Ocean Exploration and Research

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MAPPING DATA ACQUISITION AND PROCESSING SUMMARY REPORT

EX-19-04: 2019 Technology Demonstration (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.

Contents

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 EX-19-04, to present a summary of the overall mapping results and mapping related cruise activities, and also briefly describe other cruise objectives including technology demonstrations and remotely operated vehicle (ROV) activities. A detailed description of the *Okeanos Explorer's* mapping capabilities is available in the 2019 NOAA Ship *Okeanos Explorer* Survey Readiness Report, which is available in the NOAA Central Library here: https://doi.org/10.25923/kkwz-5t70. A separate cruise report fully detailing the Remotely Operated Vehicle (ROV) activities and technology demonstration projects of the cruise titled, 'Cruise Report: EX-19-04, 2019 Technology Demonstration (ROV & Mapping)' will be available in the NOAA Central Library.

3. Cruise Objectives

EX-19-04 commenced on July 18, 2019 in Norfolk, Virginia and concluded on August 1, 2019 in Davisville, Rhode Island. Continuous operations took place throughout the Northeast U.S. Continental Margin and on the Northeast U.S. continental shelf off of Virginia, Maryland, Delaware, New Jersey, New York, Rhode Island and Massachusetts.

Mapping operations included the use of the ship's deepwater mapping systems (Kongsberg EM 302 multibeam sonar, EK split-beam fisheries sonars, Knudsen 3260 chirp sub-bottom profiler sonar, and Teledyne Acoustic Doppler Current Profilers), and expendable bathythermographs (XBTs) in support of multibeam sonar mapping operations.

Other operations consisted of demonstrations of emerging and nascent technology, *Deep Discoverer* and *Seirios* ROV dives to support technology demonstrations, and limited shore participation via telepresence.

The technology demonstration projects were evaluated for their ability to support OER and partner data needs, and for their potential to benefit the larger oceanographic research community. NOAA OER pursued internal, private, and academic partnerships to host these projects. Specifically, these included:

- Integration and shakedown of a REMUS 600 Autonomous Underwater Vehicle (AUV)
- Deployment of a towed Kraken Robotics/ThayerMahan Katfish with Synthetic Aperture Sonar (Katfish SAS)

- Integration and testing of a Kraken Robotics SeaVision laser scanner on the ROV *Deep Discoverer*
- Integration/testing of a One Way Travel Time Inverted Ultra Short Baseline (OWTTIUSBL) from the Woods Hole Oceanographic Institution (WHOI) on the ROV *Deep Discoverer*

An overarching objective was to provide authoritative and actionable data to regional stakeholders of historical and archeological significance.

This expedition contributed to NOAA's Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), a major multi-year, multi-national collaborative field program focused on raising collective knowledge and understanding of the North Atlantic. This campaign provides timely, actionable information to support decision-making based on reliable and authoritative science. It also serves as an opportunity for the nation to highlight the uniqueness and importance of these deepwater environments. ASPIRE builds on the momentum of past U.S. campaigns and international initiatives to support ecosystem-based management of marine resources.

The complete objectives for this cruise are detailed in the EX-19-04 Project Instructions, which are archived in the NOAA Central Library and can be accessed here: https://doi.org/10.25923/mnxw-2m13.

4. Summary of Mapping Results

EX-19-04 mapped 7,001 square kilometers of seafloor on and off the continental shelf offshore of Virginia, Maryland, Delaware, New Jersey, New York, Rhode Island and Massachusetts during the 14 days-at-sea (Figure 1 and Table 1). Multibeam bathymetry data coverage is shown in Figure 1.

