Ocean Exploration and Research

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT:

EX-15-04 Leg 4, Hohonu Moana 2015: Exploring the Deep Waters off Hawai'i (ROV & Mapping)

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1. Introduction

The NOAA Office of Ocean Exploration and Research is the only federal program dedicated to exploring our deep ocean, closing the prominent gap in our basic understanding of U.S. deep waters and seafloor and delivering the ocean information needed to strengthen the economy, health, and security of our nation.

Using the latest tools and technology, OER **explores** previously unknown areas of our deep ocean, making discoveries of scientific, economic, and cultural value. Through live video streams, online coverage, training opportunities, and real-time events, OER allows scientists, resource managers, students, members of the general public, and others to actively **experience** ocean exploration, expanding available expertise, cultivating the next generation of ocean explorers, and engaging the public in exploration activities. From this exploration, OER makes the collected data needed to **understand** our ocean publicly available, so we can maintain the health of our ocean, sustainably manage our marine resources, accelerate our national economy, and build a better appreciation of the value and importance of the ocean in our everyday lives.

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2. Report Purpose

The purpose of this report is to briefly describe the acoustic seafloor and water column mapping data collection and processing methods used during exploration expedition EX-15-04 L4, and to present a summary of the overall mapping results and mapping related cruise activities. A detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2015 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report, available at doi:10.25923/hhvn-7d52. A full description of Remotely Operated Vehicle (ROV) operations and sample collections completed during the cruise is available in a separate Expedition Report available in the NOAA Central Library with the title "*Cruise Report: EX-15-04 L4, Hohonu Moana 2015: Exploring the Deep Waters off Hawai'i (ROV & Mapping).*"

3. Cruise Objectives

EX-15-04 L4 was one of a series of NOAA Ship *Okeanos Explorer* expeditions from 2015 to 2017 planned to contribute to NOAA's multi-year Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE). NOAA priorities for the CAPSTONE campaign included a combination of science, education, outreach, and open data objectives that will support management decisions at multiple levels. CAPSTONE was a 3-year effort designed to provide critical new information on the deep water resources within the U.S. marine national monuments and sanctuaries located throughout the Pacific. The primary goal of all *Okeanos Explorer* expeditions in this campaign was to obtain baseline characterizations of the very poorly known deep water areas and resources in these extensive marine protected areas.

EX-15-04 L4 operations focused on collecting data on sites near the Johnston Atoll within the Pacific Remote Islands National Marine Monument (PRINMM), sites offshore of Oahu and Ni'ihau en route to the PRINMM, and sites within the Papahānaumokuākea Marine National Monument. Areas of relatively abrupt bathymetry such as rift zone ridges and ridge features were targeted due to the likelihood of hosting extensive communities of deepwater corals and sponges, as well as potential manganese crust habitats in depths between 1,000 and 2,500 meters. A complete list of cruise objectives is available in the Project Instructions document for the cruise.

The EX-15-04 L4 expedition was a 19-day expedition that started on September 12, 2015 and ended on September 30, 2015. The cruise started and ended in port facilities in Pearl Harbor in Honolulu, HI. The expedition included 24-hour per day operations, with daytime ROV dives supported with shore-side participation via telepresence technology and overnight mapping operations.

4. Summary of Mapping Results

Multibeam mapping operations covered an area of 17,249 square kilometers of seafloor over a linear ship track distance of 3,566 kilometers. Multibeam bathymetry data coverage and ROV dive locations are shown in Figure 1.

