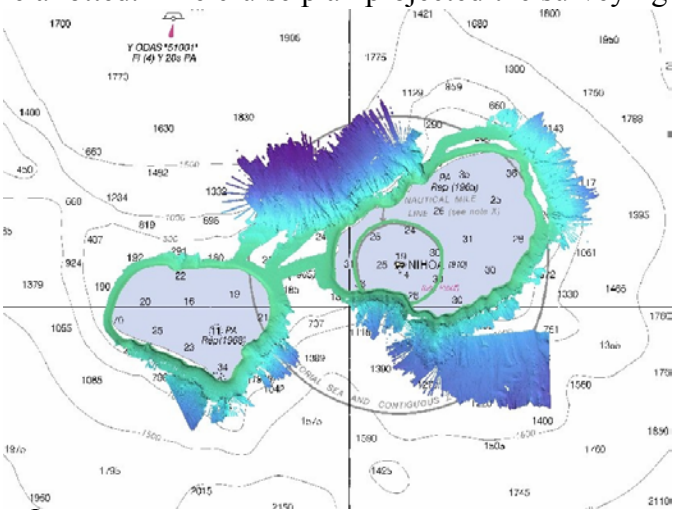

Fig. 7. *Kilo Moana m*ultibeam swath surveys around Nihoa Island. Light blues are shallower areas, while dark blues are deeper.

The resulting surveys resembled the shape of a donut or eyeglasses, with a circular or oblong ring of mapped seafloor surrounding an area of no data (Fig. 7). The blank center areas are where it is both too shallow to operate the deep draft *Kilo Moana* and/or inside the three nautical mile limit from any emergent land that is under State of Hawaii jurisdiction and not that of the NWHICRER. Even though these surveys might look a little odd at first, the data they represent will enable much more precise location of the boundaries for each of the RPA's than is currently possible.

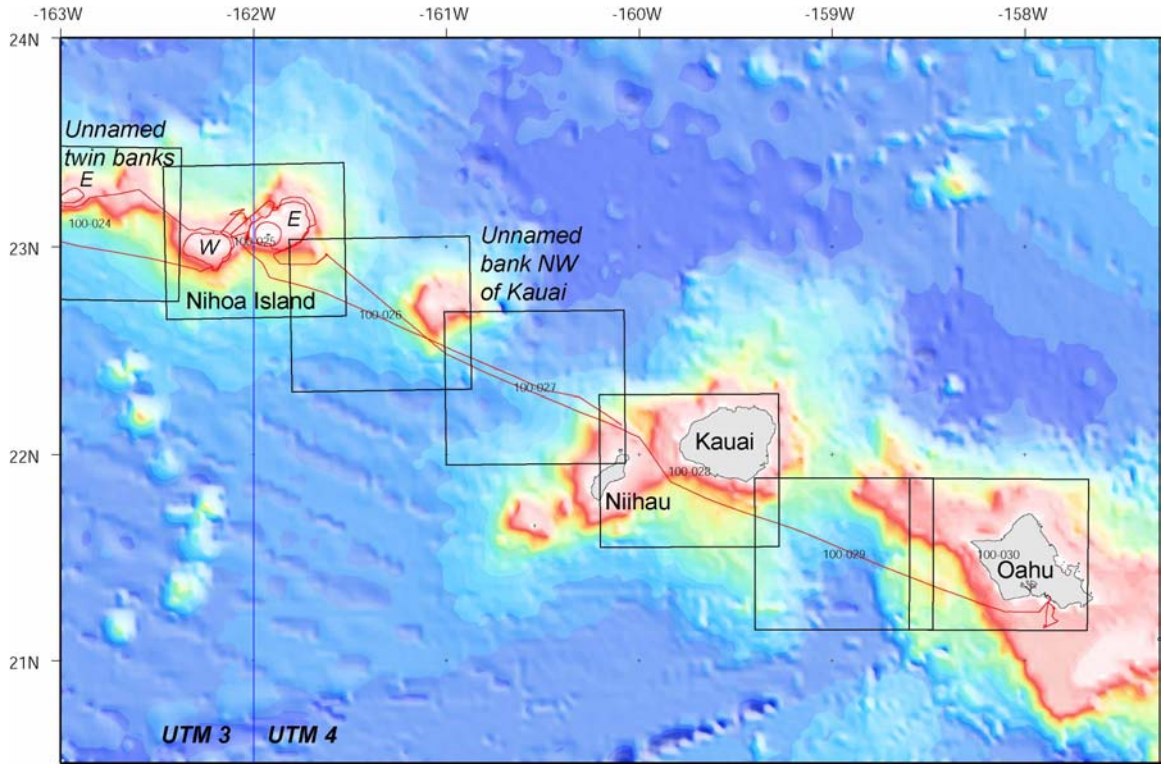

Fig. 15. Chart series (boxes) with ship track (red line) from Oahu to Nihoa on low resolution bathymetry.

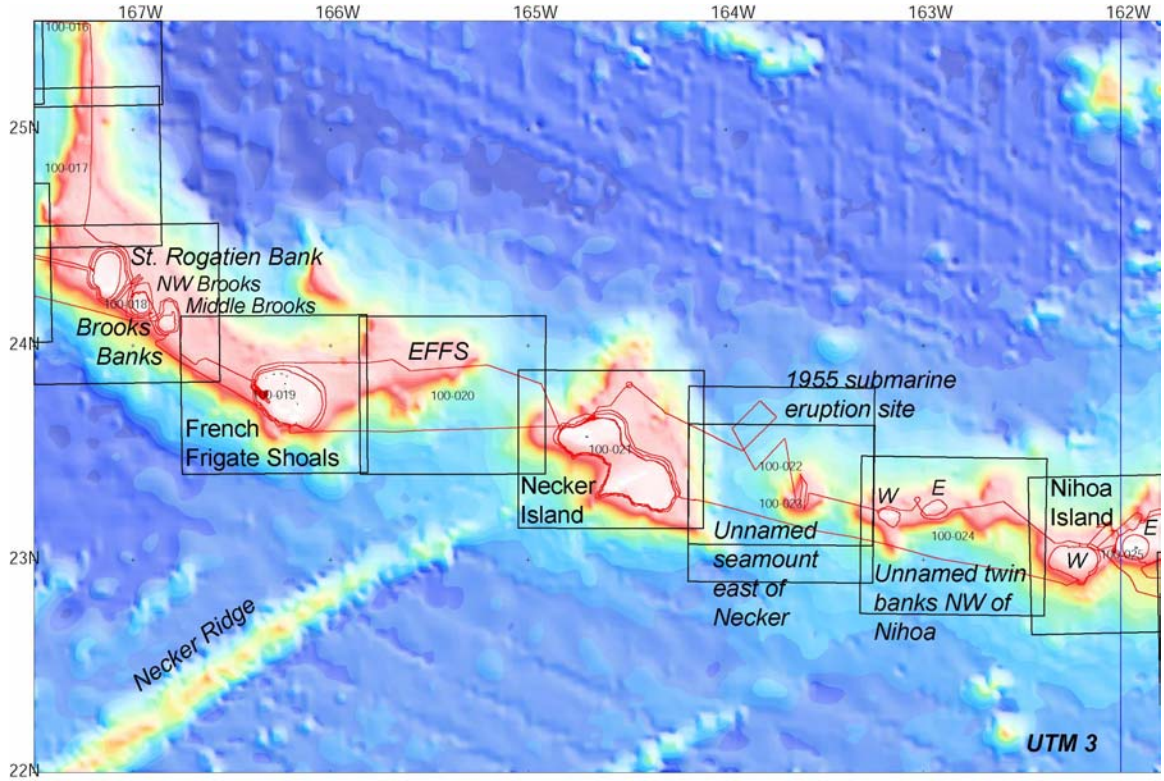

Fig. 16. Chart series (boxes) with ship track (red line) from Nihoa Island to St. Rogatien Bank on low resolution predicted global bathymetric dataset (hot colors are shallow, cool colors are deep).

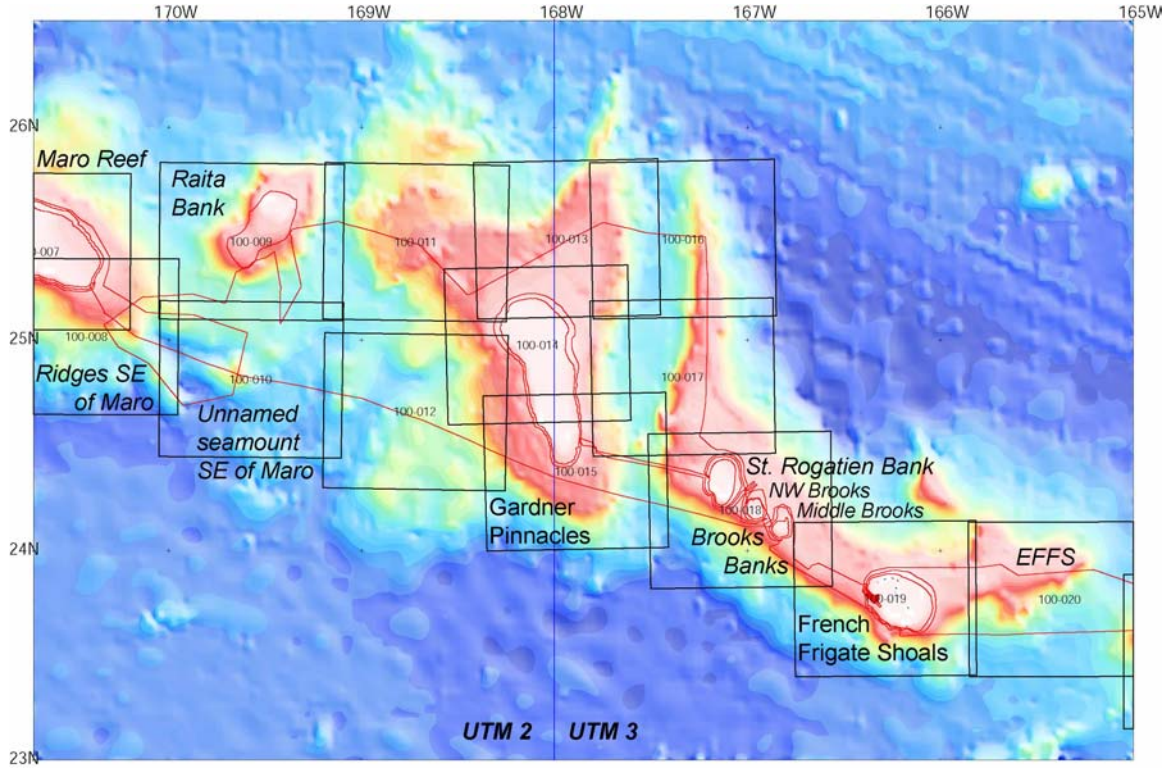

Fig. 17. Chart series (boxes) with ship track (red line) from East French Frigate Shoals to Maro Reef on low resolution predicted global bathymetric dataset (hot colors are shallow, cool colors are deep).

