Ocean Exploration and Research

doi: 10.25923/6bg9-8417

Expedition Report: EX-21-03 2021 ROV Shakedown (ROV and Mapping)

United States Mid-Atlantic
Norfolk, Virginia, to Newport, Rhode Island
June 13-27, 2021

Authors:
Matt Dornback[1]
Kasey Cantwell[2]
Shannon Hoy[1]

[1] Cherokee Nation Federal under contract with NOAA Office of Ocean Exploration and Research
[2] NOAA Office of Ocean Exploration and Research

October 08, 2021

NOAA Office of Ocean Exploration and Research
1315 East-West Hwy
Silver Spring, MD 20910

Abstract

In June of 2021, the NOAA Office of Ocean Exploration and Research conducted a shakedown of the remotely operated vehicle (ROV), video, telepresence, and sampling operations aboard NOAA Ship *Okeanos Explorer*. The ROV engineers tested and calibrated ROVs *Deep Discoverer* and *Seirios's* new ROV motor controllers, auto position software, lighting system, hydraulic system, ME-20 low-light camera, high- definition ancillary ROV cameras, and sector-scanning sonar. In total, the expedition team conducted 11 ROV dives ranging from 560 to 4,730 m depth. The expedition explored the Currituck landslide feature off of North Carolina, the mid-Atlantic abyssal plain, Caryn Seamount, and Toms, Hudson, and Uchupi Canyons offshore the U.S. mid-Atlantic coast. The expedition located and identified the wreck of *Humaitá* (ex-USS *Muskallunge*), an American World War II-era submarine that also served in the Brazilian Navy. Diverse benthic communities were observed at 4 of the 11 surveyed dive sites. A total of 16 samples were collected: 3 geological, 5 biological, and 8 commensal. In addition to the shakedown, science, and exploration successes, the ship's personnel also participated in education and outreach events.

This report can be cited as follows:
Dornback, M., Cantwell, K., Hoy, S. (2021). Expedition Report: EX-21-03: 2021 ROV Shakedown (ROV and Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Rep. 21-03.
https://doi.org/10.25923/6bg9-8417

For further information, direct inquiries to:
NOAA Office of Ocean Exploration and Research
1315 East-West Hwy
Silver Spring, MD 20910
Phone: (301) 734-1014
Email: oceanexplorer@noaa.gov

Table of Contents

1. Introduction

The NOAA Office of Ocean Exploration and Research (OER) is the only federal program dedicated to exploring the deep ocean, closing prominent gaps in our basic understanding of U.S. deep waters and the 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. To better understand our ocean, OER makes exploration data available to the public. This allows us, collectively, to more effectively maintain ocean health, 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.

1.1 Atlantic Seafloor Partnership for Integrated Research and Exploration

Data collected during expeditions on NOAA Ship *Okeanos Explorer* from 2018 to 2021 directly contribute to the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), a major multiyear, multinational collaborative field program focused on raising collective knowledge and understanding of the North Atlantic Ocean. ASPIRE builds on the momentum of past U.S. campaigns and international initiatives to support ecosystem-based management of marine resources. ASPIRE also provides information relevant to NOAA's emerging Blue Economy priorities, which, in addition to ocean exploration, are seafood production, tourism and recreation, marine transportation, and coastal resilience.

2. Expedition Overview

From June 13 to June 21, 2021, OER conducted a shakedown of its dual-body remotely operated vehicles (ROVs) *Deep Discoverer* and *Seirios* and other mission systems on NOAA Ship *Okeanos Explorer* in the Atlantic Ocean between Norfolk, Virginia, and Newport, Rhode Island (EX-21-03). In addition to assessing mission readiness of systems and testing new equipment , OER and partners used telepresence-enabled ocean exploration to collect critical baseline information and improve knowledge about unexplored and poorly understood deepwater areas of Caryn Seamount, Toms Canyon, Hudson Canyon, and Uchupi Canyon offshore the US mid-

Atlantic coast. EX-21-03 was part of a series of expeditions contributing to ASPIRE. Previous expeditions in this region include EX-19-03 L2 and EX-19-04. While the primary purpose of EX-21-03 was to field-test mission systems, it also provided timely, actionable information to support decision-making based on reliable and authoritative science. Like other ASPIRE expeditions, it also served as an opportunity for NOAA to highlight the uniqueness and importance of deepwater environments.

2.1 Rationale for Exploration Shakedowns

OER conducts systems shakedown expeditions at the beginning of every field season to ensure smooth operations for the expeditions that follow. ROV shakedown expeditions are designed to stress test every component of the ROV, computer, data, and telepresence systems. They are also designed to be flexible regarding where and when to dive so troubleshooting and repair of systems can take top priority.

As part of the planning for this expedition, OER collaborated with the scientific and management community to assess the exploration needs and data gaps in unknown and poorly known areas along the mid-Atlantic U.S. continental margin. To define the operating area for this expedition, OER considered the 2018 Call for Input, results from the 2018 ASPIRE Workshop (NOAA Office of Ocean Exploration and Research, no date), and priorities from resource managers.

Data and information from this expedition will help improve our understanding of the deep-ocean habitats of the U.S. continental margin and the connections between communities throughout the Atlantic basin. It will also inform deep-sea management plans for habitat areas of particular concern, marine protected areas, and national marine sanctuaries; support local scientists and managers seeking to understand and manage deep-sea resources; and stimulate subsequent exploration, research, and management activities.