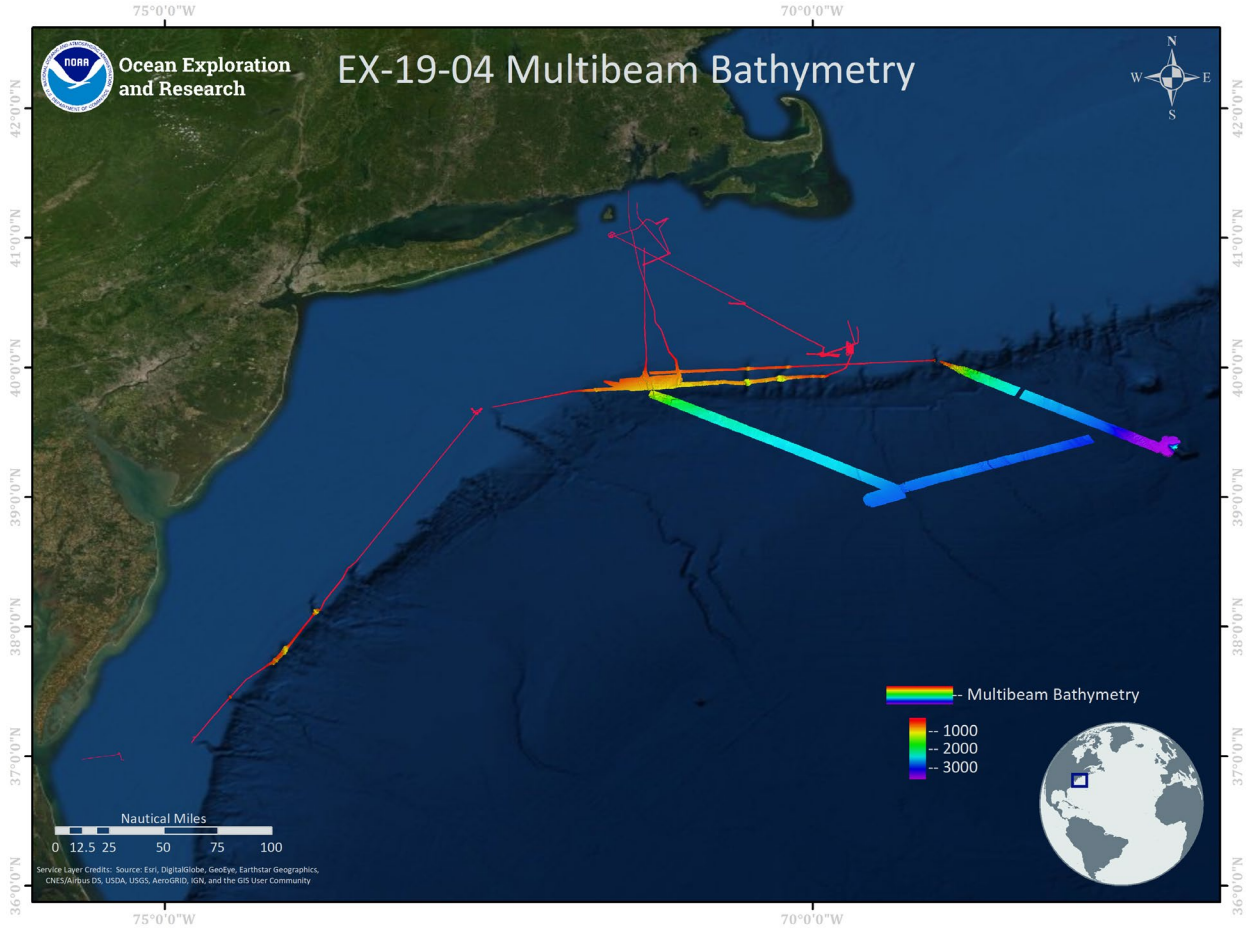

Figure 1. Overview of bathymetric mapping coverage completed during EX-19-04.

5. Mapping Statistics

Table 1. Summary statistics of ocean mapping work completed during EX-19-04.

Dates of data collection	July 18 – August 01, 2019
Ship's draft: Start of cruise (07/18/2019) End of cruise (08/01/2019)	 Fore: N/A, Aft STBD: N/A" Fore: N/A; Aft STBD: N/A"
Linear kilometers of survey with EM 302	2,980
Square kilometers mapped with EM 302	7,001
Number / data volume of EM 302 raw bathymetric / bottom backscatter multibeam files (.all)	390 / 45.2 GB (53/ 4.12 GB restricted access)
Number / data volume of EM 302 water column multibeam files (.wcd)	390 / 103 GB (53/ 7.14 GB restricted access)
Number / data volume of EK60/80water column split-beam files (.raw)	678 / 43.6 GB (92/2.91 GB restricted access)
Number / data volume of sub-bottom sonar files (.segy, .kea, .keb)	696 / 3.84 GB (111/ 486 MB restricted access)
Number of XBT casts	61 (4 files restricted access)
Number of CTD casts (including test casts)	0

6. Mapping Sonar Setup

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 3300 meters. In waters shallower than 3300 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 is patch tested annually and the results are reported in the annual readiness report which is available in the NOAA Central Library.

Simrad EK60/80/ EK80 Split-beam Sonars

The ship operated four Simrad EK60/80/ EK80 split-beam fisheries sonars: 18 kHz (EK60), 70 kHz (EK80), 120 kHz (EK60), and 200 kHz (EK60). These sonars are quantitative scientific echosounders 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. These sonars were calibrated on the EX-19-02 cruise, and calibration values from that cruise were applied to the EK sonars for EX-19-04. The 2019 EK60/80& EK80 Calibration Report (https://doi.org/10.25923/wzk7-6d52) is available in the NOAA Central Library. The 70 kHz is capable of operating in narrowband or wideband mode with a frequency modulated ping. The ship also has a 38 kHz EK60/80transducer, but it is in need of replacement and was not operated on this cruise.

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.

Teledyne ADCPs

The ship utilizes a 38 kHz Teledyne RDI Ocean Surveyor Acoustic Doppler Current Profiler (ADCP), with a ~1000 meter range; and a 300 kHz Teledyne RDI Workhorse Mariner ADCP, with a ~70 meter range. The ADCPs gather data prior to ROV deployments in order to assess currents at the dive site in support of safe operations. They are generally kept running throughout the ROV dives. The ADCPs were not run concurrently with the other sonars during mapping operations due to interference issues.

7. Data Acquisition Summary

Mapping operations included data collection via the EM 302 multibeam sonar, EK60/80 split-beam (18, 70, 120, and 200 kHz) sonars, and Knudsen 3260 sub-bottom profiler. Data were collected by each sonar concurrently during the transits.

Survey lines were planned to either maximize edge matching of existing bathymetric data, or to fill data gaps in areas with existing bathymetric coverage. In regions with no existing data, lines were planned to optimize potential exploration discoveries. Focused multibeam mapping operations happened concurrently with towed Katfish SAS and REMUS 600 operations on the continental shelf in shallow (50-100 meters) waters off of Virginia, New York, Rhode Island and Massachusetts. There will be a separate cruise report that will discuss the Katfish SAS and REMUS 600 data in more detail.

During EX-19-04 some EM 302, EK60/80 and Knudsen sub-bottom data were collected under Underwater Cultural Heritage (UCH) protocols. Post cruise, these data were determined by OER to be non-public in order to preserve these UCH sites. Data from July 18th, 2019 21:11:41 to July 19th 2019 09:12:30 UTC is restricted and July 22, 20th 03:27:28 to July 22, 2019 09:47:17 UTC is restricted. These data are annotated in Table 1. Persons interested in accessing this data can contact ncei.info@noaa.gov.