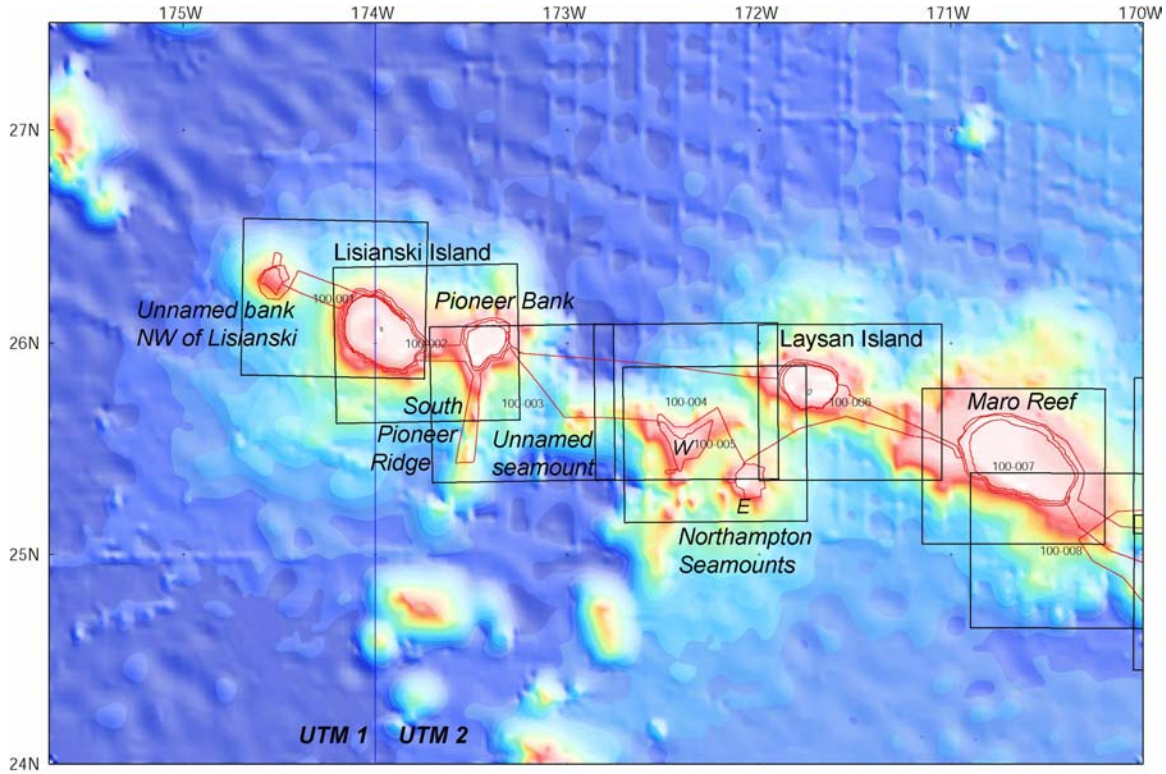

Fig. 18. Chart series (boxes) with ship track (red line) from Maro Reef to unnamed bank NW of Lisianski.

R/V *Kilo Moana* (AGOR 26)

Introduction and SWATH Design

The Research Vessel *Kilo Moana* is of a unique SWATH design – for Small Waterplane Area, Twin Hull. Essentially, it is a kind of pontoon boat/catamaran hybrid, whereby the main machinery such as motors, generators, pumps, etc are housed in two submerged cylinders attached to the main hull by narrow pylon-like metal "sails" (Fig. 12). The main hull that houses the living, science, and control areas is suspended above the waterline and only the narrow sails encounter the air-seawater interface, thus reducing frictional resistance and allowing faster speeds with less fuel consumption. In addition, the vessel is more stable because it *cuts* through the water rather than *plowing* through it and its wider dimension inhibits rolling from side to side. The primary goal of this new addition to the fleet is to extend the ability to perform research effectively in higher sea states. There has been an increasing demand for more research activity at higher latitudes where rougher seas are the norm.

Fig. 12. R/V *Kilo Moana* on mission trials in the Atlantic (left, *KiMo* website) and close-up of the port hull bow showing submarine-like shape, stabilizing canard (fin) and small air-water interface (from P. Johnson).

Kilo Moana was built in Jacksonville, Florida at the Atlantic Marine, Inc. shipyard. As with most other research vessels in the academic fleet, it was sponsored by the U.S. Navy. However, this is the first one procured using integrated product teams that included government, industry, and operator representatives working in a collaborative process from concept design through detailed design and construction. The prime contractor leading the industry team was Lockheed Martin Corporation.

Mission

The R/V *Kilo Moana*, which means "Oceanographer" in the Hawaiian language, is designed to operate in coastal waters and the deep ocean. Meant to perform general oceanography and multidisciplinary studies, typical missions might include: sampling and data collection of air, water, and seafloor parameters; seafloor mapping surveys from shallow to trench depth; launch, towing, and recovery of scientific gear; operating underwater vehicles, and

shipboard data processing and sample analyses within the numerous onboard laboratories (Fig. 13).

The mission of need for the Northwestern Hawaiian Islands cruise is the multibeam sonar seafloor mapping systems that have been integrated into the ship design. These include both shallow water and deepwater systems to cover the complete range from nearshore to the deepest depths in the world's oceans.

Deepwater Multibeam Echo Sounder *(Simrad EM 120)*

This system is a 12 kHz, 191 beam, bathymetric sonar system capable of hydrographic charting and seafloor acoustic backscattering imaging in water depths up to 11,000 meters – thus able to map the deepest trenches on Earth. A multibeam system allows the collection of numerous data points from one "ping" across the track (perpendicular to the ship motion), therefore covering a swath of seafloor instead of just one individual sounding depth below the vessel as with less complex single beam echo sounders. The *EM 120* produces 191 depth points per ping in a swath of up to 150° (depends on depth) which translates to an across track coverage of approximately six times the water depth (in up to 2000 m water depth). For example, a swath width of 20 km can be achieved in deep water depending on the composition of the seafloor. Arrays of sonar transmitters and receivers are located along the bottom of the port hull.

Deepwater Multibeam Echo Sounder *(Simrad EM 1002)*

This unit operates on the same theory as the *EM 120* but with a higher frequency to allow better resolution in shallow waters. It is a 95 kHz, 111 beam systems designed to operate from the shoreline to a depth of about 1000 m. Angular coverage is also up to 150°, translating to a swath width of 1500 m in deeper waters and 7.5 times the water depth in shallower waters. This sonar system will be the primary tool for the coral reef and habitat mapping projects. High ping rates in shallow water work make data processing and storage a real challenge. Powerful computer workstations with large disks and high volume tape backups are required, along with complex post-processing software that allows visualization of large portions of the data sets to speed the editing process. Please see the sections on Mapping the NWHI and Sonar Technology for more details on the methodology, data types received, and what can be studied using them.

Principal Characteristics

Length overall: 185 feet
Beam (width): 88 feet
Draft at max load: 25 feet
Displacement: 1996-2542 LT
Operability: Sea state 6 (low end)
Range: 10,000 nm at 11 kts
Endurance: 50 days
Mission payload: 100 LT
Speed: 15 kts max sustained, 12 kts survey speed
Propulsion: Diesel electric, 4 generators, 2 propellers
Accommodations: 17 crew, 31 scientists

Line and Areal Mileage

The areal mileages were calculated by breaking up the cruise into approximate project survey areas and then tiling the data with 200-meter square tiles. An estimate of the area covered was determined by counting the tiles (Table 2).

In order to calculate the line mileages, the necessary data were extracted from the ship's logging system via the data report generator. This provided a one minute update rate time series of ship's position, speed, etc for the whole cruise. To calculate the various linear nautical mile totals, the simplest thing to do was calculate "miles per minute" for each entry, assuming that the ship's speed was relatively constant over that minute. The ship's speed was output in knots, entered into a spreadsheet, and divided by 60, to give the approximate distance traveled during that one minute period. These distances were then totaled over various ranges corresponding to the time we spent in a particular survey area. This gave a reasonable estimate of the linear miles devoted to each area (Table 3), differing from the 4691 nm (8688 km) total that includes >1400 nm (>2593 km) of transits.

Table 2. Square Unit Area Totals by Survey Location

Location of Survey	$n.mi^2$	km^2
Nihoa	1561	5354
Necker	1648	5652
FFS	619	2123
Gardner	1073	3680
Maro	1557	5340
Laysan	743	2548
Pioneer	1029	3529
Lisianski	607	2082
Northampton	711	2439
Raita	692	2373
Brooks/Rogatien	946	3245
TOTALS	**11,186**	**38,365**

Table 3. Line Mileage Totals by Survey Site and Target Depth

Location of Survey	Target depth in fathoms	Survey nautical miles	Survey distance kilometers	Site subtotal in n.mi.	Site subtotal in km
E & W Nihoa Island	100/25	237	439		
W & E Nihoa Island	Deep & between	70	130	**307**	**569**
Unnamed twin banks NW of Nihoa	100	127	235	**127**	**235**
1955 eruption site	Deep	80	148	**80**	**148**
Necker Island	100/25	278	515		
Necker Island	25	154	285	**432**	**800**
French Frigate Shoals (FFS)	100	124	230		
FFS shoal		73	135		
FFS ~25-fm survey	~25	109	202	**306**	**567**
Middle & NW Brooks Banks	100	92	170		
NW & Middle Brooks Banks	25	84	156	**176**	**326**
St. Rogatien	100	102	189		
St. Rogatien	25	57	106	**159**	**294**
St. Rogatien to Brooks Banks	Fill between banks	83	154	**83**	**154**
Gardner Pinnacles	100/25	266	493	**266**	**493**
Raita Bank		71	131	**71**	**131**
Maro Reef	25/100	260	482		
N Maro deep		92	170		
SE Maro ridges and crater		133	246	**485**	**898**
Laysan Island	50/100	134	248	**134**	**248**
E Northampton Seamount		45	83		
W Northampton Seamount		89	165	**134**	**248**
Pioneer Bank	25/100	122	226		
S Pioneer Ridge		79	146	**201**	**372**
Lisianski Island	100/25	196	363		
Lisianski Island	25	76	141	**272**	**504**
Unnamed smt NW of Lisianski	100	39	72	**39**	**72**
	TOTALS	**3,272**	**6,060**		

Future Survey Coverage Plans

An onboard analysis was performed by the NOAA hydrographers (Fig. 37, left and right) to determine how much additional coverage would be required to completely map the four areas listed in Table 4 from a depth of less than 100 fm to 1500 fm. The breakdown of the three depth ranges indicates that the mileage and time required to fully map the shallowest regions is excessive, while the time required for the two deeper ranges is more reasonable. A series of four planning chartlets from which these statistics were derived from is included below (Figs. 38-41).

Table 4. NWHI Future Multibeam Survey Planning Statistics for Select Areas

Location of Survey	# of lines	Total line n.mi.	Total line km
Nihoa Island (less than 100 fm)	218	2323	4302
Nihoa Island (100-500 fm)	48	299	554
Nihoa Island (500-1500 fm)	7	294	545
Necker Island (less than 100 fm)	193	2829	5240
Necker Island (100-500 fm)	16	457	846
Necker Island (500-1500 fm)	2	257	476
FFS, St. Rogatian and Brooks Banks (less than 100 fm)	529	3499	6480
FFS, St. Rogatian and Brooks Banks (100-500 fm)	109	2215	4102
FFS, St. Rogatian and Brooks Banks (500-1500 fm)	3	439	813
Gardner Pinnacle (less than 100 fm)	234	7321	13559
Gardner Pinnacle (100-500 fm)	46	1440	2668
Gardner Pinnacle (500-1500 fm)	5	202	375
TOTALS	**1,410**	**21,576**	**39,959**

Notes:

1) 100% bottom coverage was used for line spacing and is conservatively based on 3–5 times water depth.

2) DTM's generated from the 2002 NWHI multibeam mapping cruise were taken into consideration.