This expedition also contributed to the ongoing collaboration with the NOAA Office of National Marine Sanctuaries Maritime Heritage Program, the Navy History and Heritage Command, NOAA Deep Sea Coral Research and Technology Program and the Mid-Atlantic Fishery Management Council.

2.2 Objectives

EX-21-03 operations were focused on the shakedown and operational readiness of ROV operations aboard *Okeanos Explorer*. In addition to engineering objectives related directly to the ROVs, objectives also included the preparedness of existing and new telepresence capabilities and training of new personnel. Overnight operations included mapping using the ship's suite of sonars. While this expedition focused mainly on shakedown objectives, when possible, ROV and mapping operations were conducted in priority areas for exploration based on input from the wider science community. Input on exploration areas was given by the Mid-Atlantic Fishery Management Council, the Navy History and Heritage Command, and various academic partners.

The following objectives are separated into the different facets of a NOAA Ocean Exploration expedition onboard the *Okeanos Explorer*. The categories include ROV Engineering, Science, Remote Participation, Video and Telepresence Engineering, Acoustic Mapping, Data Management, and Ship Familiarization. The objectives are focused on the operational readiness of ROV operations for the field season, and opportunistic science objectives that can be achieved during shakedown operations.

ROV Engineering

- Load and reintegrate ROVs *Deep Discover* and *Seirios*.
- Review ROV launch, recovery, and emergency procedures with mission team and ship's crew to facilitate training for new personnel and refresher training for experienced personnel.
- Complete a series of ROV dunk tests to practice launch and recovery evolutions.
- Run an ROV dive simulation to review launch and recovery operations including aft deck controls, dynamic positioning system, and emergency recovery training as needed with new personnel and/or as requested by OER or the commanding officer.
- Calibrate and test the ultrashort baseline (USBL) positioning system.
- Test the updated ROV hydraulic system and motors.
- Calibrate the new motor system control software.
- Dive at progressively deeper depths starting at approximately 1,000 m and finishing at 5,000 m over the course of five or more dives.
- Test the ROV systems and conduct pilot training using the manipulator arms, when diving on benthic exploration targets, and when diving on an archaeological target.
- Review protocols and conduct ROV operations in the water column.
- Test and evaluate the BlueView scanning sonar added to *Deep Discoverer*.
- Identify the process to export and preserve data from BlueView scanning sonar.
- Test new lights and controls installed on *Deep Discoverer.*
- Test maritime heritage procedures with a new geotagging video frame capture system.
- Test the temperature probe functionality after reintegration into *Deep Discoverer.*
- Integrate new low light camera and test position of camera on both *Seirios* and *Deep Discoverer* for optimal data collection

Science

- Train a new expedition coordinator in all expedition-related roles.
- Dive on underexplored areas such as Caryn Seamount and mid-Atlantic underwater canyons in the Frank R. Lautenberg Deep-Sea Coral Protection Area, as time, engineering testing and logistics allowed.
- Survey, locate, and dive upon the *Humaitá* (ex-USS *Muskallunge*).
- Test ArcOnline access and utility for field use on ROV expeditions.
- Review and test the new ethanol storage system, and review and update emergency procedures and SOPS.
- Test the quality of the ethanol now stored in the new ejectable 02 Deck container before and after each ROV expedition.
- Test new dive summary metrics and integration of metrics into the dive summary form.
- Review, update and develop SOPs related to ROV expedition operations.

Remote Participation

- Test new technologies to enhance shoreside participant situational awareness during dives including SeaTube sensor visualization.
- Test remote access to sample data management systems and workflow.
- Test new wet lab camera and telepresence-enabled sampling setup to enable remote sample processing assistance.
- As the primary engineering objectives allow, enable participants on shore to engage remotely.

Video and Telepresence Engineering

- Test terrestrial and high-speed satellite links.
- Verify Global Foundation for Ocean Exploration (GFOE)-managed telepresence systems perform as expected.
- Test all subsea video equipment on *Deep Discoverer* and *Seirios* and ensure their proper integration into the video system. Ensure proper field of view and angles for all newly installed cameras.
- Test all shipboard video equipment (hangar, deck cameras, wire camera, etc.) and ensure their proper integration into the video system.
- Document and test potential process for the live streaming of video from the wet lab to enable participants on shore to view samples in real time.
- Test ability to conduct Google Meet at sea based on new network traffic routing integrated in Fiscal Year 2020.

- Test new ME20 extremely lowlight camera.
- Test new 4K camera.
- Test new camera controllers.

Acoustic Mapping

- During overnight mapping operations, test and develop processes for the EM 304 that were not completed during EX-21-01.
- Collect new multibeam sonar data in areas where data already exists to improve data quality and detect changes in the seafloor.

Data Management

- Test remote access to onboard sample data management computer systems.
- Verify GFOE-managed data systems perform as expected.
- Update standard operating procedures to reflect GFOE-managed network changes.
- Install and test the Ocean Networks Canada server and subsequently test new data visualizations available through SeaTube V3.
- Test, troubleshoot, and evaluate new ArcOnline map showing live ship operations.

Ship Familiarization

- Test and continue to build familiarity with *Okeanos Explorer's* new dynamic positioning system.
- Conduct aft control training.
- Conduct small boat operations and training as conditions permit.
- Review and test the new ethanol emergency procedures with the science party.
- Practice and discuss a man overboard scenario drill during ROV recovery (possibly in conjunction with the emergency ROV recovery drill).