Throughout the cruise, multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary, and line spacing was planned to ensure at least ¼ swath width overlap between lines. Cutoff angles in the multibeam acquisition software Seafloor Information System (SIS) were generally left wide open for maximum exploration data collection and routinely adjusted on both the port and starboard side to ensure the best data quality and coverage.

During the transit between Norfolk and Hudson Canyons a small survey was conducted at the suggestion of Rod Mather (University of Rhode Island) who was onboard as an archeology lead. The target is unidentified and warrants further exploration. Target shown in EM 302 bathymetry in Figure 2.

Multibeam data received real time surface sound velocity corrections via the Reson SVP-70 probe at the sonar head, as well as through profiles generated from XBTs conducted at intervals no greater than 3 hours, as dictated by local oceanographic conditions. 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.

Simrad EK60/80/ EK80 split-beam water column sonar data were collected throughout the majority of the cruise (Figure 3). Data were monitored in real time for quality but were not post-processed. EK60/80

Knudsen 3260 sub-bottom profiler data were also collected during the majority of the cruise (Figure 4).

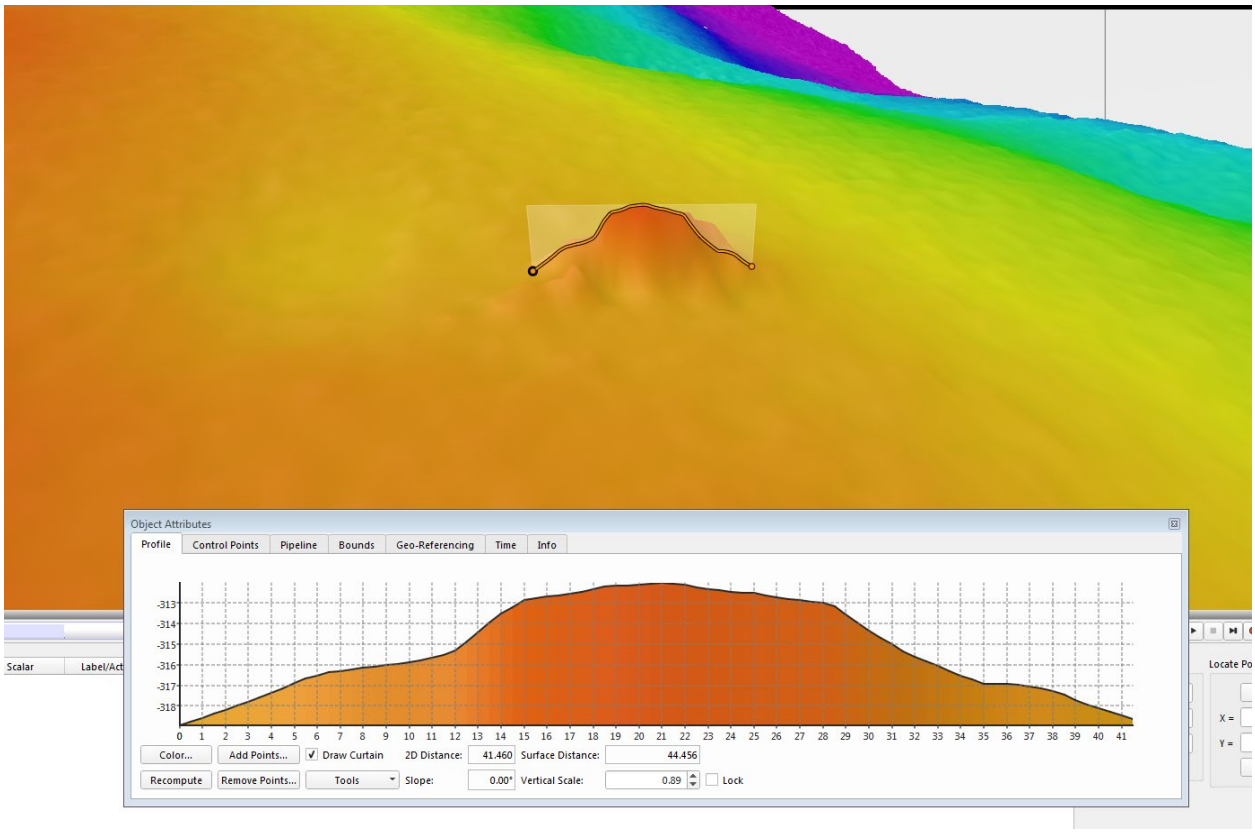

Figure 2. During the transit between Norfolk and Hudson Canyons, a short survey was performed at the request of Rod Mather, onboard archeologist. This target rests in about 315 meters of water. Vertical exaggeration 6x, depth in meters, 25 meter cell size.