Cruise Overview Map

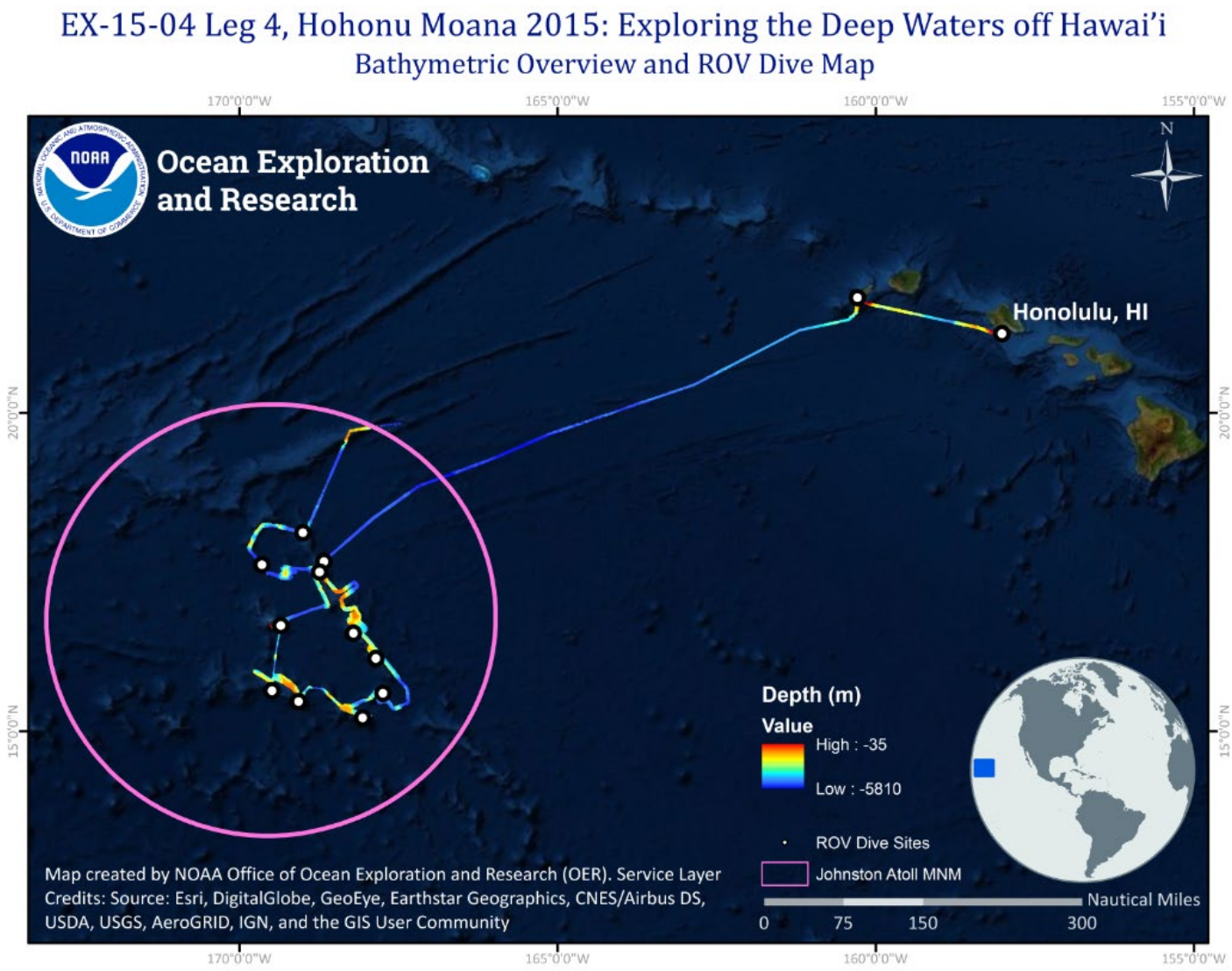

Figure 1. Cruise map showing overall EX-15-04 L4 multibeam bathymetry coverage completed during the expedition. Depth units are in meters. White dots represent completed ROV dive locations.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-15-04 L4.