3. Participants

EX-21-03 included onboard mission personnel as well as shore-based science personnel who participated remotely via telepresence. See **Table 1** for the onboard personnel who supported EX-21-03. Appendix A contains the shore-based personnel.

Table 1. EX-21-03 onboard mission team personnel

Name	Title	Affiliation
Cantwell, Kasey	Expedition Coordinator	NOAA Office of Ocean Exploration and Research
Hoy, Shannon	Mapping Lead	NOAA Office of Ocean Exploration and Research/Cherokee Federal
Dornback, Matt	Expedition Coordinator (Training)	NOAA Office of Ocean Exploration and Research/Cherokee Federal
Baechler, Neah	Mapping Watch Lead	University Corporation of Atmospheric Research
McLetchie, Karl	ROV Lead	Global Foundation for Ocean Exploration
Aragon, Fernando	Data Manager	Global Foundation for Ocean Exploration
Wright, Chris	ROV Engineer	Global Foundation for Ocean Exploration
Lanning, Jeff	ROV Engineer	Global Foundation for Ocean Exploration
Mohr, Bobby	ROV Engineer	Global Foundation for Ocean Exploration
Jenson, Anya	ROV Engineer	Global Foundation for Ocean Exploration
Kennison, Sean	ROV Engineer	Global Foundation for Ocean Exploration
Lister, Andy	ROV Engineer	Global Foundation for Ocean Exploration
Murphy, Lars	ROV Engineer	Global Foundation for Ocean Exploration
Mefford, Jon	ROV Engineer	Global Foundation for Ocean Exploration
Durbin, Mark	Telepresence Engineer	Global Foundation for Ocean Exploration
Doros, Brian	Telepresence Engineer	Global Foundation for Ocean Exploration
Brian, Roland	Video Engineer	Global Foundation for Ocean Exploration
Bailey, Caitlin	Videographer	Global Foundation for Ocean Exploration

4. Methodology

To accomplish its objectives, EX-21-03 used:

- OER's dual-bodied ROV system (ROVs *Deep Discoverer* and *Seirios*) to conduct daytime seafloor and water column surveys, as well as to collect a limited number of samples to help further characterize the deepwater fauna and geology of the region.
- Sonar systems (Kongsberg EM 304 multibeam sonar, Knudsen 3260 sub-bottom profiler, Simrad EK60 and EK80 split-beam sonars, and Teledyne acoustic Doppler current profilers) to conduct mapping operations at night and when the ROVs were on deck.
- A high-bandwidth satellite connection to provide real-time ship-to-shore communications (telepresence).

All environmental data collected by NOAA must be covered by a data management plan to ensure they are archived and publicly accessible. The data management plan for EX-21-03 is in "Project Instructions: EX-21-03, 2021 ROV Shakedown (ROV & Mapping)" (Dornback, et. al., 2021).

4.1 ROV Seafloor Surveys

During the EX-21-03 shakedown, engineering objectives superseded science survey objectives. *Deep Discoverer* and *Seirios* were pressure tested and calibrated on a series of progressively deeper dives on increasingly complex topography. Testing of new systems and components included a new ROV control system, thruster motors, motor controllers, hydraulic system, upgraded high-definition camera system, extreme-low-light camera, a LED lighting system, and a scanning sonar. ROV pilot training was also a priority during the shakedown expedition.

ROV dive operations supported the expedition objectives in Section 2.2 and included high-resolution visual surveys of seafloor and water column habitats as well as geological and biological sampling. During each dive, the ROVs descended to the seafloor and then moved from waypoint to waypoint, ensuring proper ROV system functioning and documenting the geology and biology of the area. Each ROV dive was approximately 8-10 hours, conditions and logistics permitting. Dives were primarily conducted during the day (operations are described in detail in Quattrini et al., 2015 and Kennedy et al., 2019). Information about the general process of site selection, collaborative dive planning, scientific equipment on the ROVs, and the approach to benthic exploration used on *Okeanos Explorer* can be found in Kennedy et al. (2019).

Onboard and shore-based scientists identified each organism encountered to the lowest taxon possible based on data available during real-time assessment. Additionally, they provided geological interpretations of the observed substrate throughout each ROV seafloor survey. These geological and biological observations were recorded using Ocean Networks Canada's SeaTube. These data will be quality controlled and quality assured at the University of Louisiana at Lafayette by ASPIRE science advisor Dr. Scott France and his laboratory.

On dive was conducted with mid-water exploration. For water column exploration, a series of transects were performed during vehicle ascent following the completion of the benthic/seafloor exploration. Transects primarily targeted the deep scattering layer and the waters directly above and below it. Specific transect depths were decided each day during ROV descent through an evaluation of the Simrad EK60 and EK80 data; ROV conductivity, temperature, depth (CTD) data; and the acoustically determined position of the deep scattering layer. Dive 10 of EX-21-03 featured 20-minute water column transects at the depths of 500, 450, and 375 m. More information can be found in the dive summary (see Section 7.1.1).

4.2 Sampling Operations

A limited number of geological and biological samples were collected on the seafloor using ROV *Deep Discoverer*'s five chamber suction sampler and two manipulator arms in conjunction with geological and biological collection boxes. The primary goal of the sampling operations during this expedition was to test telepresence-enabled sampling operations and to collect voucher samples to be made publicly available for site characterization.