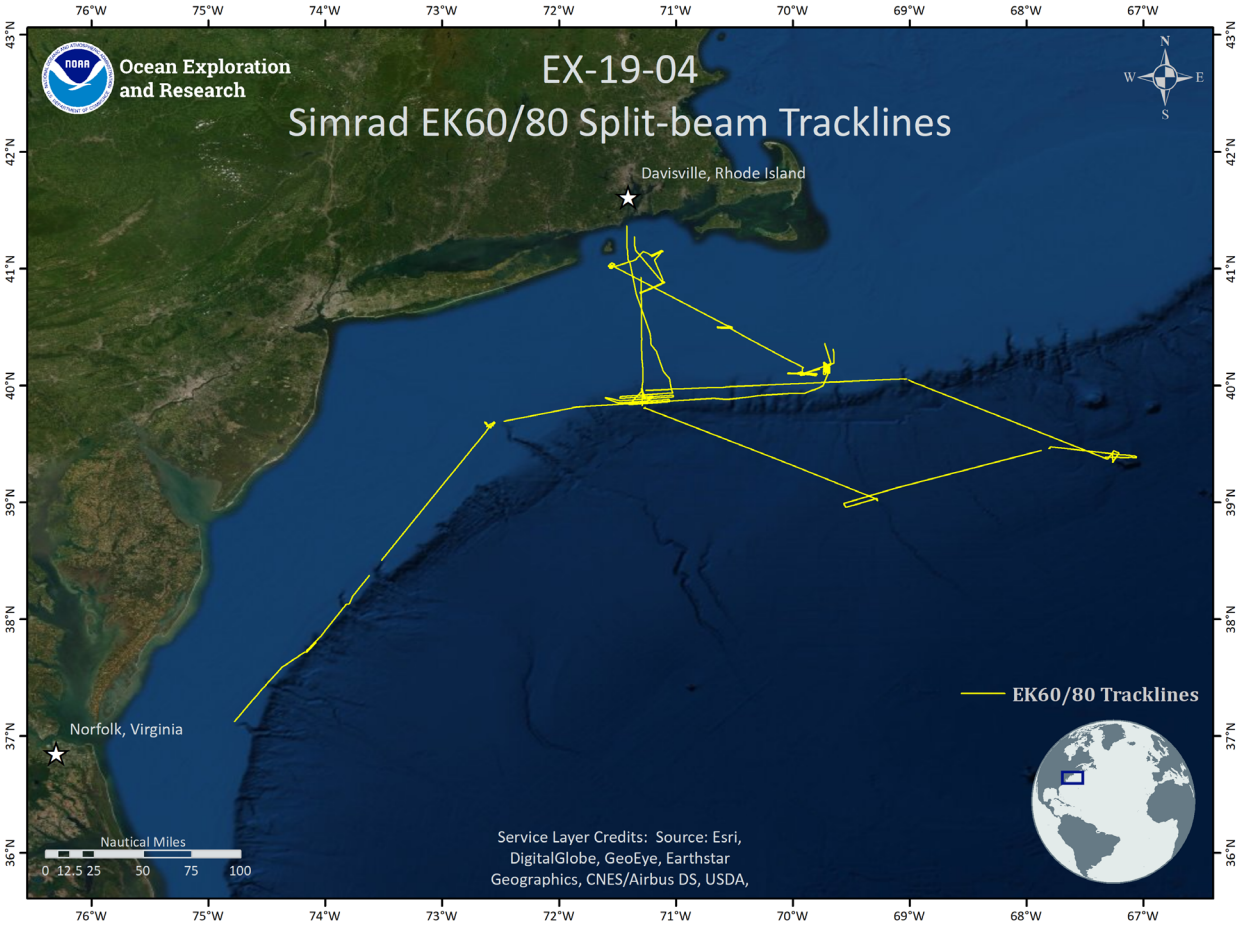

Figure 3. Simrad EK60/80 split-beam sonar data tracklines (in yellow) collected during EX-19-04.