Dates of cruise	September 12 – September 30, 2015
Linear kilometers of survey with EM 302	3,566
Square kilometers mapped with EM 302	17,249
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	329 files/ 15.2 GB
Number / Data Volume of EM 302 water column multibeam files	329 files/ 54.5 GB
Number / Data Volume of EK 60 water column split beam files (.raw)	497 files / 3.68 GB
Number / Data Volume of sub-bottom sonar files (.segy, .kea, .keb)	252 files / 2.83 GB
Number of XBT casts	42
Number of CTD casts (including test casts)	0

6. Mapping Sonar Setup

The following sonars were operated during the cruise:

Kongsberg EM 302 Multibeam Sonar

NOAA Ship *Okeanos Explorer* is equipped with a 30 kilohertz (kHz) Kongsberg EM 302 multibeam sonar capable of detecting the seafloor in up to 10,000 meters of water and conducting productive mapping operations in 8,000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3,300 meters. In waters shallower than 3,300 meters the system is operated in dual swath mode, and obtains up to 864 soundings per ping by generating two swaths per ping cycle. The multibeam sonar is used to collect seafloor bathymetry, seafloor backscatter, and water column backscatter data. Backscatter represents the strength of the acoustic signal reflected from a target, such as the seafloor or bubbles in the water column. The system undergoes a patch test calibration annually and the results are reported in the annual readiness report.

Simrad EK 60 Split-beam Sonar

The ship operated an 18 kHz Simrad EK 60. This sonar is a quantitative scientific echosounder calibrated to identify the target strength of water column acoustic reflectors - typically biological scattering layers, fish, or gas bubbles – providing additional information about water column characteristics and anomalies.

Knudsen 3260 Sub-bottom Profiler

The ship is equipped with a Knudsen 3260 sub-bottom profiler that produces a frequency-modulated chirp signal with a central frequency of 3.5 kHz. This sonar is used to provide echogram images of shallow geological layers underneath the seafloor to a maximum depth of approximately 80 meters below the seafloor. The sub-bottom profiler is normally operated to provide information about sub-seafloor stratigraphy and features. The data generated by this sonar are fundamental to helping geologists interpret the shallow geology of the seafloor.

7. Data Acquisition Summary

Mapping operations included EM 302 multibeam, EK 60 split-beam, and Knudsen sub-bottom profiler data collection. Throughout the cruise, multibeam data quality was monitored in real-time by acquisition watch standers. Ship speed was adjusted to maintain data quality as necessary and line spacing was planned to ensure one-quarter to one-third swath width overlap between lines. Cutoff angles in SIS were generally left wide open for maximum exploration data collection, and were adjusted on both the port and starboard side during focused survey operations to ensure the best data quality and coverage. Data were corrected for sound velocity in real-time using Reson SVP-70 probe data at the sonar head. Reson sound velocity values were constantly compared against secondarily derived sound speed values from the ship's onboard thermosalinograph flow-through system as a quality assurance measure. Expendable Bathythermographs (XBTs) were conducted every 2 to 6 hours during mapping operations to provide temperature profiles of the water column in order to calculate sound velocity profiles. These profiles are used while surveying with the multibeam sonar in order to properly account for sound speed changes and ensure the most accurate bathymetry data possible.

Simrad EK 60 split-beam water column sonar data and Knudsen 3260 sub-bottom profiler data were collected continuously during the cruise while mapping, but not during ROV dive operations. Data were monitored in real time for quality but were not post-processed.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Figure 2 shows the multibeam data processing workflow for this cruise. EM 302 Built-in Self Tests (BISTs) were run throughout the cruise to monitor multibeam sonar system status and are available as ancillary files in the sonar data archives. Raw multibeam bathymetry data files were acquired by SIS, and were imported into CARIS software. In CARIS, attitude and navigation data stored in each file were checked, and erroneous soundings were manually removed using CARIS Swath Editor and Subset Editor. With the vast majority of surveying completed in deep water, depth measurements were not adjusted for tides, as they are an essentially insignificant percent of the overall water depth. Data cleaning projects were in UTM zone projections for the operations area. Final data products were exported and archived as field geographic WGS84 coordinate reference frame (i.e., unprojected).