3) Line tables are divided at the 100- and 500-fm lines in anticipation of using different multibeam systems.

4) The *R/V Kilo Moana* is capable of surveying all lines greater than the 100-fm subset.

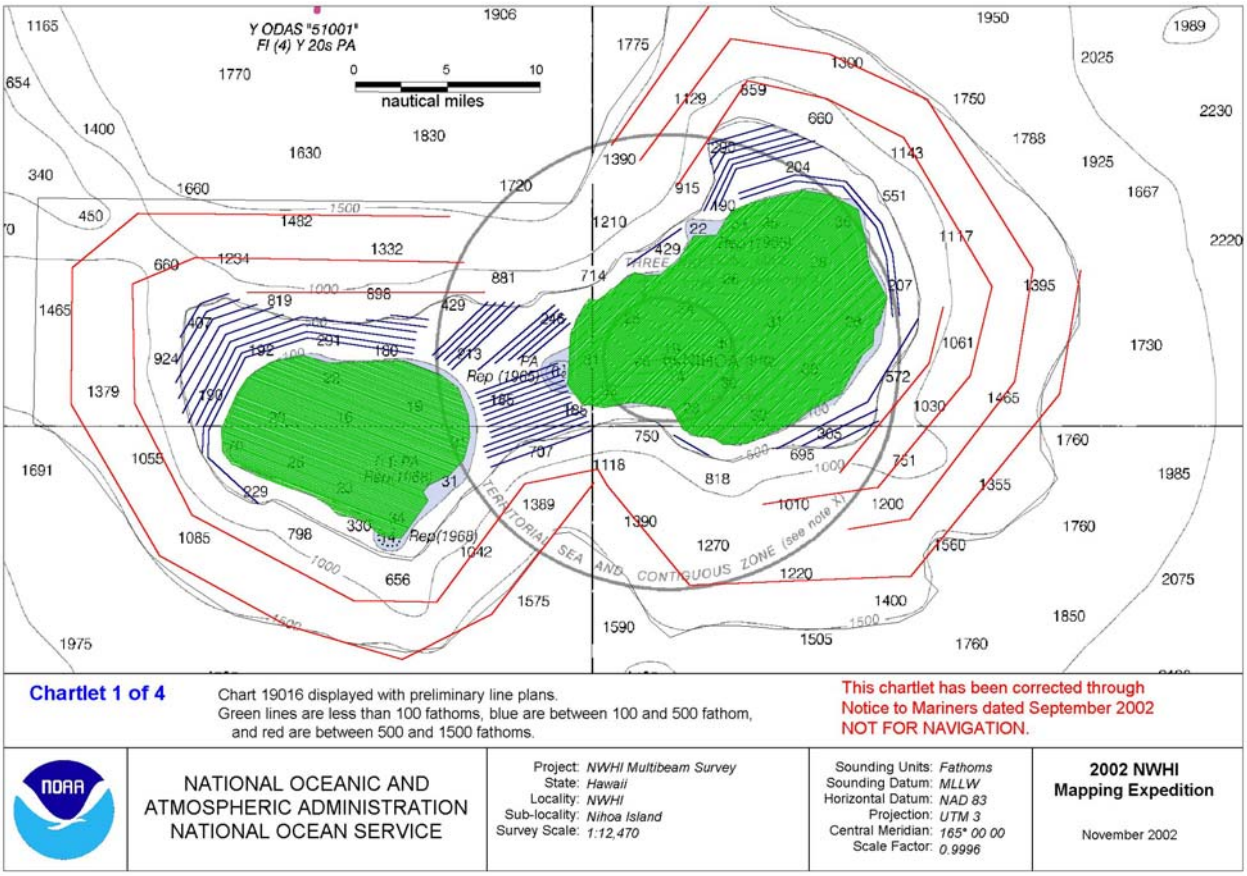

Fig. 38. Survey line planning chartlet for the Nihoa Island area. Lines in green (very tight), blue, and red.

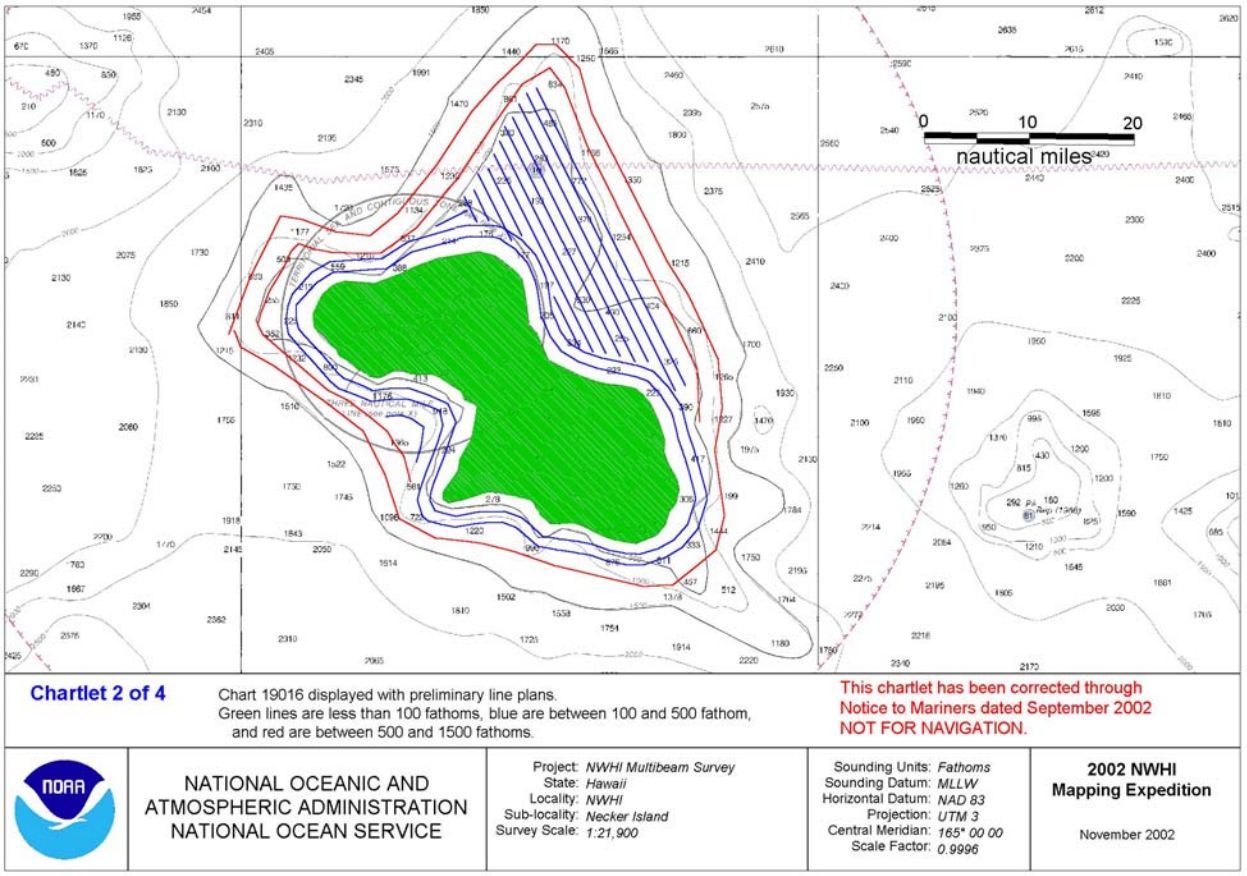

Fig. 39. Survey line planning chartlet for the Necker Island area. Lines in green (very tight), blue, and red.

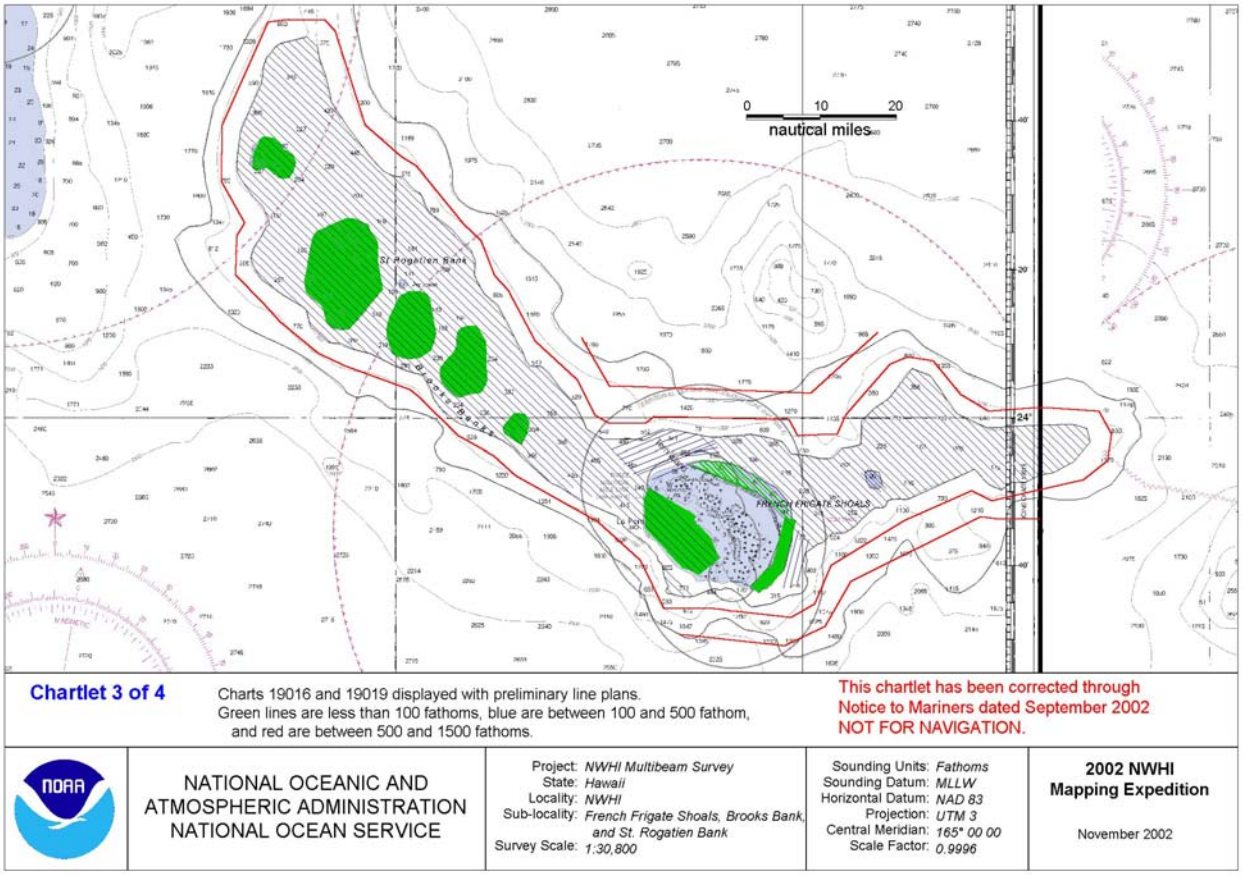

Fig. 40. Survey line planning chartlet for French Frigate, Brooks, and Rogatien Banks. Lines as in Fig. 38.