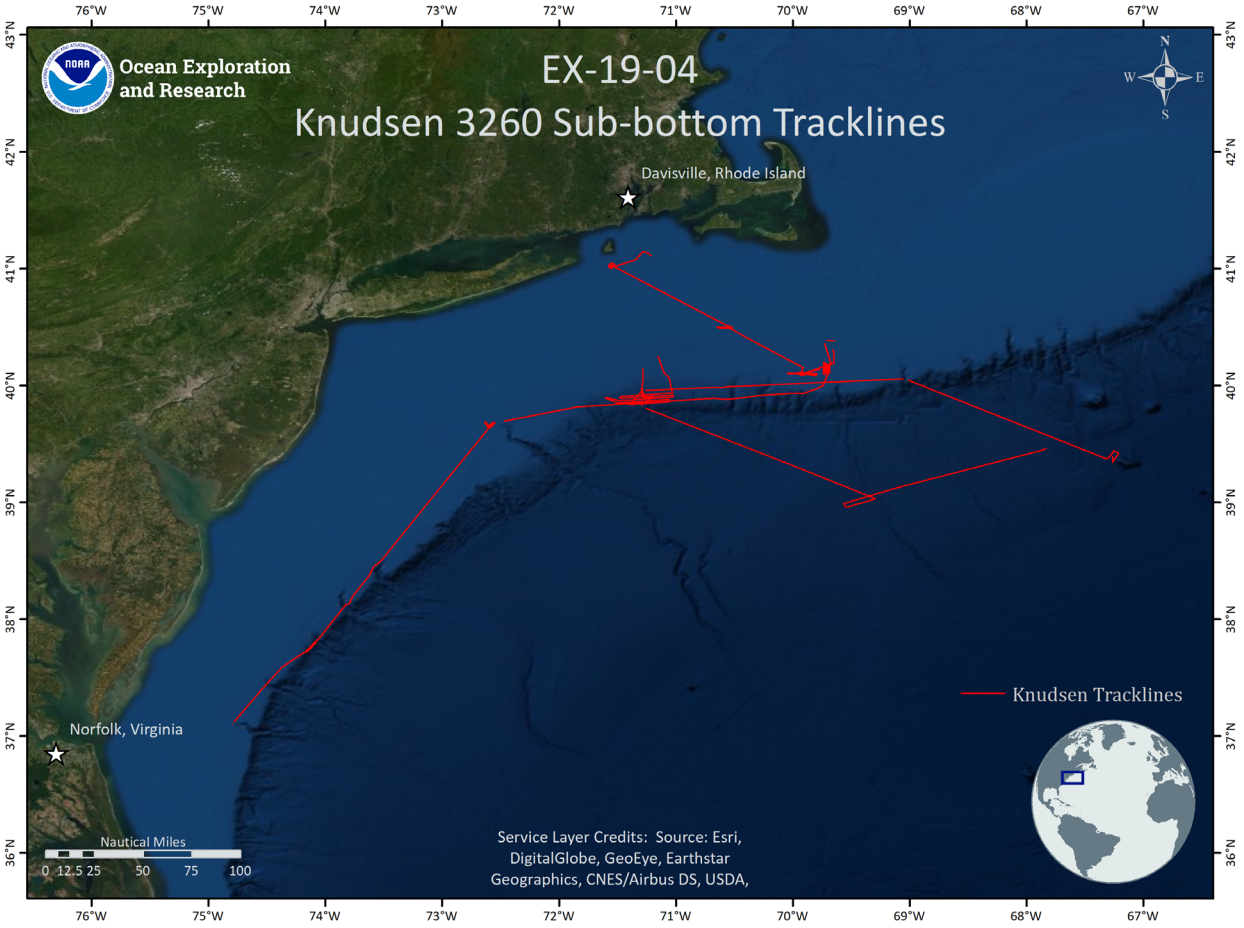

Figure 4. Sub-bottom profiler data tracklines (in red) collected during EX-19-04.

8. Multibeam Sonar Data Quality Assessment and Data Processing

Between July 18 and July 24 the majority of the EM 302 data that was collected was in shallow (50-100 meters) water on the Continental Shelf. Neither XBTs nor Sound Speed Manager were sufficient to correct for changes in sound speed. Additionally, XBTs could not be launched on a regular schedule during towed Katfish SAS operations due to wire entanglement. As a result, much of this data contains sound speed artifacts as shown in Figure 5.

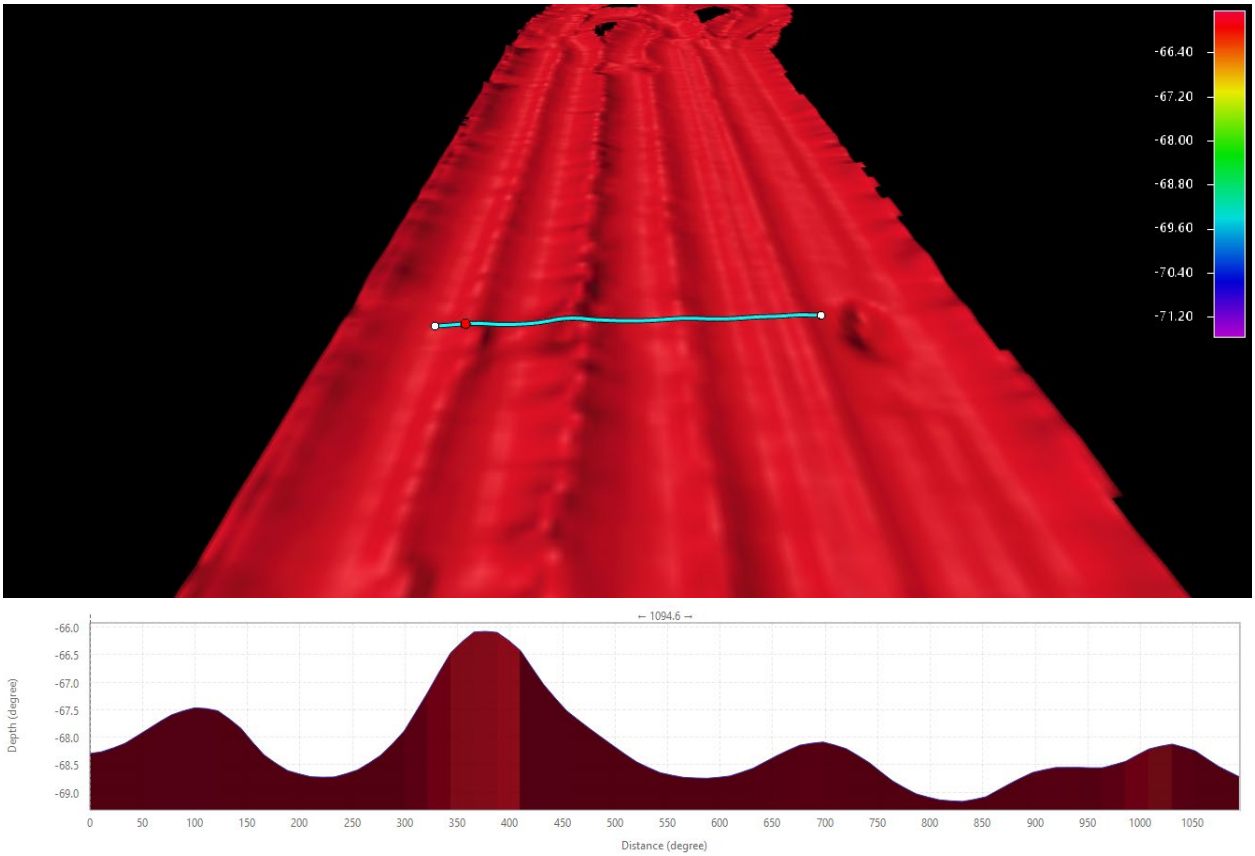

Figure 5. Sound speed velocity artifacts in the EM 302 data collected in shallow (~67 meters) water. Bottom image of profile of cyan line above. Depth in meters, x6 vertical exaggeration, 15 meter cell size. Color depth bar in meters.