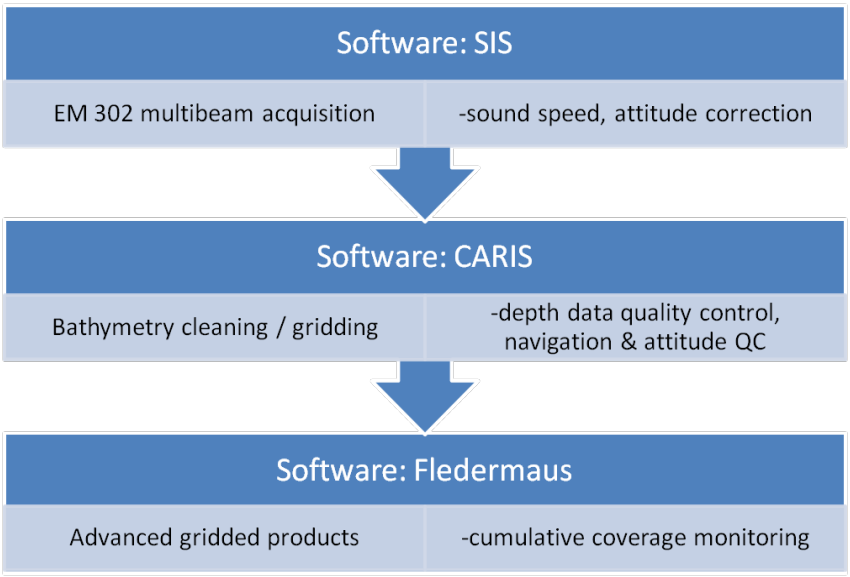

Figure 2. Shipboard multibeam data processing workflow.

Crosslines

Comparing depth values from orthogonal survey lines is a standard hydrographic quality control measure to evaluate the consistency of the multibeam sonar data collected during a cruise. A crossline was run on September 24, 2015 as shown in Figure 3. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software and confirmed the data meet the requirements for an International Hydrographic Order 2 survey. The results are shown below.

Crossline file:
0249_20150924_033303_EX1504L4_MB

Mainscheme line file:
0234_20150923_073721_EX1504L4_MB

0237_20150923_092522_EX1504L4_MB

0241_20150923_113819_EX1504L4_MB

0245_20150923_135759_EX1504L4_MB

Depths listed ("Z") are in meters.

Statistic	Value
Number of points of comparison	262720
Grid Cell Size	100
Difference Mean	4.914
Difference Median	3.659
Difference Std. Dev	17.840
Difference Range	[-176.13, 99.80]
Mean + 2*Stddev	40.595
Median + 2*Stddev	39.340
Data Mean	-2732.983
Reference Mean	-2737.897
Data Z-Range	[-3798.50, -1749.40]
Reference Z-Range	[-3814.33, -1758.60]
Order 2 Error Limit	62.980
Order 2 # Rejected	2196
Order 2 P-Statistic	0.008359
Order 2 Survey	**ACCEPTED**