For each sample collected, the date, time, latitude, longitude, depth, salinity, temperature, and dissolved oxygen content were recorded at the time of collection. Geological samples were acquired for age dating and geochemical composition analysis. Biological collections targeted samples that represented potential new species, range extensions of animals not previously known to occur in the region, dominant species at the site, and/or rare morphotypes. Samples targeted to contribute to transatlantic connectivity studies were also collected.

After vehicle recovery, samples were examined for associated organisms, labeled, photographed, and entered into a database with all relevant metadata. Any associated organisms found were separated from primary samples and processed separately as "associate" samples.

Geological samples were air dried and placed in rock bags or small containers depending on the size of the sample. These samples will be shipped to the Marine and Geological Repository at Oregon State University after the conclusion of the OER field season aboard *Okeanos Explorer*. The samples will be photographed, and their data will be entered into the university's online database. Thin and polished sections will be made for each hard-rock sample. Descriptions and photos are included in the database.

Biological samples were subsampled for inclusion in the Smithsonian's National Museum of Natural History Biorepository for future barcoding and DNA extraction. For this purpose, a small subsample, consisting of not more than 1 cm^2 of tissue, was removed from the original sample and placed in 95% analytical grade ethanol (EtOH).

For most of the biological samples, the remainder of the sample was also preserved in 95% ethanol. For select taxa, vouchers or subsamples were preserved in 10%, 5%, or 4% buffered formalin per recommendation from taxonomic experts and guidance provided by the Smithsonian's National Museum of Natural History. Full details of the preservation of each biological sample are in the associated metadata record. All voucher samples and subsamples were shipped to the Smithsonian's National Museum of Natural History for long-term archiving and public access.

4.3 Acoustic Operations

Acoustic operations included Kongsberg EM 304 multibeam, Simrad EK60 and EK80 split-beam, Knudsen sub-bottom profiler, and acoustic Doppler current profiler (ADCP) data collection (Candio et al., 2021). The schedule of mapping operations included overnight transits and whenever the ROVs were on deck. Multibeam mapping data already exists for the entire operating area for EX-21-03. Instead of filling data gaps in areas with incomplete bathymetry coverage, the acoustic operations focused on surveying changes over time and improving on existing data. Targeted acoustic operations included sub-bottom surveys of the Currituck landslide off of North Carolina, multibeam bathymetry of Caryn Seamount, water column sonar of the diurnal migration in Hudson Canyon, and shipwreck hunting using the multibeam sonar off of the shelf of Rhode Island.

4.3.1 Multibeam Sonar (Kongsberg EM 304)

Multibeam seafloor mapping data were collected using the Kongsberg EM 304 sonar, which operates at a frequency of 30 kHz. Multibeam mapping operations were conducted during all overnight transits between ROV dive sites. Multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary. The EX-21-03 Mapping Data Report (Hoy et al., 2021), has detailed information about the acoustic surveys.

Whenever possible, transits were designed to optimize coverage over seafloor areas with no previous high-resolution mapping data. In these focus areas, line spacing was generally planned to ensure 30% overlap between lines at all times. Cutoff angles in the Seafloor Information System (SIS) software were generally adjusted on both the port and starboard sides to ensure the best balance between data quality and coverage. Overnight surveys were also completed in areas that were previously mapped with a lower resolution multibeam sonar system.

Multibeam mapping operations were conducted directly over planned ROV dive sites to collect seafloor mapping data to help refine dive plans. These operations collected data on seafloor depth (bathymetry), seafloor acoustic reflectivity (seafloor backscatter), and water column reflectivity (water column backscatter).

Additional multibeam operations included acoustic imaging of the upper water column while transiting the Gulf Stream and maritime heritage surveys to support the search for potential ROV dive targets. Archaeological reconnaissance resulted in the discovery of the location of the scuttled *Humaitá* (ex-USS *Muskallunge*).

4.3.2 Sub-Bottom Profiler (Knudsen Chirp 3260)

The primary purpose of the Knudsen Chirp 3260 (3.5 kHz) sonar is to image sediment layers underneath the seafloor to a maximum depth of about 80 m below the seafloor, depending on the specific sound velocity of the substrate. The sub-bottom profiler was operated simultaneously with the multibeam sonar during mapping operations to provide supplemental information about the sedimentary features underlying the seafloor. The Currituck landslide feature on the continental slope off of North Carolina was surveyed to determine how the landslide has shifted over time (Hoy et al., 2021).

4.3.3 Split-Beam Sonars (Simrad EK60 and EK80)

Okeanos Explorer is equipped with five split-beam transducers, three Simrad EK60 general purpose transceivers and two Simrad EK80 wideband transceivers. The frequencies of the EK60 are 18, 38, 120, and 200 kHz. The frequency of the EK80 is 70 kHz.

These sonars were used continuously throughout EX-21-03 during both overnight mapping operations and daytime ROV operations. The sonars provided calibrated target strength measurements of water column features such as dense biological layers and schools of fish. EK60 and EK80 data were also used during midwater transects of ROV dives to detect the depth of the deep scattering layer, which is an aggregation of biological organisms in the water column and to survey the diurnal migration in the water column (Hoy et al., 2021).