Figure 6 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 in SIS, then imported into QPS Qimera for processing. In Qimera, the attitude and navigation data stored in each file were checked, and erroneous soundings were removed using 2-D and 3-D editors. Gridded digital terrain models were exported utilizing QPS Fledermaus software and posted to the ship's ftp site for daily transfer to shore. Final bathymetry QC was completed post-cruise onshore. Depth measurements were not adjusted for tides, as for typical Okeanos survey operations they represent 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).

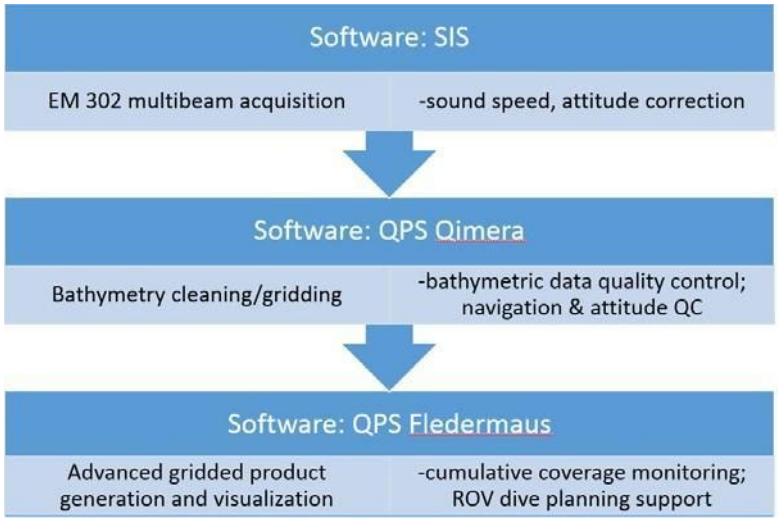

Figure 6. Shipboard multibeam data processing workflow.

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 July 26, 2019 as shown in Figure 7. Crossline analysis was completed using the Crosscheck Tool in QPS Qimera software. The results are shown below.

Crossline file:

0029_20190726_091759_EX-19-04_MB.all

Mainscheme line files:

0041_20190727_012346_EX-19-04_MB.all

0048_20190727_051211_EX-19-04_MB.all

Statistic	Value (units in meters)
Number of points of comparison	434746
Grid Cell Size	30
Difference Mean	--0.655746
Difference Median	-0.655746
Difference Std. Dev	3.132134
Difference Range	[-19.71, 21.80]
Mean + 2*Stddev	6.920015
Median + 2*Stddev	6.920015
Data Mean	-639.227998
Reference Mean	-638.572252
Data Z-Range	[-848.84, -507.42]
Reference Z-Range	[-851.24, -505.11]
Order 1 Error Limit	8.316483
Order 1 # Rejected	10749
Order 1 P-Statistic	0.024725
Order 1 Survey	**ACCEPTED**

These results confirm that the data collected meet International Hydrographic Organization Order 1 specifications for data quality.

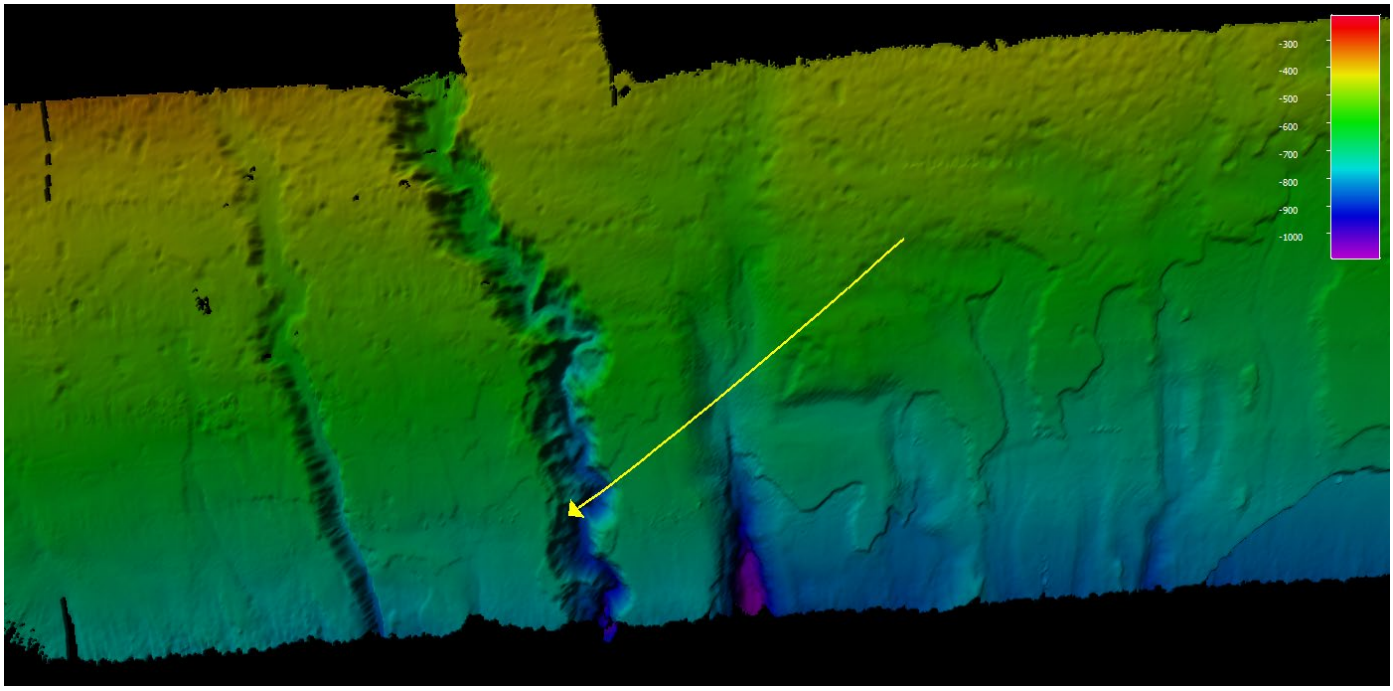

Figure 7. EX-19-04 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines. Depth color bar in meters.