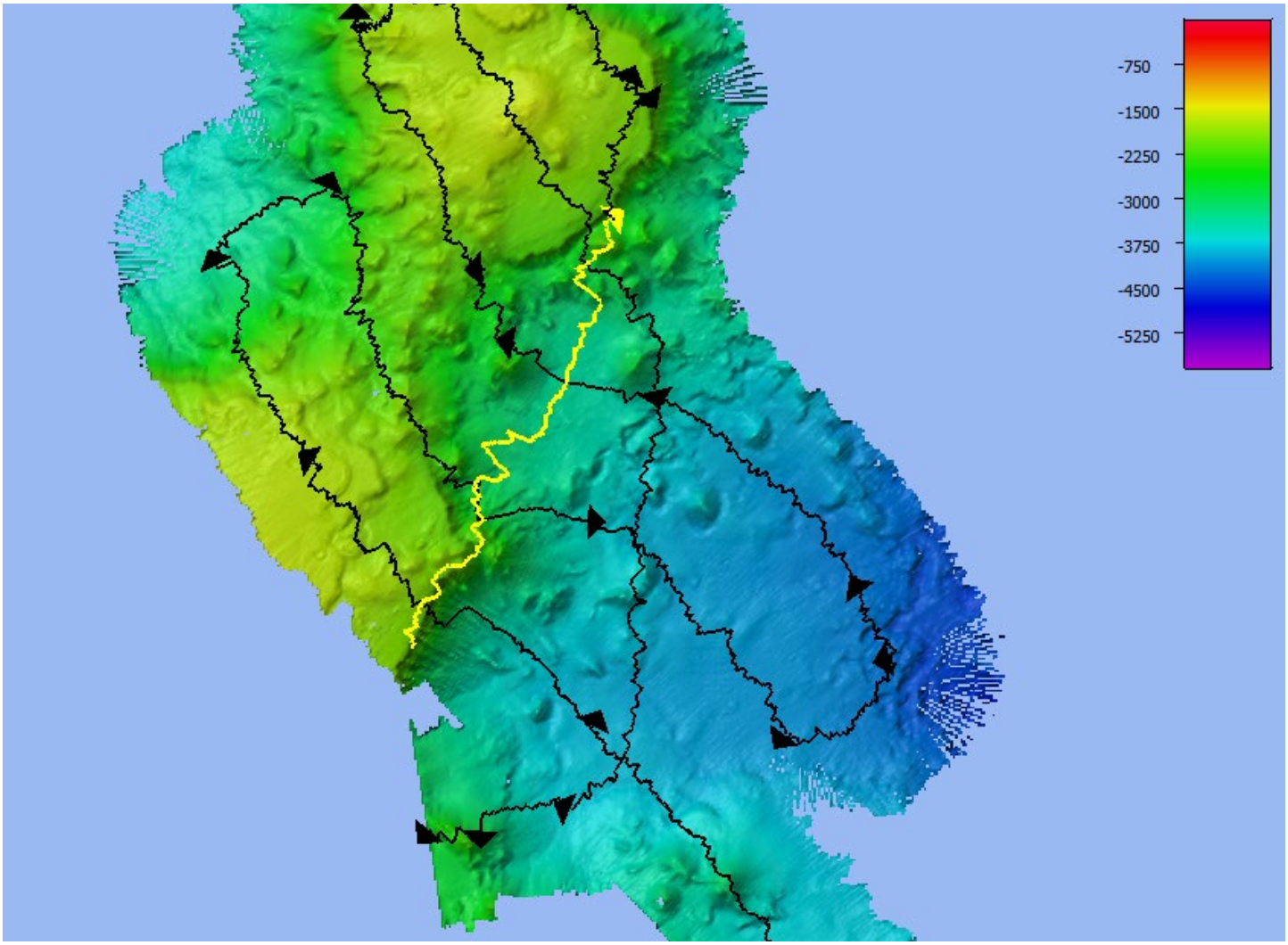

Figure 3. EX-15-04 L4 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

9. Data Archival Procedures

All mapping data collected by the NOAA Ship *Okeanos Explorer* are archived and publicly available within 90 days of the end of each cruise via the National Centers for Environmental Information (NCEI) online archives. The complete data management plan (which describes the raw and processed data formats produced for this cruise) is available as an appendix in the EX-15-04 L4 project instructions available in the NOAA Central Library at https://repository.library.noaa.gov/view/noaa/10628. Ancillary and supporting files are archived with the sonar datasets. These include:

EM 302 Multibeam bathymetry and bottom backscatter dataset:

- Mapping watch stander log
- Multibeam acquisition and processing log

Simrad EK 60 split-beam water column dataset:

- Mapping watch stander log

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watch stander log

EM 302 Multibeam water column dataset:

- Mapping watch stander log
- Multibeam acquisition and processing log

All sonar data are permanently discoverable at https://www.ngdc.noaa.gov/

EM 302 and EK 60 water column data, supporting data, and informational logs are available in the NCEI Water Column Sonar Archives:

- EM 302 water column data can be found here: http://doi.org/10.7289/V5PG1PQ6
- EK 60 water column data can be found here: http://doi.org/10.7289/V5T72FFX

Sub-bottom profiler data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/. For assistance in accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-15-04 L4 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files are available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/bathymetry/ (last accessed 3/3/2020).