4.3.4 Acoustic Doppler Current Profiler (Teledyne Workhorse Mariner and Teledyne Ocean Surveyor ADCPs)

Okeanos Explorer is equipped with two ADCPs: a Teledyne Workhorse Mariner (300 kHz) and a Teledyne Ocean Surveyor (38 kHz). The ADCPs provide information on the speed and direction of currents underneath the ship. They were used throughout ROV dives to support safe deployment and recovery of the vehicles. The ADCPs were not used during multibeam mapping due to sonar interference with the EM 304. The 38 kHz ADCP experienced a malfunction during the previous expedition (EX-21-02) and was not used during EX-21-03.

4.3.5 Expendable Bathythermograph (XBT) Systems

Expendable bathythermographs (XBTs) were collected every 1-6 hours and applied in real time using SIS. Sound speed at the sonar head was determined using sound speed from a flow-through thermosalinograph (TSG).

4.4 Conductivity, Temperature, and Depth

Conductivity, temperature, and depth (CTD) measurements were collected with the integrated ROV CTD system. This system records data from the CTD and associated sensors on every dive. Additional sensors installed on the CTD include measured light scattering (LSS), dissolved oxygen (DO), and oxygen reduction potential (ORP).

5. Clearances and Permits

Pursuant to the National Environmental Policy Act (NEPA), OER is required to include in its planning and decision-making processes appropriate and careful consideration of the potential environmental consequences of actions it proposes to fund, authorize, and/or conduct. The companion manual for NOAA Administrative Order 216-6A describes the agency's specific procedures for NEPA compliance.

An environmental review analysis was completed for this expedition in accordance with Section 4 of the companion manual. Based on this review, a categorical exclusion was determined to be the appropriate level of NEPA analysis necessary, as no extraordinary circumstances existed that required the preparation of an environmental assessment or environmental impact statement. This document is on file with OER and can be provided upon request.

OER conducted an analysis on the potential impacts to marine mammal species as a result of *Okeanos Explorer*'s oceanographic research and seafloor mapping under the Marine Mammal Protection Act (MMPA). It was determined that, due to the high-frequencies, narrow beamwidths, relatively low source levels of the onboard sonars, and transient nature of the expeditions, it is unlikely that activities aboard *Okeanos Explorer* would meet the definition of harassment under the MMPA.

As required under Section 7 of the Endangered Species Act (ESA), OER conducted an informal consultation with NOAA Fisheries' Office of Protected Resources to request their concurrence with OER's biological evaluation determining that *Okeanos Explorer* operations conducted as part of ASPIRE may affect, but are not likely to adversely affect, ESA-listed marine species. In a letter dated February 3, 2021 (Sowers, D., 2021), the chief of the ESA Interagency Cooperation Division in NOAA Fisheries' Office of Protected Resources wrote that NOAA Fisheries concurs with OER's determination that proposed ASPIRE expeditions are not likely to adversely affect ESA-listed marine species.

OER also consulted with NOAA Fisheries' Greater Atlantic Regional Fisheries Office (GARFO) on potential impacts of ASPIRE operations to essential fish habitat (EFH) in the Greater Atlantic Region between April 1, 2021, and September 31, 2021, under the Magnuson-Stevens Fishery Conservation and Management Act. OER received a letter of acknowledgement from GARFO on March 10, 2021 (Sowers, D., 2021).

EX-21-03 included a dive on an underwater cultural heritage site (Dive 11). The location of it is restricted under the NHPA and is not disclosed as part of this expedition report.

5.1 Marine Archaeology

NOAA's procedures and policies on marine archaeology are informed by the Federal Archaeology Program, U.S. legislation on the treatment of cultural remains, and the UNESCO Convention for the Protection of the Underwater Cultural Heritage. OER supports the standards for conducting marine archaeological activities enumerated in the annex rules of the UNESCO Convention on the Protection of the Underwater Cultural Heritage.

Preservation and protection of prehistoric and historic cultural resources is the policy of the federal government, and OER has a responsibility to consider the effects of its activities on these resources. If data are found to be sensitive because they reveal the location of a historically significant cultural resource, Section 304 of the National Historic Preservation Act (NHPA) provides that the head of a federal agency or other public official shall withhold from public disclosure information about the location, character, or ownership of a historic property when disclosure may cause a significant invasion of privacy, risk harm to the historic property, or impede the use of a traditional religious site by practitioners. This document uses the term underwater cultural heritage, or UCH, to refer to historic and prehistoric traces of human existence that are totally or partially underwater. For further information on NOAA Ocean Exploration UCH policies, please refer to Dornback M. (2021).

6. Schedule and Map

EX-21-03 was a total of 15 days at sea, from June 13, 2021, to June 27, 2021. The expedition departed from Norfolk, Virginia, and returned to port in Newport, Rhode Island. See **Table 2** for a day by day breakdown of EX-21-03. There were 12 scheduled dives, with 11 dives achieved (see **Tables 5 and 6** for details). A tropical storm transited from the Gulf of Mexico through the Carolinas and entered the operating area when the ship was around Caryn Seamount. Two dives at Caryn Seamount were canceled, and the ship sought shelter around Rhode Island and Massachusetts. See **Figure 1** for a map of EX-21-03's track, dive sites, and bathymetry collected.