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-19-04 Project Instructions, which will be available in the NOAA Central Library. Ancillary and supporting files are archived with the sonar datasets. These include:

EM 302 Multibeam bathymetry and bottom backscatter dataset:

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log
- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)

Simrad EK split-beam water column dataset:

- Mapping watch stander log
- Weather log
- EK data log

Knudsen 3260 Sub-bottom Profiler dataset:

- Mapping watch stander log
- Weather log
- Sub-bottom data log

EM 302 Multibeam water column dataset:

- Mapping watch stander log
- Weather log
- Sound velocity profile log
- Multibeam acquisition and processing log

- Built-In-System-Tests (BISTs)
- Processor Unit Parameters
- Text files of telnet sessions on the EM 302 transceiver unit (TRU)
- Multibeam water column data review log if data were reviewed for presence of seeps in Fledermaus MidWater or QPS Qimera

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

At the time of writing this report, EM 302 and EK60/80/ 80 water column data, supporting data, and informational logs were/will be available in the NCEI Water Column Sonar Archives: https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html (last accessed 03/24/2020).

Sub-bottom data, supporting data, and informational logs will be available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/. For any challenges accessing SBP data, send an inquiry to ncei.info@noaa.gov requesting access to EX-19-04 Knudsen 3260 sub-bottom raw and processed data.

EM 302 bathymetry data, supporting informational logs, and ancillary files were/will be available in the NCEI Data Archives accessible at https://maps.ngdc.noaa.gov/viewers/bathymetry/(last accessed 03/24/2020).

10. Cruise Calendar

All times listed are local ship time, -5 hours from UTC

July 2019 – August 2019

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				18 Mobilization complete. Depart Norfolk, Virginia. Arrive Norfolk Canyon to begin Katfish SAS operations.	19 Overnight Katfish SAS operations completed. EM 302 mapping was completed in tandem with towed Katfish SAS operations.	20 Overnight transit mapping. Mapping, REMUS 600 and Katfish SAS operations completed near the head of Hudson Canyon.
21 Towed Katfish SAS and REMUS operations completed south of Rhode Island. EM 302 acquired data during operations.	22 Katfish SAS, EM 302 and REMUS operations south of Nantucket.	23 EM 302 operations south of Block Island. Katfish SAS operations south of Block Island. Transit outside of 25 nautical miles.	24 Overnight surveying in shallow water. Ship arrived Davisville pier for demobilization.	25 Mobilization of OWTTIUSBL, MIT 360 Camera and SeaVision alongside Davisville Pier.	26 Overnight transit to Dive 01. Dive 01 near Block Canyon with SeaVision.	27 Dive 02 on USS Baldwin. Overnight transit mapping to Hydrographer Canyon.
28 Dive 03 in Hydrographer canyon. Transit mapping overnight to Mytilus Seamount.	29 Dive 04 OWTTIUSB near Mytilus Seamount. Overnight transit mapping.	30 Dive 05, midwater. Overnight Transit mapping.	31 Dive 06 near Block Canyon. Overnight transit mapping to Narragansett.	August 01 Arrive Davisville Pier, demobilization, sonar systems secured.		

11. Daily Cruise Log Entries

Generated from the daily expedition situation reports. All times listed are in local ship time (-5 hours from UTC)

July 18

Mobilization was completed successfully. Ship departed Norfolk around 1015. Server mode with Sound Speed manager was found to be broken - troubleshooting has begun. Most of this leg will be in <150 meters of water. Ship arrived near Norfolk Canyon to begin overnight operations with Katfish SAS.

July 19

Overnight operations with Katfish SAS were completed successfully. Mission team had planned on a REMUS 60 deployment but due to weathered the deployment was cancelled. The decision was made to begin transit to our next operating area around Hudson Canyon.

XBT autolauncher maintenance was completed and it is functioning normally and should result in less failed launches. Troubleshooting continued between CTD 1 computer Sound Speed Manager and SIS. Synthetic profile mode is now functioning. EM 302 mapping continues during Katfish SAS operations. XBT wires were found tangled with the towed Katfish SAS wire and XBTs will cease during towed Katfish SAS operations.

July 20

Ship arrived on station at the head of Hudson Canyon. REMUS 600 was deployed for survey near the head of Hudson Canyon. Towed Katfish SAS was also deployed for object identification testing and surveys of the USS Murphy. Data acquisition continued with the EM 302 during towed Katfish SAS operations. Towed Katfish SAS was recovered, REMUS 600 was recovered and ship began transit to next operational area.

During much of the day three distinct data types were being acquired: REMUS 600 multibeam and environmental data as it completed its autonomous mission, Katfish SAS, and the standard set of ships mapping data. It was also the first cruise of the *Okeanos* that included simultaneous AUV and ship-based mapping operations in separate locations.

Sound speed artifacts are present in the EM 302 data. XBTs are being conducted in support of REMUS 600 operations. Sound speed profiles from XBT and Sound Speed Manager are being using for post-processing of REMUS 600 data.