10. Cruise Calendar

All times listed are local ship time, which was -10 hours from UTC

September 2015

Sun	Mon	Tues	Wed	Thur	Fri	Sat
					11 Ship alongside in Honolulu, HI.	12 Start of expedition. ROV Dive 1. Transit mapping.
13 ROV Dive 2. Transit mapping.	14 Transit mapping.	15 Transit mapping.	16 ROV Dive 3. Mapping operations conducted over East Karin Ridge.	17 Supplies were delivered to researchers on Johnston Atoll. ROV Dive 4. Overnight mapping.	18 ROV Dive 5. Overnight mapping.	19 ROV Dive 6. Overnight mapping.
20 ROV Dive 7. Overnight mapping.	21 ROV Dive 8. Overnight mapping.	22 ROV Dive 9. Overnight mapping.	23 ROV Dive 10. Overnight mapping.	24 ROV Dive 11. Overnight mapping.	25 ROV Dive 12. Overnight mapping.	26 ROV Dive 13. Overnight mapping.
27 ROV Dive cancelled due to weather. Sonars secured due to sea state.	28 Transit to Hawaii. Sonars secured due to sea state.	29 Transit to Hawaii. Sonars secured due to sea state.	30 Arrival to Honolulu, HI.			

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time which was Hawaii Standard Time (HST) (-10 hours from Coordinated Universal Time (UTC)).

September 12, 2015
NOAA Ship *Okeanos Explorer* departed Pearl Harbor, O'ahu, about 0930 this morning to commence Leg 4 of the Hohonu Moana Expedition. All sonars were turned on for the short transit to the Dive 1 location, and seas were calm. The multibeam passed all BIST tests on the first attempt and ran normally.

Transit mapping operations commenced in the evening as the ship transited between Dive 1 and Dive 2 of the expedition.

September 13, 2015
Dive 2 was conducted today just southwest of the island of Ni'ihau, the first and only dive within state waters. This dive site was requested by the Humpback Whale Sanctuary, and is in an area that is being considered as part of a proposed expansion to the Sanctuary.

Overnight mapping operations followed a transit line towards Johnston Atoll. All sonars operated normally. Survey speeds were between 9 and 10 knots.

September 14, 2015
Transit mapping operations continued en route to Johnston Atoll over a charted ridgeline that appears to be disproved. Weather conditions were less conducive to survey operations, however data quality remained fair to good. A live interaction was attempted with a school group, but failed due to poor VSAT connection.

September 15, 2015
Transit mapping operations continued en route to Johnston Atoll. All sonars operated normally, with fair to good data quality. Two planned live interactions with school groups were cancelled due to poor VSAT connection.

September 16, 2015
Dive 3 of this expedition was conducted along a deep spine feature along the Karin Ridge, northeast of Johnston Atoll, and was the first dive inside the PRIMNM.

Following the dive, mapping operations focused on the East Karin Ridge. Sonar quality improved as the seas subsided.

September 17, 2015

The ship pulled in to the boat basin at Johnston Atoll in the morning to deliver supplies to researchers on the island. Multibeam data were collected while transiting in and out of the Johnston Atoll shipping channel, which has not been mapped since 1964 and is no longer maintained. Depths were in the 30-40 foot range, and the data were very noisy. The mapping team is working with the Office of Coast Survey to determine if the data quality is sufficient for charting.

Dive 4 was conducted on the southeast side of Johnston Atoll along a ridge leading up to a plateau feature.

Following the dive, overnight mapping operations were conducted on two focused lines running parallel to coverage collected on EX-15-04 Leg 1, completing coverage over a ledge feature.

September 18, 2015
Dive 5 was conducted on Deep Twin Ridge on the south side of the Johnston Seamounts within the PRIMNM.

The EM 302 was started in marine mammal mode, and the PPS time sync light turned red and the sonar would not ping. Restarting the TRU and multibeam computer solved the problem. Data quality was good, and mapping operations continued over the ledge feature first mapped during EX-15-04 Leg 1.

September 19, 2015
Dive 6 was conducted approximately 65 nautical miles south of Johnston Atoll. This area contained the highest abundance of corals observed within the PRIMNM.