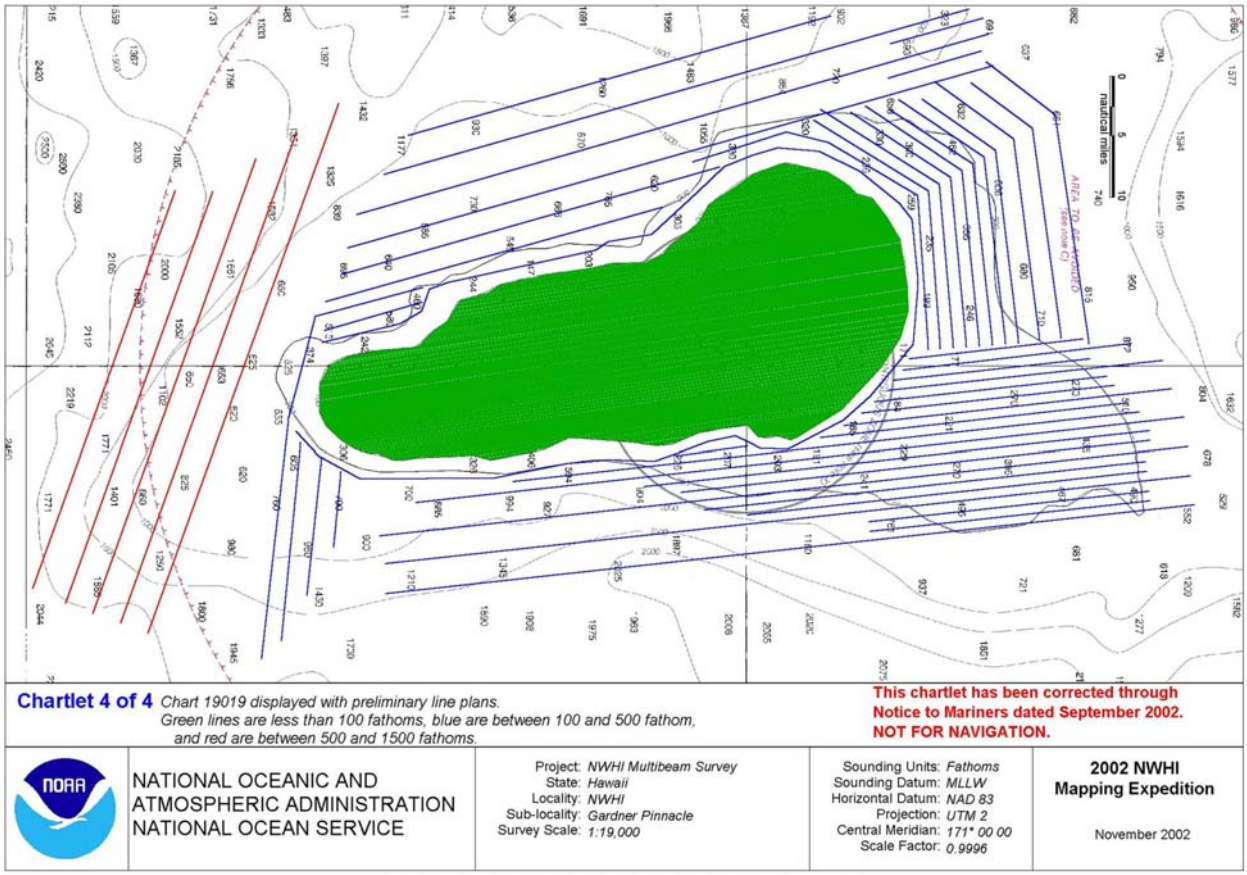

Fig. 41. Survey line planning chartlet for Gardner Pinnacles (north is to the right). Lines as in Fig. 38.

Onboard Bathymetric and Sidescan Backscatter Data Processing

The technical staff of *Kilo Moana* oversaw the operation of the multibeam sonar systems and processing of the data. The science team provided dedicated watchstanders and some assisted with data cleaning. It should be noted that the NOAA Office of Coast Survey representatives participating in the cruise collected and edited their own set of data in different software packages (CARIS and HYPACK) so as to maintain consistency with NOAA charting office requirements. They took the *_raw.all files from the data logging computers and post-processed it from there.

Whenever possible, both multibeam systems were concurrently run with data collected and processed separately. Later the bathymetry for the *EM 120* and *EM 1002* were merged while the sidescan backscatter data for each system was gridded and plotted separately, owing to the distinctiveness of these types of data. The *EM 120* was used for the deep areas and shallower than 100 fm (180 m), though data acquisition was terminated for the 25-fm (45-m) surveys. Conversely, the *EM 1002* was used for the shallowest surveys (occasionally <10 fm under keel) to approximately 600 m water depth, depending on bottom type and hull or sea noise.

Daily quality control plots and grids were batch processed through an automated cleaning, gridding, and plotting sequence using the freeware *MB-System* (version 5.0.beta22) and *GMT-System* (version 3.4.1) software on a Julian Day basis. The files were first converted from the original *_raw.all *Simrad* format (MB56) to format MB71 because format MB56 does not contain data areas to retain some bathymetry and sidescan changes made during post-processing. When the processing scripts were developed, the version of MB-System used did not work with the recommended conversion to MB57.

Later, the bathymetry data were converted to Generic Sensor Format (GSF) and manually edited in Science Applications International Corporation's (SAIC) Survey Analysis and Area Based Editor (*SABER*) multibeam processing software. This effort was led by P. Johnson with assistance from J. Miller, L. Murai, N. Cabana, and J.R. Smith. SAIC developed SABER under a multi-year program with the Naval Oceanographic Office (NAVOCEANO) to provide a graphics-based hydrographic editing tool that that allows large volumes of hydrographic data to be manipulated based on either time or area, which enables accurate final charts to be produced rapidly. *SABER* replaces labor-intensive, line-by-line editing of hydrographic data with an area-based editing approach, enabling one to visualize a surface as well as edit all data collected in a survey area using a multi-view editor. The data processed in *SABER* are saved in GSF, which can be processed by *MB-System* to produce XYZ triplets that can be integrated into other software packages (*GMT-System*, *ArcGIS*, etc.) for merging with other data and chart production.

This is the command used to grid the Simrad bathymetry data:

```
mbgrid -F1 -A2 -G3 -N -C2 -Iinfiles $mbbounds -E$cell_grd/$cell_grd          -
                                O$chart.bty.nn
```

The sidescan backscatter component of the data was processed in a completely different stream because the GSF format output by the *SABER* bathymetry editing module does not yet include the backscatter imagery. The auto-cleaned bathymetry files in MB71 format from the daily batch jobs were used as input to the sidescan run that follows the recommended sidescan processing for *SeaBeam 2100* data as outlined in the *MB-System* documentation under the *mbsystem* manual page.

Gridding, plot construction, and conversion to *Arcview* grids then took place in batch jobs. Page-size chart sets of 30 x 1:475,000 and 93 x 1:237,500 charts were produced onboard, each with a corresponding grid. Four sets of these charts were made including combined bathymetry, *EM 120* sidescan, *EM 1002* sidescan, and annotated ship tracks. Duplicate sets of 1:100,000 and 1:50,000 large

format A0 size charts were also produced, except for the navigation charts. Instead, annotated ship tracks are included on the A0 sidescan charts. The grids are in *GMT-System* style binary *netCDF* format.

For sidescan backscatter processing, first, for both systems an angle priority file was created.

```
-78.0  0.2
-45.0  1.0
-15.0  0.8
-14.9  0.1
 14.9  0.1
 15.0  0.8
 45.0  1.0
 78.0  0.2
```

Next, a series of programs was run in batch mode to filter and correct the sidescan backscatter data using the option values listed with the program names in the example file header comment record. The first is for the *EM 120* and the second for the *EM 1002* with the same sequence but different values. Note that the program listing sequence is in reverse chronological order.

Simrad EM 120 Sidescan Processing Sequence

```
Program MBINFO
Version $Id: mbinfo.c,v 5.11 2002/07/20 20:56:55 caress Exp $
MB-system Version 5.0.beta22

Swath Data File:      em120-295-222122-0002-raw.all.mb71.clean.das.mb71
MBIO Data Format ID:  71
Format name:          MBF_MBLDEOIH
Informal Description: L-DEO in-house generic multibeam
Attributes:           Data from all sonar systems, bathymetry,
                     amplitude and sidescan, variable beams and pixels,
                      binary, centered, L-DEO.

Comments in file em120-295-222122-0002-raw.all.mb71.clean.das.mb71:
  Sidescan data altered by program MBANGLECORRECT
  Version $Id: mbanglecorrect.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <lalo> at <Sun Nov  3 04:22:17 2002>
  Sidescan values corrected by dividing by
    a user supplied function of grazing angle.
  Control Parameters:
    MBIO data format:    71
    Input file:       em120-295-222122-0002-raw.all.mb71.clean.da.mb71
    Output file:      em120-295-222122-0002-raw.all.mb71.clean.das.mb71
    Longitude flip:      0
    Data kind:           2
    Default depth:       0.000000
    Scaling factor:      1000.000000
    Smoothing dimension: 0
    Length mode:         2
    Length max:          5.000000
    Static angle correction file: avg_ss.dat
    Static sidescan corrections: <CLIP>

  Sidescan data altered by program MBANGLECORRECT
```

```
  Version $Id: mbanglecorrect.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <lalo> at <Sun Nov  3 04:22:14 2002>
  Beam amplitude values corrected by dividing by
    a user supplied function of grazing angle.
  Control Parameters:
    MBIO data format:    71
    Input file:        em120-295-222122-0002-raw.all.mb71.clean.d.mb71
    Output file:       em120-295-222122-0002-raw.all.mb71.clean.da.mb71
    Longitude flip:      0
    Data kind:           1
    Default depth:       0.000000
    Scaling factor:      100.000000
    Smoothing dimension: 0
    Length mode:         2
    Length max:          5.000000
    Static angle correction file: avg_amp.dat
    Static sidescan corrections: <CLIP>

  Data filtered by program MBFILTER
  Version $Id: mbfilter.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <lalo> at <Sun Nov  3 04:22:02 2002>
  Processing sidescan data...
  applying median filter for smoothing
    filter low ratio threshold:   0.600000
    filter high ratio threshold:  1.670000
    filter acrosstrack dimension: 3
    filter alongtrack dimension:  3
    filter iterations:            1
  Control Parameters:
    MBIO data format:   71
    Input file:         em120-295-222122-0002-raw.all.mb71.clean
    Output file:        em120-295-222122-0002-raw.all.mb71.clean.d.mb71
    Longitude flip:     0
    Data kind:         2

  This bathymetry data automatically edited by program MBCLEAN version $Id:
mbcleanold.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Wed Oct 23 02:38:19 2002>
  Control Parameters:
    MBIO data format:   71
    Input file:         em120-295-222122-0002-raw.all.mb71
    Output file:        em120-295-222122-0002-raw.all.mb71.clean
    Longitude flip:     0
    Cleaning mode:      4 (zero both beams of each outlier slope)
    Maximum slope:      3.500000
    Minimum distance:   0.010000
    Maximum distance:   0.250000
    Outer beams zapped: 30
    Depth range checking on:
      Minimum acceptable depth: 1.000000
      Maximum acceptable depth: 10000.000000
    Depth fractional range checking on:
      Minimum acceptable depth fraction: 0.920000
      Maximum acceptable depth fraction: 1.070000
    Depth deviation from median checking off
```

```
  This data copied by program MBcopy version $Id: mbcopy.c,v 5.11 2002/07/20
20:56:55 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Wed Oct 23 02:38:13 2002>
  Control Parameters:
    Input file:         em120-295-222122-0002-raw.all
    Input MBIO format:  56
    Output file:        em120-295-222122-0002-raw.all.mb71
    Output MBIO format: 71
    Ping averaging:     1
    Longitude flip:     0
    Longitude bounds:   -360.000000 360.000000
    Latitude bounds:    -90.000000 90.000000
    Begin time:         1962 2 21 10 30 0 0
    End time:           2062 2 21 10 30 0 0
    Minimum speed:      0.000000
    Time gap:           1.000000
```