Table 2. EX-21-03 schedule. Ancillary events not in bold are non-operational events relating to outreach with news outlets and education groups.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
6/6	**6/7**	**6/8**	**6/9**	**6/10**	**6/11** **Move aboard day** **In bubble prep** **Dunk test**	**6/12** **In bubble prep** **Load stores** **Emergency recovery walkthrough**
6/13 **Depart Norfolk @ 0900** **Transit + overnight mapping**	**6/14** **USBL calibration @ 0800** **Overnight mapping**	**6/15** **Dive 1** **Currituck 1** **670 m** **1000-1530** **Overnight mapping**	**6/16** **Dive 2** **Currituck 2** **80 m** **0830-1030** **Dive 3** **Currituck 3** **1017 m** **13:45 - 1700** **Overnight mapping** Interview with McClatchy News Group	**6/17** **Dive 4** **Norfolk Abyssal Plain** **2,850 m** **0830-1700** **Overnight mapping**	**6/18** **Dive 5** **Bermuda Transect** **4,370 m** **0830-1700** **Overnight mapping**	**6/19** **Dive 6** **Caryn Seamount** **3,797 m** **0830-1700** **Overnight mapping**

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
6/20 **No dive, weathered out** **Phase detection mapping (morning)** **Transit + overnight mapping (with occasional breaks due to weather)**	**6/21** **No dive, weathered out** **Shallow mapping USGS priority box** **Direct transit with no mapping**	**6/22** **Dive 7** **Hudson Shallow** **560 m** **13:00-1730** **Overnight mapping** Education professional development live interaction	**6/23** **Dive 8** **Toms Canyon** **1,838 m** **0830-1700** **Overnight mapping**	**6/24** **Dive 9** **Hudson Steep** **1,401 m** **1100m** **0830-1700** **Overnight mapping** National Ocean Sciences Bowl interaction	**6/25** **Dive 10** **Uchupi Canyon** **1,286 m** **0830-1700** **Overnight mapping** National Ocean Sciences Bowl interaction	**6/26** **Dive 11** **USS *Muskellunge*** **635 m** **0830-1700** **Overnight mapping** Interview with WTKR News 3 Norfolk
6/27 **Transit** **Arrive in Newport** **EX-21-03 Mission personnel depart**	**6/28** **In port** **EX-21-03 Mission personnel depart**	**6/29** **In port**	**6/30**	**7/1**	**7/2**	**7/3**

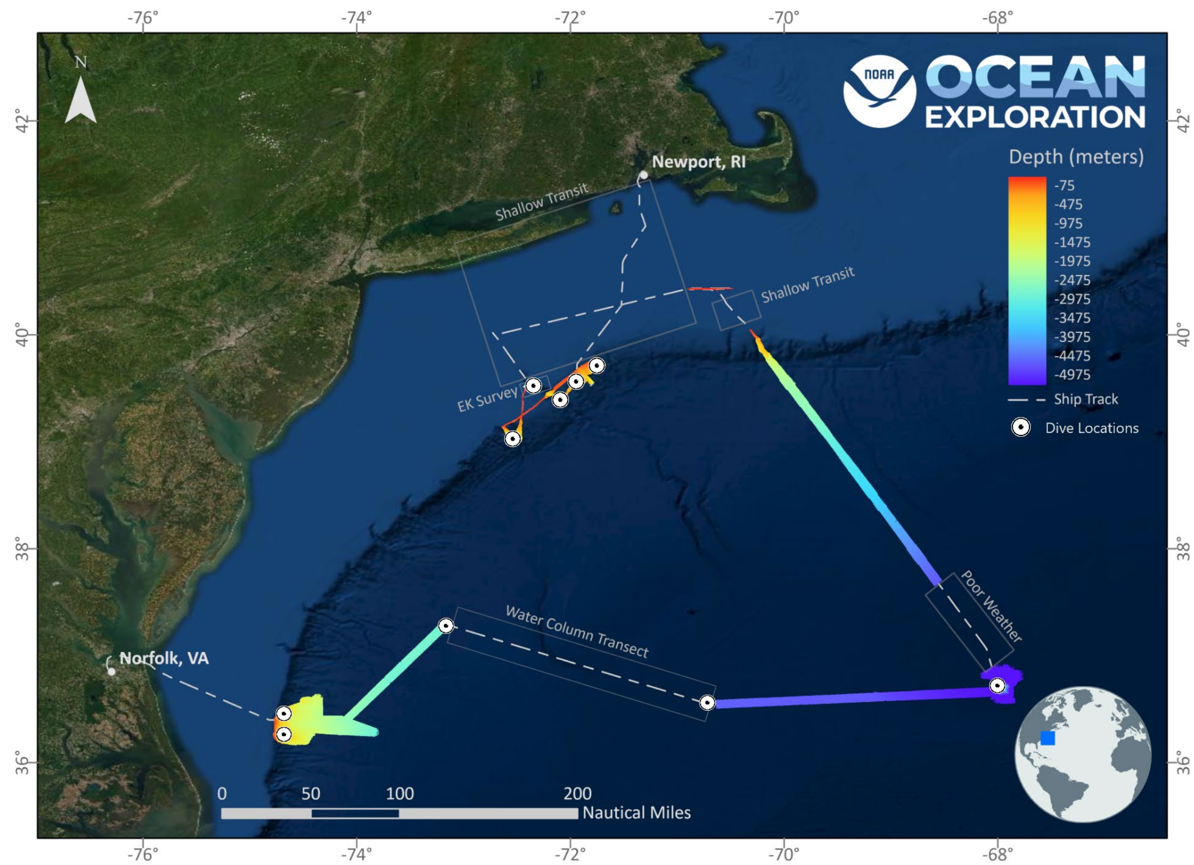

Figure 1. Map showing EX-21-03's track, 11 ROV dive sites, and bathymetry data collected. *Figure created using ArcGIS. Hoy et al. (2021) details the information collect outside of the standard acoustic operations.*

7. Results

Metrics for EX-21-03's major exploration and scientific work are summarized in **Tables 3 and 4**. More detailed results are presented in the subsections that follow.