Mapping operations focused on expanding coverage around the Johnston Seamounts. Data quality remained good overnight. The mapping team tested the auto phase setting on the sub-bottom profiler, but it remained problematic.

September 20, 2015
Dive 7 was conducted on a pair of associated cones on an unnamed seamount/guyot plateau at the southernmost point of the expedition.

Mapping operations focused on filling a large holiday on the guyot/plateau system that dives have been occurring on, as well as over the seamount where tomorrow's dive is planned to investigate.

September 21, 2015
Dive 8 was conducted on a cone rising 300 meters above the plateau of an unnamed seamount. This dive had the best VSAT connection and most participation from shore thus far. The VSAT connection appears to be dependent on sea state.

Mapping operations conducted during the transit to Dive 9 included data collection over an uncharted seamount that was observed in the satellite derived bathymetry. The remainder of the transit edge mapped EX-15-04 Leg 1 data on the east side of Karin Ridge.

September 22, 2015
Dive 9 was conducted on Karin Ridge. A high abundance and high density coral garden was observed.

Mapping operations focused on edge matching a feature east of Karin Ridge that was initially mapped during EX-15-04 Leg 1.

September 23, 2015
Dive 10 was conducted on Karin Ridge. During the decent, the vehicle was stopped to investigate a thin layer of very reflective objects at 150 meters. The objects appeared to be very small lantern fish.

Overnight mapping operations employed the "exploration sticks" model to map parts of Karin Ridge. Since there was not adequate time to fully ensonify this area, gaps in exploration were used to get a better idea of the shape and location of the ridge shelf. Data quality was good.

September 24, 2015
Dive 11 was conducted on Karin Ridge, exploring the crest of a ridge extending south from the same feature explored on Dive 3.

Overnight mapping operations focused on a sparsely mapped seamount to the west of Karin Ridge. Data quality remained good.

September 25, 2015
Dive 12 was conducted on a small, unnamed abyssal ridge. This was the deepest dive ever conducted within the PRIMNM Johnston Atoll boundaries.

Due to an issue with one of the ship's generators, mapping speeds were reduced to 5-7 knots. Some edge matching of existing coverage occurred before transiting to the next dive site. Data quality began to degrade when heading to the east as seas picked up.

September 26, 2015
Dive 13 was conducted on the northwest end of the Karin Seamounts. Five ten-minute midwater transects were conducted on the ascent.

Transit mapping occurred to the next dive site following the recovery of the ROV. Data quality was degraded as weather conditions continue to deteriorate.

September 27, 2015
The scheduled ROV dive was canceled due to weather. The ship commenced the transit back to Honolulu, and the sonars were secured due to the increased sea state.

September 28-29, 2015
Sonars were secured during the transit to Hawaii due to sea state.

September 30, 2015
The ship pulled in to port in Pearl Harbor, HI this morning.

12. References

The 2015 NOAA Ship *Okeanos Explorer* Mapping Systems Readiness Report can be obtained in the NOAA Central Library (https://doi.org/10.25923/hhvn-7d52) or by contacting the NOAA OER mapping team at oar.oer.exmappingteam@noaa.gov.

The EX-15-04 L4 Project Instructions can be obtained from the NOAA Central Library. The EX-15-04 L4 Data Management Plan is an appendix of the project instructions.

The following data were used as background data throughout the expedition:

- Tozer, B. , D. T. Sandwell, W. H. F. Smith, C. Olson, J. R. Beale, and P. Wessel, Global bathymetry and topography at 15 arc seconds: SRTM15+, Accepted Earth and Space Science, August 3, 2019. https://doi.org/10.1029/2019EA000658
- NOAA Nautical Charts
- Various datasets downloaded from the NCEI archives via NOAA AutoChart.

A full description of Remotely Operated Vehicle (ROV) operations and sample collections completed during the cruise is available in a separate Expedition Report available in the NOAA Central Library with the title "*Cruise Report: EX-15-04 L4, Hohonu Moana 2015: Exploring the Deep Waters off Hawai'i (ROV & Mapping).*"