Simrad EM 1002 Sidescan Processing Sequence

```
Program MBINFO
Version $Id: mbinfo.c,v 5.11 2002/07/20 20:56:55 caress Exp $
MB-system Version 5.0.beta22

Swath Data File:     em1002-295-222059-0003-raw.all.mb71.clean.das.mb71
MBIO Data Format ID:  71
Format name:          MBF_MBLDEOIH
Informal Description: L-DEO in-house generic multibeam
Attributes:           Data from all sonar systems, bathymetry,
                     amplitude and sidescan, variable beams and pixels,
                      binary, centered, L-DEO.

Comments in file em1002-295-222059-0003-raw.all.mb71.clean.das.mb71:
  Sidescan data altered by program MBANGLECORRECT
  Version $Id: mbanglecorrect.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Mon Nov 11 06:16:52 2002>
  Sidescan values corrected by dividing by
    a user supplied function of grazing angle.
  Control Parameters:
    MBIO data format:    71
    Input file:      em1002-295-222059-0003-raw.all.mb71.clean.da.mb71
    Output file:     em1002-295-222059-0003-raw.all.mb71.clean.das.mb71
    Longitude flip:      0
    Data kind:           2
    Default depth:       0.000000
    Scaling factor:      1000.000000
    Smoothing dimension: 0
    Length mode:         2
    Length max:          5.000000
    Static angle correction file: avg_ss.dat
    Static sidescan corrections: <CLIP>

  Sidescan data altered by program MBANGLECORRECT
  Version $Id: mbanglecorrect.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Mon Nov 11 06:16:49 2002>
  Beam amplitude values corrected by dividing by
    a user supplied function of grazing angle.
  Control Parameters:
```

```
    MBIO data format:    71
   Input file:        em1002-295-222059-0003-raw.all.mb71.clean.d.mb71
 Output file:         em1002-295-222059-0003-raw.all.mb71.clean.da.mb71
    Longitude flip:      0
    Data kind:           1
    Default depth:       0.000000
    Scaling factor:      100.000000
    Smoothing dimension: 0
    Length mode:         2
    Length max:          5.000000
    Static angle correction file: avg_amp.dat
    Static sidescan corrections: <CLIP>

  Data filtered by program MBFILTER
  Version $Id: mbfilter.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Mon Nov 11 06:15:44 2002>
  Processing sidescan data...
  applying median filter for smoothing
    filter low ratio threshold:   0.050000
    filter high ratio threshold:  1.870000
    filter acrosstrack dimension: 12
    filter alongtrack dimension:  3
    filter iterations:            3
  Control Parameters:
    MBIO data format:   71
    Input file:        em1002-295-222059-0003-raw.all.mb71.clean
    Output file:       em1002-295-222059-0003-raw.all.mb71.clean.d.mb71
    Longitude flip:     0
    Data kind:         2

  This bathymetry data automatically edited by program MBCLEAN version $Id:
mbcleanold.c,v 5.2 2001/07/20 00:34:38 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Wed Oct 23 05:46:30 2002>
  Control Parameters:
    MBIO data format:   71
    Input file:         em1002-295-222059-0003-raw.all.mb71
    Output file:        em1002-295-222059-0003-raw.all.mb71.clean
    Longitude flip:     0
    Cleaning mode:      4 (zero both beams of each outlier slope)
    Maximum slope:      3.500000
    Minimum distance:   0.010000
    Maximum distance:   0.250000
    Outer beams zapped: 3
    Depth range checking on:
      Minimum acceptable depth: 1.000000
      Maximum acceptable depth: 10000.000000
    Depth fractional range checking on:
      Minimum acceptable depth fraction: 0.920000
      Maximum acceptable depth fraction: 1.070000
    Depth deviation from median checking off

  This data copied by program MBcopy version $Id: mbcopy.c,v 5.11 2002/07/20
20:56:55 caress Exp $
  MB-system Version 5.0.beta22
  Run by user <mapper> on cpu <iho> at <Wed Oct 23 05:46:28 2002>
  Control Parameters:
    Input file:         em1002-295-222059-0003-raw.all
    Input MBIO format:  56
```

```
Output file:        em1002-295-222059-0003-raw.all.mb71
Output MBIO format: 71
Ping averaging:     1
Longitude flip:     0
Longitude bounds:   -360.000000 360.000000
Latitude bounds:    -90.000000 90.000000
Begin time:         1962 2 21 10 30 0 0
End time:           2062 2 21 10 30 0 0
Minimum speed:      0.000000
Time gap:           1.000000
```

The following program *mbmosaic* was then used to grid all the individual sidescan backscatter data files into final *netCDF* grid mosaics for each system separately. Unlike the bathymetric data that was merged together, the multibeam backscatter data for different systems of varying resolution often do not combine well.

```
mbmosaic -A4 -C5 -E$cell_grd/$cell_grd -G3 -Iinfiles2 -R$Rg -N -
O$outdir/$chart.ss.nn.f -F0.01 -Yangle_priority.dat
```

Where *cell_grd* depends on the system, but can be as small as 16 m for the *EM 120* and 1 m for the *EM 1002*, *infiles* is an inclusive data file list, and *Rg* is the area of interest.

Equipment Concerns Affecting Data Quality

Uncompensated vessel heave problem

We saw a heave artifact in the *EM 1002* data when operating in relatively shallow water (~50 m) over flat bathymetry. Depending on sea state, this appeared to be introducing a 0.5–1.0 m "ripple" with a period of ~10 seconds in what should be an otherwise flat bottom (Fig. 44). This artifact was consistently perpendicular to the ship's track, regardless of heading. Vessel attitude and heave conditions which resulted in this artifact were ~± 1-m heave (as translated to the transducer by the *POS MV*), and ± 2–3 degrees of pitch and roll. The period of the artifact matches the period of the HPR data, and lags the heave input by ~1.5 seconds. We did not observe the "butterfly" pattern associated with a roll artifact and the observed pitch in 50 m of water is insufficient to cause the error we saw.

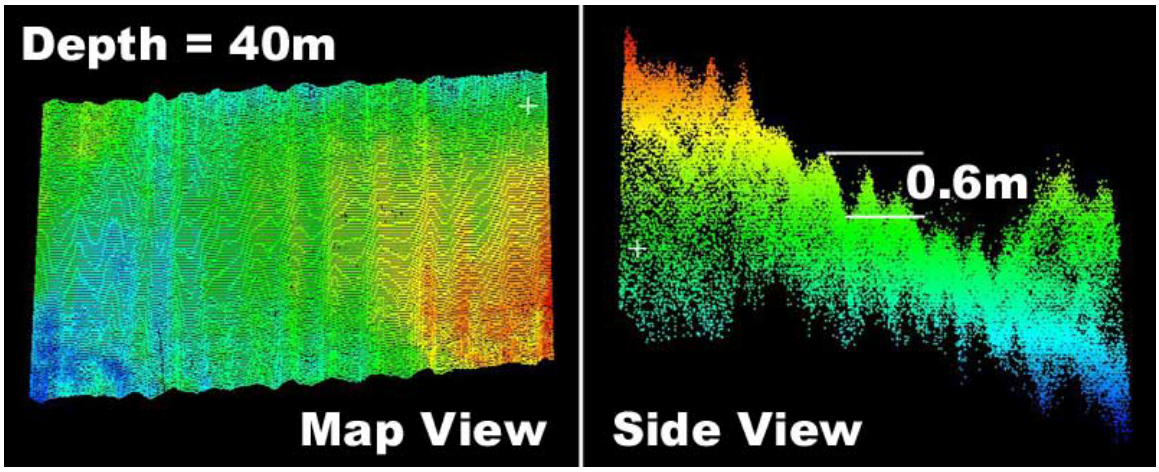

Fig. 44. Illustration of the possible uncompensated vessel heave problem described in the text. The data used to produce this figure was collected in 30–40 meters water depth. It is a typical example of what was seen when there was an apparent motion problem in shallow water. The time between the "peaks" in the data is about 9–11 seconds and the amplitude is approximately 0.2–0.6 meters. The problem did not manifest itself well on flat calm days. The phenomenon was not reproduced because of survey locations and conditions.

The fact that this problem appears to manifest itself exclusively as a heave error first suggests that there could be a latency in the heave signal from the *POS MV*. Since this latency appears to only affect heave, that points toward the *POS* heave bandwidth filter as a possible cause. Currently, this is set at 20 seconds, and the 10 second period of the heave should not be close enough to the roll-off frequency of the filter to introduce a phase lag. Another source of latency could be a constant time lag between the *POS* and *Simrad* acquisition system; although this has been measured during trials to be zero and would probably affect pitch and roll as well. Both of these possibilities could be tested by running lines over a shallow, flat area in heavy seas while systematically trying different values for the attitude latency in the *Simrad* and heave bandwidth in the *POS*.

If latency is ruled out, an error in lever arm measurement from the *POS* reference point (the granite block) to the vessel's center or rotation, and/or from the reference point to the *EM 1002* sonar head could be to blame. Such an error would result in incorrect computation of "remote heave" at the transducer. These offsets were surveyed in the shipyard, and have been rechecked for sign convention and consistency during this cruise, with no obvious errors found.

Finally, it is possible that the *POS MV* IMU has become misaligned. However, given the remote location of the IMU in the ship, and the magnitude of misalignment necessary to produce the observed error, this seems to be the least likely possibility. Also, such an error would be expected to manifest itself in a roll error as well as heave.

Auxiliary GPS offset problem

A potential second problem was found to be an incorrect offset of the auxiliary GPS for the *POS MV*. The Z-axis of the auxiliary GPS was suspect. The *POS MV* had a Z-offset of 4.340 meters set for this device, while the primary has a Z-offset of -28.153. We believed the offset should actually be on the order of -24 meters unless we were looking at this in the wrong reference frame. While we did think this could be causing the error in the heave that we saw, it was reported to *Simrad* personnel onshore since they set up these two GPS sensors. After their review, it was found that indeed the 4.34 value was incorrect and the proper value of Z(m)=-23.800 was entered on 01 Nov 2002, day 305 HST.

EM 1002 sidescan problem

Since installation the *Simrad EM 1002* shallow water multibeam system has produced erroneous sidescan backscatter data on the starboard side. The problem manifests itself as a consistent set of what is best described as along-track banding, or "freeway lanes," on a certain set of beams along the length of the record, making the data on the starboard side generally unusable. While on this cruise, we changed various settings at the direction of the onshore *Simrad* representative to no avail. Turning sector tracking did not change the data in any way. Changing the TVG and high/low frequency had little effect. A graphic depiction of the problem is presented in Figure 45. The Hawaii Mapping Research Group at the University of Hawaii is confident that the problem can be taken care of in their sidescan processing software once they write a filter to convert the *Simrad* datagrams into their format. Running it through the AVG module of their MR1 sidescan processing tools should allow us to recover full use of that component of the data.