Table 3. Summary of exploration metrics for EX-21-03

Exploration Metrics	Totals
Days at sea	15
Days at sea in U.S. waters	12
Linear km mapped by EM 304	2,403
Square km covered by EM 304	9,822
Square km covered by EM 304 in U.S. waters	6,209

Exploration Metrics	Totals
Vessel CTD casts	0
XBT casts	76
ROV dives	11
ROV dives in U.S. waters	9
Maximum ROV seafloor depth (m)	4,730
Minimum ROV seafloor depth (m)	560
Total time on bottom (hh:mm:ss)	42:29:54
Water column survey time (hh:mm:ss)	1:04:38
Total ROV time (hh:mm:ss)	68:12:02

Table 4. Summary of scientific metrics for EX-21-03: The first five metrics are also included as scientific metrics in Table 6.

Scientific Metrics	Totals
Potential undescribed or novel species and new records observed*	0
Dives during which living corals and sponges were observed	8
Dives during which chemosynthetic communities were observed	0
Dives during which active seeps/vents were observed	0
Dives during which diverse benthic communities were observed	4
Total samples	16
Biological samples (primary)	5
Biological associate samples	7
Geological samples	3
Geological associate samples	1
Actively participating scientists, students, and resource managers	18

* Organisms unknown to science or an extension of their known range of geolocation or depth

7.1 ROV Survey Results

Depth ranges explored during the 11 ROV surveys were between 560 and 4,730 m. During the 11 dives, the ROVs spent a total of 42.5 hours on the bottom and slightly over 1 hour conducting water column exploration. See **Tables 5 and 6** for dive-specific information.

Table 5. Summary information for the 11 ROV dives conducted during EX-21-03

Dive #	Site Name	Date (yyyymmdd)	On Bottom Latitude (dd)	On Bottom Longitude (dd)	Max Depth (m)	Dive Duration (hh:mm:ss)	Bottom Time (hh:mm:ss)	Water Column Exploration Time (hh:mm:ss)
1	Currituck 1	20210615	36.42319° N	074.75314° W	670.4	5:05:07	3:17:21	0:00:00
2	Currituck 2*	20210616	36.29016° N	074.69548° W	86.4	1:43:24	0:00:00	0:00:00
3	Currituck 3	20210616	36.29003° N	074.69675° W	1,017.4	2:15:58	0:53:41	0:00:00
4	Norfolk Abyssal Plain	20210617	37.29381° N	073.16708° W	2,849.4	7:48:31	4:30:38	0:00:00
5	Bermuda Transect	20210618	36.54377° N	070.69525° W	4,370.9	7:28:37	2:32:04	0:00:00
6	Caryn Seamount	20210619	36.66884° N	067.92761° W	3,796.6	7:56:57	3:32:49	0:00:00
7	Hudson Shallow	20210622	39.53018° N	072.37736° W	560.2	4:40:33	3:39:16	0:00:00
8	Toms Canyon	20210623	38.97929° N	072.49214° W	1,838	7:55:10	5:24:44	0:00:00
9	Hudson Steep	20210624	39.37422° N	072.08323° W	1,401.8	7:52:29	6:08:31	0:00:00
10	Uchupi Canyon	20210625	39.54483° N	071.79155° W	1,286.3	8:07:05	6:41:34	1:04:38
11	Maritime Heritage Dive, USS Muskellunge	20210626	UCH**	UCH**	634.9	7:18:11	5:49:16	0:00:00

* Dive 2 was recalled shortly after launch due to an equipment malfunction on the ROV
**the location of underwater cultural heritage sites are restricted and protected under the National Historic Preservation Act. Refer to Section 5.1 for more information.

Table 6. Summary of scientific metrics for the 11 ROV dives conducted during EX-21-03: Potential undescribed or novel species and new records observed, dives during which living corals and sponges were observed, dives during which chemosynthetic communities were observed, dives during which active seeps/vents were observed, dives during which diverse benthic communities were observed, and samples collected.

Dive #	Site Name	Undescribed Species	Corals & Sponges	Chemo-synthetic Community	Active Seeps & Vents	Diverse Benthic Community	Primary Biological Samples	Associate Biological Samples	Primary Geological Samples	Associate Geological Samples
1	Currituck 1	no	no	no	no	no	0	0	0	0

Dive #	Site Name	Undescribed Species	Corals & Sponges	Chemo-synthetic Community	Active Seeps & Vents	Diverse Benthic Community	Primary Biological Samples	Associate Biological Samples	Primary Geological Samples	Associate Geological Samples
2	Currituck 2	no	no	no	no	no	0	0	0	0
3	Currituck 3	no	no	no	no	no	0	0	0	0
4	Norfolk Abyssal Plain	no	yes	no	no	no	0	0	0	0
5	Bermuda Transect	no	yes	no	no	no	0	0	0	0
6	Caryn Seamount	no	yes	no	no	yes	2	3	1	0
7	Hudson Shallow	no	yes	no	no	yes	0	0	0	0
8	Toms Canyon	no	yes	no	no	no	1	0	1	0
9	Hudson Steep	no	yes	no	no	yes	2	4	1	1
10	Uchupi Canyon	no	yes	no	no	no	0	0	0	0
11	Maritime Heritage Dive, USS *Muskellunge*	no	yes	no	no	yes	0	0	0	0