July 21

Ship arrived on site near NOAA Automated Wreck and Obstruction Information System (AWOIS) Wreck 1505 to deploy the REMUS 600 in order to search for the *U-550*. Deployment was successful. Mission confirmed the presence of a previously reported oil sheen at the surface and were able to map and confirm the location of nearby AWOIS Wreck 1487 in the ship's multibeam which will be integral for Katfish SAS survey planning for overnight surveying.

REMUS 600 was successfully recovered in the afternoon and the Katfish SAS was deployed. Operations were complicated by long line fishing gear. Survey operations were completed near AWOIS Wreck 1505, the wreck was not definitively located. At 2000, the team in concert with EX Command decided that the area near Wreck 1487 contained too much fishing gear for safe operations and the decision was made to head north in search of wreckage from the *Pan Pennsylvania*. Overnight the Katfish SAS team covered a lot of ground and found one wreck site.

Sound speed artifacts remain in the data. Wreck 1487 was mapped by the EM 302 today which will help guide survey operations overnight. There are ongoing issues with the KVM Keyboard Video Mouse router (KVM) and MBPROCs. Data is being restricted under UCH protocols.

July 22

Katfish SAS operations were completed overnight and identified an unknown wreck site. Katfish SAS was recovered in the morning and the REMUS 600 was deployed to survey another area in search of the *U-550* wreck. During REMUS operations, the ship went to map an adjacent area. REMUS 600 was recovered in the afternoon, and the Katfish SAS was deployed to complete survey operations over Wreck 1487. Water making was secured as this area is the site with an active oil sheen. Using the EM 302 data collected the day before, Katfish SAS operations were able to successfully target the site. After Katfish SAS recovery, ship transited to an area south of Block Island.

Sound speed artifacts persist in EM 302 data. XBTs are being completed in support of REMUS operations. Data cleaning has fallen behind due to dense, shallow data. Real-time gridding in SIS is intermittent likely due to gridding settings and high data density.

July 23

Overnight transit to south of Block Island was completed. Weather was elevated compared to the last few days. Katfish SAS had an Uninterruptible Power Supply (UPS) issue and while troubleshooting, we used the EM 302 to identify the orientation and exact location of the wreck of the USS Bass. After UPS issues were resolved, Katfish SAS was deployed and data was

acquired over the fourth of four historic submarine in Rhode Island waters. The first three were mapped in the summer of 2018 with Katfish SAS. After survey operations were completed over the Bass, ship began transit to Cox Ledge for additional wreck search operations. During the transit, the Katfish SAS showed another UPS issue and it was recovered for the final time. Surveying continued of the potential wreck sites using the ship's systems. Overnight ship transited outside of 25 nautical miles from shore to make water and dump sewage.

Most of the day we were in shallow, <40 meters of water. Server mode was run on Sound Speed Manager.

July 24

Overnight data acquisition occurred in shallow water and Sound Velocity artifacts are present in the data. One of the watch leads will continue processing onshore. Ship arrived Davisville Pier for demobilization of the first part of EX-19-04 and mobilization of second set of objectives. Katfish SAS and REMUS 600 were removed and WHOI OWTTIUSBL, MIT 360 camera and Kraken SeaVision laser scanner were brought onboard.

July 25

Mobilization of OWTTIUSBL, SeaVision and MIT 360 camera alongside pier in Davisville. The EM 302 was showing errors in the telnet and was having issues with TX board communication. Transmit Receive Unit (TRU) was restarted, Built-in self-test (BIST) that passed and the unit was functioning normally. Three boxes of XBTs were brought onboard from the Rhode Island warehouse. There were communication issues between 'POSCONFIG' computer and the KVM system.

July 26

ROV Dive 01 in Block Canyon. SBP .sgy files not transferring to shore due to naming issue, naming issue resolved. Multibeam main scheme lines completed for crossline analysis.

July 27

Overnight transit mapping. ROV Dive 02 on EX mapping target confirmed to be USS Baldwin. As Dive 02 was conducted on an Underwater Cultural Heritage (UCH) site (USS Baldwin), and the position information is restricted per OER's UCH policies and is protected under the National Historic Preservation Act. Larges changes in salinity/sound speed have been observed and XBTs are being completed every 2 hours.

July 28

ROV Dive 03 on Hydrographer Canyon. BISTs continue to pass after ROV recovery. Overnight transit to Mytilus Seamount.

July 29

ROV Dive 04 near Mytilus Seamount. Overnight transit mapping.

July 30

ROV Dive 05 focused on the midwater rather than benthic habitat. UHDAS has recommended putting the 38OS in either broadband or narrowband mode, but not both since in both modes the system cannot get enough good pings due to the sync. They did hedge this however, reporting since we are on station, the current may not be changing all that much. It seems as if the data, while not ideal, is still fine for our current use of the ADCP.

July 31

Dive 06 near Block Canyon. Overnight transit mapping**.**

August 01

Arrive Davisville, RI pier. Mapping systems secured.

12. References

The 2019 NOAA Ship *Okeanos Explorer* Survey Readiness Report can be obtained from the NOAA Central Library here: https://doi.org/10.25923/kkwz-5t70.

The EX-19-04 Project Instructions can be obtained from the NOAA Central Library here: https://doi.org/10.25923/mnxw-2m13 The EX-19-04 Data Management Plan is an appendix of the project instructions.

2019 EK60/80/ 80 Calibration Report is available in the NOAA Central Library at doi.org/10.25923/wzk7-6d52.

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

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Various datasets downloaded from the NCEI archives via NOAA Autogrid; https://www.ngdc.noaa.gov/maps/autogrid/, last accessed March 2020

NOAA Automated Wreck and Obstruction Information System; https://nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html, last accessed March 2020