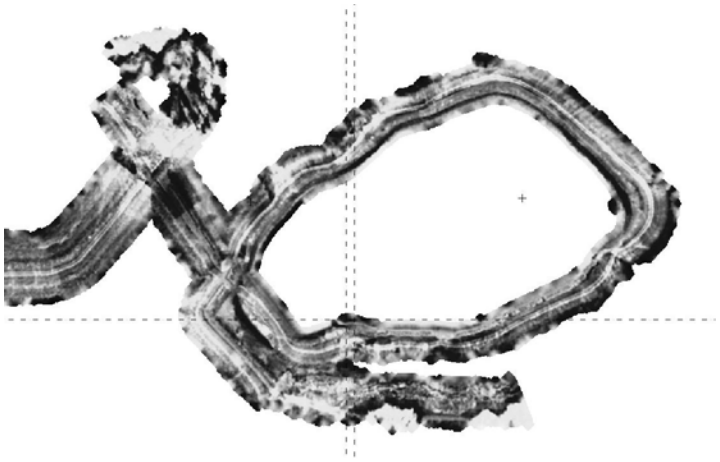

Fig. 45. Illustration of *EM 1002* sidescan backscatter banding problem, possibly resulting from the need for proper AVG corrections.

QTC bottom classification system problem

The Quester Tangent bottom classification system was hooked to the 38 kHz output of the single beam *Simrad EA 500* single beam echosounder. Unfortunately, there were changes in the signal that may have been automatic to the *Simrad EA 500* and the STAG engineer could not get the system to stay on one specific setting. As a result, the *QTC* classification data may not be usable. Basically, the dumber the echosounder used, the better. See **Appendix 6** on the ***QTC*** system for further information on the product.

Ship's gyro problem

An increasing heading drift in the main bridge gyro used for ship navigation was noticed by day 312 and tests were conducted. It was eventually secured on day 315. Following the cruise, the technician determined that it overheated, the fluid boiled off, and the instrument burned up inside its casing. The failure did not affect the mapping data except that ship's gyro data is missing from the onboard data logging system once it was shut down. Alternate systems were used to stay on the survey track lines.

APPENDIX

Appendix 1. Master Survey Log

Appendix 2. STAG equipment and SVP log

Additional Sensor Data Logged

Appendix 3. Positioning Systems and Survey Navigation Methodology

Time

Appendix 4. *Position and Orientation System for Marine Vessels* (*POS MV*)

Appendix 5. *Kongsberg Simrad* Multibeam Echo Sounding Systems

Appendix 6. Quester Tangent Digital Acoustic Real-time Seabed Classification System

Appendix 7. Sound Velocity Profiling (SVP) Equipment and Procedures

Appendix 8. Marine Gravity Meter

Appendix 1. Master Survey Log for KM0206 Cruise

Survey	Description	Date(s)	Time Start	Time End	120 Data	1002 Data
Transit 1	Transit from Oahu to Nihoa Island	295-296	2215	1830	complete	off @ 2351
Nihoa Island						
CTD, etc.	Sea watches begin	296	1830	2030		
Transit 1a from CTD site to 100 fm survey		296	2030	2256	complete	secured
Eastern Nihoa 100 fm survey		296-297	2256	0457	complete	complete
Transit 2	Transit between E. Nihoa and W. Nihoa	297	0457	0542	complete	complete
Western Nihoa 100 fm survey		297	0542	1213	complete	complete
Hove To		297	1213	1702	complete	off @ 1243
Transit 3	Transit from Hove To to western E. Nihoa	297	1702	1832	complete	secured
Western East Nihoa 6½ fm sounding investigation (not found)		297	1832	2032	complete	complete
SW part of East Nihoa 100 fm survey		297	2032	2055	complete	complete
Nihoa Island 3 nautical mile circle survey		297	2055	0034	off @ 2155	complete
					on @ 0030	
SE part of East Nihoa 100 fm survey (now completed)		298	0034	0339	off @ 0118	complete
					on @ 0143	
East Nihoa outer northern survey (deep)		298	0339	0752	complete	off @ 0601
						on @ 0724
West Nihoa, redo SE side, incl. 14 fm sounding survey (not found)		298	0752	1000	complete	off @ 0946
Transit 4	Transit from Nihoa to Necker Island	298	1000	1852	complete	secured
Necker Island						
CTD, etc.		298	1852	2030		
Transit 4a from CTD site to 100 fm survey		298	2030	2110	reboot/gap	on @ 2052
Necker 100 fm survey		298-299	2110	1339	complete	complete
Necker outer northern survey (deep)		299	1339	1747	complete	complete
5 fm sounding investigation (not found on this run, will revisit later)		299	1747	1924	complete	complete
Necker 25 fm survey		299-300 300	1924	1230	off @ 1924 on @ 2230 off @ 2357 on @ 0054 off @ 0058 on @ 0214	complete
Transit 5	Transit from Necker Island to FFS	300	1230	1940	gap @ 1506	off @1345
French Frigate Shoals						
CTD, etc.		300	1940	2059		
Transit 5a from CTD site to 100 fm survey		300	2059	2114	complete	secured
FFS 100 fm survey		300-301	2114	0408	complete	complete
FFS inside >shallow survey (for J.Miller)		301	0408	0600	off @ 0413	complete
FFS 100 fm survey (now complete)		301	0600	0918	complete	complete
Outer southwestern FFS (deep)		301	0918	1046	complete	complete
Transit 6	Transit from FFS to the Brooks Banks	301	1046	1613	complete	off @ 1050
The Brooks Banks and St. Rogatien Bank						
CTD, etc.		301	1613	1701		
Transit 6a from CTD site to 100 fm survey		301	1701	1726	complete	on @ 1715
Middle Brooks Bank 100 fm		301	1728	2115	complete	complete
Transit 6a	Transit from Brooks to W. Brooks	301	2115	2200	complete	complete
NW Brooks Bank 100 fm		301-302	2200	0111	complete	complete
Transit 6b	Transit from W. Brooks to St. Rogatien	302	0111	0242	complete	complete
St. Rogatien Bank 100 fm		302	0242	0730	complete	complete
Transit 6c	In between St. Rogatien to 17 fm investigation	302	0730	0830	complete	complete
17fm sounding investigation (not found)		302	0830	1005	complete	complete
St. Rogatien Bank outer southern survey (>100 fm, deep)		302	1005	1232	complete	complete
Transit 7	Transit from St. Rogatien to Gardner Pinnacles	302	1232	1600	complete	off @ 1313
Gardner Pinnacles						
CTD, etc.		302	1600	1701		
Transit 7a from CTD site to 100 fm survey		302	1701	1730	complete	secured
Gardner Pinnacle 100 fm survey		302-303	1730	0850	complete	complete
Gardner Pinnacle 25 fm survey		303-304	0850	0530	off @ 0916*	complete**
	(logged from 2152-2158 while em1002 rebooted)*		(reboot/stopped logging from 2149-2157)**			
Transit 8	Transit from Gardner to St. Rogatien Bank	304	0530	1000	complete	off @ 0541
St. Rogatien and the Brooks Banks						
St. Rogatien 25 fm survey		304	1000	1650	off @ 1000	complete
St. Rogatien outer northern survey (deep)		304	1650	2000	complete	complete
NW Brooks Bank 25 fm. survey		304-305	2000	0030	off @ 2006	complete
Transit 8a from NW Brooks to Middle Brooks		305	0030	0137	on @ 0100	complete
Middle Brooks Bank 25 fm survey		305	0137	0452	off @ 0135	complete
Transit 9 from Brooks to Maro via unnamed deep smt and SE ridge		305	0452	2000	complete	off @ 0506

Maro Reef						
CTD, etc.		305	2000	2213		
Transit 9a from CTD site to 25 fm survey		305	2213	2300	off @ 2257	secured
Maro Reef 25 fm survey		305-306	2300	1240	secured	complete
Maro Reef 100 fm survey		306-307	1240	0103	on @ 1254	complete
Maro Reef outer southern survey (deep)		307	0103	0521	complete*	complete
	(restarted em120 system @ 0258)*					
Transit 10 from Maro to Laysan Island via unnamed deep seamount		307	0520	0900	complete	off @ 0630
Laysan Island						
CTD, etc.		307	0900	1000		
Transit 10a from CTD site to 100 fm survey		307	1000	1120	complete	secured
Laysan 100 fm survey		307	1120	1813	complete	complete
Laysan 50 fm survey		307-308	1813	0051	complete	complete
Laysan outer northern survey (deep)		308	0051	0251	complete	complete
Transit 11	Transit from Laysan to Pioneer Bank	308	0251	0900	complete	off @ 0400?
Pioneer Bank						
CTD, etc.		308	0900	1015		
Transit 11a from CTD site to 100 fm survey		308	1015	1057	complete	secured
Pioneer 100 fm survey		308	1105/1057	1720	complete	complete
Pioneer 25 fm survey		308	1720	2355	off @1752	complete
Transit to begin deep northern survey (redo missed 100 fm area)		308-309	2355	0030	complete	complete
Pioneer outer northern survey (deep)		309	0030	0230	complete	complete
Transit 12	Transit from Pioneer to Lisianski Island	309	0230	0400	complete	off @ 0242
Lisianski Island						
Lisianski 100 fm survey		309	0400	1500	complete	complete
Lisianski outer northern survey (deep)		309	1500	1804	complete	off @ 1714
Lisianski 25 fm survey		309-310	1804	0418	off @ 1804	complete
Lisianski outer northern survey (deep, now complete)		310	0418	0611	on @ 0424	off @ 0442
Transit 13	Transit from Lisianski to unnamed bank to NW	310	0611	0626	complete	secured
Unnamed Bank (Seamount) NW of Lisianski						
XBT		310	0626	0630		
Unnamed bank NW of Lisianski, 100 fm survey		310	0810	0910	complete	complete
Investigation of 30 fm sounding north of unnamed bank		310	0910	1019	complete	off @ 0905
Unnamed bank NW of Lisianski, 100 fm survey (complete)		310	1019	1250	complete	complete
Transit 14	Transit from unnamed bank to Lisianski	310	1250	1822	off @ 1835	off @ 1252
Lisianski Island						
Lisianski 25 fm survey (complete)		310-311	1822	0529	secured	complete
Transit 15 from Lisianski to ridge south of Pioneer Bank		311	0529	0658	complete	off @ 0532
South Pioneer Ridge and Pioneer Bank						
South Pioneer Ridge deep survey		311	0658	1240	complete	secured
Pioneer Bank outer southeastern survey (deep)		311	1240	1419	complete	complete
Transit 16 Pioneer to Northampton Banks via unnamed deep smt		311	1419	1912	complete	complete
Northampton Seamounts/Banks						
West Northampton 100 fm survey		311	1912	2230	complete	off @ 2102
						on @ 2145
W. Northampton outer northern survey (deep)		311-312	2230	0047	complete	off @ 2234
W. Northampton 100 fm survey (complete)		312	0047	0226	complete	complete
Transit 17	Transit from W. Northampton to E. Northampton	312	0226	0648	complete	off @ 0238
East Northampton 100 fm survey		312	0648	0900	complete	off @0748
						on @ 0822
E. Northampton outer Loop		312	0900	1022	complete	off @ 0904
E. Northampton 100 fm survey (complete)		312	1022	1124	complete	complete
Transit 18 from Nhampton to Maro via SE Laysan and unnamed smt		312	1124	1645	complete	off @ 1135
Maro Reef						
XBT and continue transit to west end of Maro		312	1716	1800	complete	off @ 1730
Fill gap on 100 fm on west end of Maro		312	1800	1900	off @ 1815	complete
					on @ 1845	
Maro Reef outer northern survey (deep)		312-313	1900	0009	complete	off @ 2207
						on @ 2342
SE Maro Ridges, unnamed seamount, and crater deep surveys		313	0009	1437	complete	off @ 0009
Transit 19	Transit from Maro Reef to Raita Bank	313	1437	1601	complete	secured
Raita Bank						
Raita Bank outer southeastern survey (>100 fm)		313	1601	1722	complete	complete
Diverge from bank due to heavy weather, deep survey to south		313-314	1722	0317	complete	off @ 1722
Raita Bank outer survey (>100 fm, complete)		314	0317	1236	complete	complete
Transit 20	Transit from Raita to St. Rogatien Bank	314-315	1236	0730	complete	off @ 1236
						on @ 0406

St. Rogatien and the Brooks Banks						
St. Rogatien/Brooks Banks in between surveys (>100fm)		315	0730	1647	complete	off @ 1553
						on @ 1606
Transit 21	Transit from SE Brooks Bank to FFS	315	1647	1835	complete	complete
French Frigate Shoals						
FFS outer survey ~25 fm (complete loop)		315-316	1835	0239	off @ 1853	complete
FFS inside >shallow survey extended		316	0239	0919	secured	complete
Transit 22 from outer NW FFS to Necker via Bank 66 and EFFS		316	0919	2003	complete	off @ 1644
Necker Island						
Necker Island 25 fm survey revisited (complete redo loop)		316-317	2003	1309	off @ 2023	complete
Transit 22a north of Necker to set up for 5fm sounding investigation		317	1300	1400		off @ 1309
						on @ 1352
5 fm sounding investigation (not found)		317	1400	1715	off @ 1417	
					on @ 1715	
Transit 22b	Transit from 5 to 10 fm sounding investigations	317	1715	1920	complete	complete
10 fm sounding investigation (not found)		317	1715	1920	complete	complete
Transit 22c	From 10 fm sounding investigation to CTD site	317	1919	2010	complete	off @ 2010
CTD	Off middle of NE Necker	317	2010	2200	complete	secured
Transit 23	From CTD site to CTD winch wire dump site	317	2200	2345	complete	secured
1955 Submarine Eruption Site Survey and Unnamed Seamount						
CTD winch wire dump operations continuing to eruption site survey		317-318	2345	0130	complete	secured
1955 submarine eruption site survey		318	0130	0806	complete	secured
Unnamed seamount survey, incl. 81 fm investigation (not found)		318	0806	1330	complete	on @ 0949 off @ 1036 on @ 1118 off @ 1208 on @ 1225 off @ 1300
Transit 24 from unnamed smt to unnamed twin banks west of Nihoa		318	1330	1515	complete	on @ 1500
Unnamed Twin Banks West of Nihoa Island						
Western unnamed twin bank 100 fm survey		318	1515	1832	complete	complete
9 fm sounding investigation (not found)		318	1832	1915	complete	off @ 1910
Transit 24a	From 9 fm to eastern unnamed twin bank	318	1915	2001	complete	on @ 1915
Eastern unnamed twin bank 100 fm survey		318	2001	2330	complete	off @ 2227
Transit 25	From twin banks to West Nihoa via dogleg ridge	318-319	2330	0255	complete	on @ 0011
						off @ 0144
						on @ 0233
Nihoa Island to Oahu						
W. Nihoa outer No. survey, between, and outer E. Nihoa So. survey		319	0255	0702	off @ 0512	off @ 0535
					on @ 0525	
Transit 26	From E. Nihoa to unnamed bank NW of Kauai	319	0702	0906	complete	secured
Survey plan canceled d/t heavy weather, sea watches end		319	0906		complete	
	Last of onboard post-processed multibeam data	319		2235	complete	
Transit 27	Transit to Honolulu sea buoy	319-320	0906	1700	complete*	secured
(em120 off for a few hrs in Kauai Channel d/t operator error)*						
End of cruise		320	1700	1800	secured	secured

Note: All times and dates are UTC.

Appendix 2. STAG equipment and SVP log

```
File Name:  Readme_KiloMoana0206
Cruise Name:      NWHI Reserve
Chief Scientist: John R. Smith

STAG Technicians: Gabe Foreman, Steven Tottori

Departure:  (294)  18:01z     21 Oct. 2002  (08:01 hst Monday)
Arrival:    (295)  01:44Z     22 Oct. 2002  (15:44 hst Monday)

Departure:  (295)  22:03z     22 Oct. 2002  (12:03 hst Monday)
Arrival:    (320)  17:55Z     16 Nov. 2002  (07:55 hst Saturday)

Equipment:
  Computer:
    Logging - Main:kmlog1
    Logging - Sec: kmlog2
    Remotes:
       complab: kmlog1
       chart:   pueo
       imet:    aeo
       gravity: alaeula
       lab1:    uaukani
       chem:    iwa
       hydro:     koaekea
       wetlab:  ewa

    Processing:    kumu
    Gen Purpose:   hula, kmsun1, ClabPC

  Inertial Ref Unit: TSS POS-MV
  GPS Receivers:     P-Code, Ashtech ADU2
  Wind: Young Anemometer
  THSL: Not installed
  Fluorometer:  Not Used
  Gravimeter:  Running
  Maggy: Not used
  Sonar Systems:
    EM1002: OK
    EM120:  Ok
    EA500:  Ok
    Synchronization Unit: needs checkout

Equipment Repair log:
  Monitor(s): SamSung LTM1555S  sn:R773 31AT300133F, No control, no video
  Network:    Milan MIL-5801ST  sn:6GAM141 0144 95006767A, No fiber link

Log:
(294) 17:45z  Logging already started, chart remote running from previous day.
(294) 17:55z  Gravimeter started
(294) 18:03z  Underway Noise Testing
(294) 18:30z  SSVS pump turned on
(294) 18:30z  Simrad systems started
(294) 19:45Z  NAVSEA Noise testing begins all sonar off
(295) 01:05z  Ship going back in to Aloha Tower, SSVS pump turned off
(295) 01:44z  Arrived at Aloha Tower
(295) 22:03z  Underway - NWHI survey
```

```
(295) 22:30z  Simrad systems on, SSVS pump turned on
(295) 23:03z  Xbt cast
(296) 07:22z  kmlog1 operator error - stopped logging
(296) 07:27z  kmlog1 restarted
(296) 19:19z  Ctd cast #1
(296) 21:20z  Xbt taken,  Nihoa
(297) 22:08z  Xbt taken
(297) gap in adu2 8:18:15-8:18:50
(297) all others fine
(298) 08:18z  data gap adu2, error unknown
(298) 19:17z  Ctd cast #2
(298) 20:27z  Xbt taken,  Necker
(298) all data looks fine
(299) 07:17z  data gap adu2, error unknown
(299) gap adu2 07:17:27-7:18:02
(299) all others fine
(300) 19:55z  Ctd cast #3
(300) 21:11z  Xbt taken,  French Frigate Shoals
(301) 09:48z  data gap adu2, error unknown
(301) 16:02z  Ctd cast #4
(301) 17:05z  Xbt taken,  Brooks Bank
(302) 07:32z  data gap adu2, error unknown 3 times
(302) 16:02z  Ctd cast #5
(302) 17:06z  Xbt taken,  Gardner Pinnacles, 2 probes used. (one bad)
(303) 06:34z  SSVS cleaned
(303) 18:40z  Xbt taken
(303) gap in adu2 09:27:54-9:29:19
(303) gap in adu2 09:42:01-09:42:38
(303) all others fine
(304) 11:23z  data gap adu2, unknown error
(305) 20:55z  Ctd cast #6
(305) 22:10z  Xbt taken
(305) 22:30z  Monitor replaced in Complab.  no video or control
(306) 10:00z  Set up computer on Lab1 to output PGPS data
(306) 11:00z  Routed cable for PGPS output from Lab1 to Sonar data processing room
(306) all data fine
(307) 13:36z  data gap adu2
(307) 09:11z  CTD cast #7
(308) 09:08z  CTD Cast #8
(308) 13:30z  data gap adu2
(309) 04:15z  lost mouse and keyboard control.  Forced shutdown of kmlog1,
              rebooted and system restart ok.
(309) 13:26z  data gap adu2
(309) 20:01z  data gap adu2
(310) 08:58Z  data gap adu2
(310) 13:22z  data gap adu2
(311) 06:26z  Cleaned the SSVS sensor.  Restarted ~17.4 gpm
(311) 19:15z  lost mouse on kmlog1.  still have one terminal control.
(311) gap in adu2 01:44:34-01:45:07
(311) gap in adu2 08:56:40-08:58:25
(311) gap in adu2 13:18:14-13:25:01
(311) all others fines
(312) 04:52z  restarted the x-windows on kmlog1 using the ctrl-alt-bksp. mouse ok
(312) 17:16z  Xbt taken, West end of Maro Reef
(312) 22:30z  turned off gyro due to increasing error in heading reading
(312) 23:00z  Gyro turned on, beginning settling process
(312) gap in adu2 04:50:47-04:51:321
(312) gap in adu2 18:25:37-18:26:12
(312) gap in adu2 19:34:10-19:34:44
(312) gap in adu2 19:48:36-19:49:11
```

```
(312) gap in grav 04:50:51-04:51:41
(312) gap in pgps 04:50:47-04:51:32
(312) gap in pos-mv 04:50:48-04:51:32
(312) gap in spdgps 04:50:48-04:51:32
(312) gap in spdhdg 22:31:54-23:00:52
(312) gap in wind1 04:50:50-04:51:32
(315) 07:04z  Gyro secured not working
(316) 13:15z  data gap adu2
(317) all fine
(318) gap in adu2 08:21:48-08:22:21
(318) all others fine
(320) 17:40z Tied to dock
(320) 18:00z Data logging stopped
```

Additional Sensor Data Logged

- Thermosalinograph (*not installed on KM0206*)
- Fluorometer (*not used on KM0206*)
- Various wind data
- Set, drift, and corrections file
- Speed & heading
- Ship's gyro, RPM, and speed through the water

Appendix 3. Positioning Systems and Survey Navigation Methodology

Kilo Moana uses a Trimble PY-GPS unit (~7–10 m accuracy) and an Ashtech ADU2 system for science mission instruments and logging. During the cruise we were out of range of Differential GPS (DGPS) stations (~3–10 m accuracy) and did set up stations or use special navigation services. The multibeam systems use a derived GPS position from their own differential phase system. It can accept differential RF signals, but due to errant behavior when the RF signals fade in and out (mainly due to vessel location issues) the differential RF input to the *POS MV* was disconnected. Presently, the multibeam systems have two GPS receivers that feed into the TSS *POS MV* Inertial Measurement System (IMU) along with heading, speed, etc., and thus it provides a better fix solution. P-code & ADU2 GPS data is fed into the transceivers as backup GPS system information.

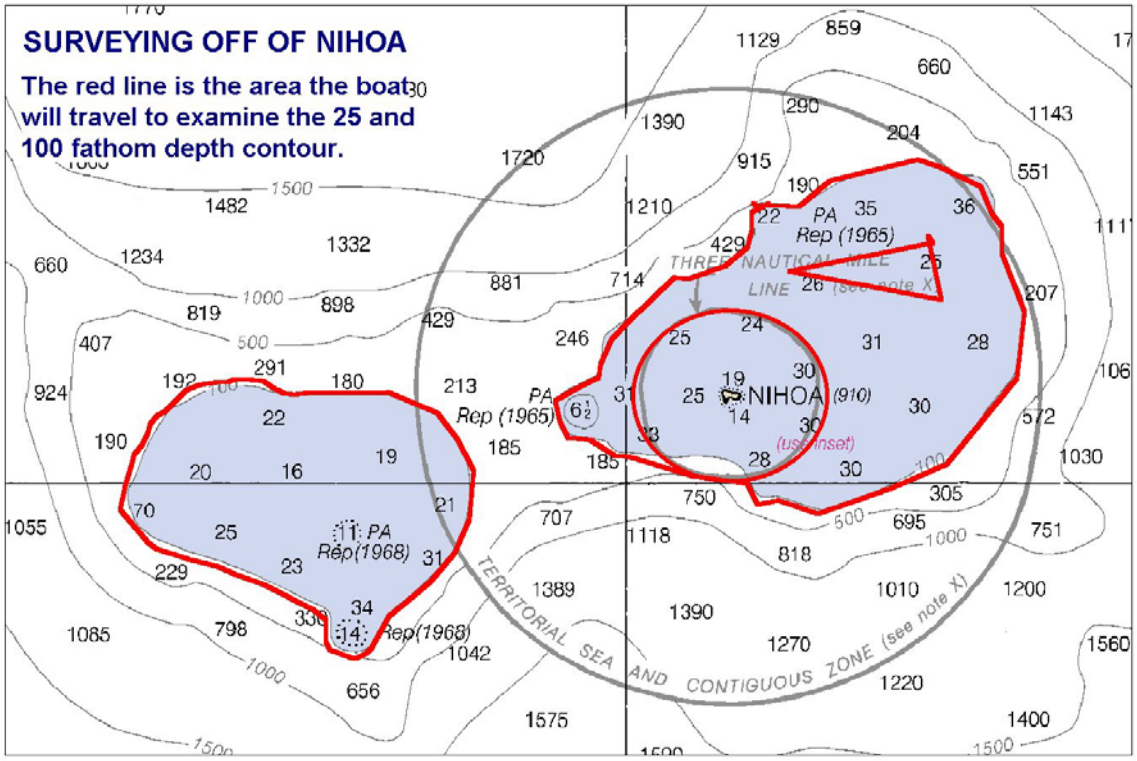

Fig. 52. Example of survey tracks on the predicted 25 and 100 fathom depth contours (red lines) based on the nautical charts, *KoK* multibeam, *Cromwell* single beam, and/or satellite imagery products from NOAA.

For this expedition we installed *Nobeltec Visual Navigation version 6.5* on the bridge and computer lab navigation computers. A preliminary set of 18 raster charts for the NWHI updated to the NAD83 datum was provided for beta testing and verification by the Marine Charting Division (MCD) of NOAA's Office of Coast Survey. This were installed on all navigation systems and used for survey planning and implementation. An estimated route consisted of numerous short segments around the 100-, 50-, or 25-fm contour of the island or submerged bank was laid out either in *Arcview* GIS and/or Nobeltec using existing data from NMFS single beam, HURL multibeam, other satellite or aerial imagery made available to us by NOAA, or simply the updated charts if there were no other data (Fig. 52). Following an initial circuit around, we could then base our next pass on these data (Fig. 53). Routes and waypoints were exported to a file, loaded and transferred on floppy disk, input to either the computer lab's clone of the bridge navigation computer and transferred via the network to the bridge or simply carried up to the bridge via "sneaker net" and loaded directly. In both cases, the *Nobeltec* export file had to be imported into the bridge computer from that station.

As for actual surveying, it was determined early on that it was more efficient to let the bridge crew run along the contour of interest based on the bridge fathometers, either the Raytheon Model 795 in the chart room (with remote display in the computer lab) or the simpler digital fathometer display in the pilot house console. The mate on watch would call course adjustments to the AB on the wheel. This tedious operation was admirably carried out by the crew, although it was difficult to follow the undulating terrain that we discovered was common to the shallow depth range we were surveying. The multibeam operators in the computer lab watched the swath displays and interacted with the bridge crew to advise whether to make a course adjustment based on missing or already existing coverage or potential hazards to navigation. This whole aspect of the cruise proved more arduous that was anticipated beforehand and the quality and ease of these shallow water contour-following surveys could be improved significantly by having a remote display of the multibeam swath(s) output to the bridge.

During the cruise, two of the NOAA Corps reps onboard sent updates regarding the adequacy of the datum shifts to MCD. With the exception of Laysan Island, it appears that the shifts were accomplished adequately for safe navigation. Of course, this is with the recognition that the charted depths are only as good as the 1930's vintage prior surveys and the sporadic Navy trackline reports issued in the 1960's. We know that by today's standards, the charted depths may be inadequate. See the *Mapping the Northwestern Hawaiian Islands – History and Mission Objectives* section for further details on what will be incorporated into the next two rounds of NWHI chart printings.

Time

The data logging computers set their time and collect data based on two NTS GPS time servers (basic GPS time, UTC) through a broadcast network. IRIG-B time is also output to LED displays in the laboratories.

Appendix 4. *Position and Orientation System for Marine Vessels*

The *TSS Position and Orientation System for Marine Vessels (POS MV)* model *320* provides extremely accurate attitude, heading, heave, position, and velocity, delivering full 6 degree-of-freedom position and orientation solutions for marine survey vessels. It represents the latest in state of the art aided inertial technology. *POS MV* was designed specifically for use with multibeam sonar, enabling adherence to International Hydrographic Survey (IHO) standards on sonar swath widths of greater than ± 75 degrees under all dynamic conditions.

Appendix 5. *Kongsberg Simrad* Echo Sounding Sonar Systems

Simrad EA 500 Hydrographic Single Beam Echo Sounder

The *EA 500* is a single or split beam echo sounding system with three transducer frequencies: 12, 38 and 200 kHz. Ranges are 13,000 m for 12 kHz operation and 500 m for 200 kHz operation. The displays were monitored for to assist with multibeam data quality assurance, and the single beam depth sounding data were recorded on the *QTC* system.

System specifications:

- Ping rate.....Max 20 pr. second
- Measurement resolution.....1 cm

- Measurement accuracy (Average sound velocity must be correct):
  - 200 kHz.....1 cm
  - 38 kHz.....5 cm
  - 12 kHz.....20 cm

EM 120 Multibeam Echo Sounder

The *Kongsberg Simrad EM 120* is designed to do mapping to full ocean depth with an hitherto unsurpassed resolution, coverage and accuracy. The receive transducer is wideband and in conjunction with a separated low frequency transmit transducer; the *EM 120* may optionally be able to deliver subbottom profiling capabilities with a very narrow beamwidth.

The nominal sonar frequency is 12 kHz with an angular coverage sector of up to 150º and 191 beams per ping as narrow as 1º. The angular coverage sector and beam pointing angles may be set to vary automatically with depth according to achievable coverage. This maximizes the number of usable beams. The beam spacing is normally equidistant with equiangle available. A combination of phase and amplitude detection is used, resulting in measurement accuracy practically independent of beam pointing angle.

The transmit fan is split in several individual sectors with independent active steering according to vessel roll, pitch and yaw. This places all soundings on a "best fit" to a line perpendicular to the survey line, thus ensuring a uniform sampling of the bottom and 100% coverage. The sectors are frequency coded (11.25 to 12.60 kHz), and they are all transmitted sequentially at each ping. The steering is fully taken into account when the pos8ition and depth of each sounding is calculated, as is the refraction due to the sound speed profile, vessel attitude, and installation angles. Pulse length and range sampling rate are variable with depth for best resolution, and in shallow waters due care is taken to the near field effects. The ping rate is only limited by the round trip travel time in the water up to a ping rate of 5 Hz.

The *EM 120* transducers are linear arrays in a Mills cross configuration with separate units for transmit and receive with the arrays divided into modules. The system on *Kilo Moana* is a 1º transmit by and 2º receive installation. The *EM 120* is a complete system. All necessary sensor interfaces, data displays for quality control, and sensor calibration, seabed visualization, and data logging are a standard part of the system, as is integrated seabed acoustical imaging capability (sidescan). The setup screens showing the parameters used are shown in Figure 55.

Simrad EM 1002 Multibeam Echo Sounder

The *Kongsberg Simrad EM 1002* multibeam echo sounder is designed for high resolution seabed mapping from the shoreline and down to a depth of 1000m. The system is easy to install, even on small vessels. The *EM 1002* has an accuracy surpassing the IHO standard, including the most stringent of the latest version, 4th edition.

The *EM 1002* uses the same transducer as the previous *EM 1000* but newer and more compact electronics and new software allows a higher ping rate, almost twice the number of beams per ping with narrower beamwidth, higher accuracy, and a much improved operator interface.

The *EM 1002* system has a maximum ping rate of more than 10 Hz, a large number of measurements per ping with 111 beams, 2º beamwidth, and electronic roll stabilization. Mechanical pitch compensation is available with an optional hull unit not installed on *Kilo Moana*. Acrosstrack coverage is up to about 1200 m in deeper waters, and in shallow waters up to 7.5 times depth beneath

the transducer. The angular coverage is fully adjustable, and for surveying to the water surface along shorelines, river banks and man-made structures, the angular coverage to one or both sides may be increased to 5º above the horizontal. The hull mounted arrays and fairing are shown in Figure 9.

The standard *EM 1002* system has three different pulse lengths (0.2, 0.7 and 2 ms) to maximize coverage in deeper waters, approximately more than 200 m. The system's nominal sonar frequency is 95 kHz. This frequency allows for small dimensions, good range capability and high tolerance to turbid waters. Integrated seabed acoustical imaging capability (sidescan) is included as standard. A combination of phase and amplitude detection is used, resulting in measurement accuracy practically independent of beam pointing angle. The *EM 1002* is a complete system with all necessary sensor interfaces, real-time compensation for vessel motion and raybending, data displays for quality control including sensor calibration, and data logging are used. The setup screens showing the parameters used are shown in Figure 56.

Appendix 7. Sound Velocity Structure Profiling Equipment and Procedures

We did CTD and SVP casts with both instruments on the same rosette to determine the sound velocity structure to approximately 1000 meters water depth (Fig. 58). At the beginning of the cruise we also deployed an XBT to several hundred meters at the same time to compare profiles. Once our confidence in, and the procedure for, the various profiling and processing methods were established, we frequently relied on the much quicker XBT's. This methodology usually worked fine because the focus of our mapping was in the shallow range of less than 200 meters. A CTD/SVP cast was preferred as the first activity upon arriving at a new site. However, often the desire was to map the shallowest areas during daylight and in those cases we deferred to a rapid XBT rather than spend 1–2 hours deploying a rosette. The multibeam systems produced an alarm display based on preset limits if the sound velocity structure model did not fit well with the incoming data. This signaled the time for a new CTD/SVP cast or XBT deployment. A total of eight CTD/SVP casts were taken and ten XBT's deployed (one bad). See the ***STAG equipment and SVP log*** in **Appendix 2** for SVP, XBT, and CTD cast information. All cast data files are included on the data archive CD-ROM.

Surface Sound Velocimeter Sensor

An Applied Microsystems SV&T Smart Sensor is housed in a tank in the sonar room in the forward port hull near the *POS MV* IMU. A water intake is mounted over the multibeam sonar array and water is continuous pumped across the sensor to report variations in surface sound velocity (SSV) to the system and multibeam operators. Accurate SSV is critical to beam forming and ray tracing for these wide swath multibeam sonars, especially in shallow water. The SVSS instrument was cleaned about every eight days.