7.1.1 Accessing ROV Data

OER Digital Atlas

ROV data from EX-21-03 are archived at NOAA's National Centers for Environmental Information (NCEI) and available through OER's Digital Atlas. To access these data, click on the Search tab, enter "EX2103" in the Enter Search Text field, and click Search. Click on the point that represents EX-21-03 to access data options. In the pop-up window, select the ROV Data Access tab for links to the ROV dive data, which is organized by dive.

NCEI Archival Dataset

The EX-21-03 NCEI archival dataset is an alternate resource for the ship and ROV data collected during the expedition. This dataset contains data collected from shipboard sensors including navigational data, meteorological data (wind), and oceanographic data (bathythermograph, sound velocity probe, thermosalinograph). Additional data include profile data (ASVP, CTD, and XBT), event logs, images, ROV ancillary data, and sample data.

ROV Dive Summaries

Individual ROV dive summaries and associated ROV dive data are archived at NCEI and available on the EX-21-03 pages of the *Okeanos Explorer* ROV Expeditions website.

ROV Dive Video

To search, preview, and download dive video for *Okeanos Explorer*, go to the OER Video Portal.

SeaTube

OER works closely with Ocean Networks Canada to implement SeaTube, a web-based annotation interface for ROV operations on expeditions aboard *Okeanos Explorer*. SeaTube is the digital equivalent to a scientist's logbook. It is used by onboard and shore-based scientists to log real-time observations on a variety of topics. To watch a video of a dive and search and export annotations, click on the "Expeditions" tree and select "NOAA," "2021," and "NOAA EX2103 ROV Shakedown Expedition." To play an individual dive, hover the mouse over the desired dive and press the play icon (triangle). To search, click the magnifying glass icon in the top right corner of the list pane or hover the mouse over the desired dive and press the magnifying glass icon.

7.2 Sampling Operations Results

A total of 16 samples were collected during EX-21-03: 3 geological samples, 5 biological samples, and 8 associate samples (see **Table 6** for more cumulative results).

The geological samples included a manganese encrusted rock at Caryn Seamount, a mudstone from Toms Canyon, and two samples from the Hudson Steep dive: a sedimented rock and a mudstone collected while collecting a coral. See **Table 7** for full details of the geological samples collected.

There were 5 biological samples that were purposely collected (primary samples) as well as 7 samples that were incidentally collected (associate samples). In total, these samples amounted to 12 individuals. The biological samples included an anemone and geodia sponge from Caryn Seamount, an unidentified hydrozoan from Toms Canyon, and *Anthomastus* sp. and antipatharian corals from Hudson Steep. See **Table 8** for full details of the biological samples collected.

Table 7. Inventory of geological samples collected during EX-21-03

Dive #	Site Name	Sample #*	Sample ID	Preservation	Collection Rationale	Date (yyyymmdd)	UTC Time (hhmmss)	Latitude (dd)	Longitude (dd)	Depth (m)	Weight (kg)
6	Caryn Seamount	EX2103_D06_02G	Loose Rock - Mg Encrusted	Dried	Characteristic of Site	20210619	165500	36.669	-67.929	3,785	n/a
8	Toms Canyon	EX2103_D08_01G	Mudstone	Dried	Characteristic of Site	20210623	143813	38.982	-72.495	1,835	0.731
9	Hudson Steep	EX2103_D09_02G	Sedimented Rock	Dried	Characteristic of Site	20210624	180241	39.374	-72.078	1,257	1.32
9	Hudson Steep	EX2103_D09_01B_A01	Mudstone	Dried	Characteristic of Site	20210624	155118	39.374	-72.078	1,344	n/a

*Geological sample number with "_A##" indicates associate sample.

Table 8. Inventory of biological samples collected during EX-21-03

Dive #	Site Name	Sample#*	Sample ID	Preser-vative	Collection Rationale	Date (yyyymmdd)	UTC Time (hhmmss)	Latitude (dd)	Longitude (dd)	Depth (m)	Salinity (ppt)	Temper-ature (C)	Dissolved Oxygen (mg/l)
6	Caryn Seamount	EX2103_D06_01B	Hydrozoa	95% EtOH	Characteristic of Site	20210619	154600	36.669	-67.929	3,791	35.065	2.451	8.306
6	Caryn Seamount	EX2103_D06_03B	Geodia	95% EtOH	Connectivity Study	20210619	175600	36.670	-67.929	3,772	35.047	2.184	8.254
6	Caryn Seamount	EX1903L2_D01_A02	Hydrozoa	95% EtOH	n/a	20190621	172847	38.984	-72.493	1,729	34.959	3.598	8.311
6	Caryn Seamount	EX2103_D06_02G_A01	Actinea	95% EtOH	n/a	20210619	165500	39.374	-72.079	1,344	34.976	4.254	8.199
6	Caryn Seamount	EX2103_D06_02G_A02	Bryozoa	95% EtOH	n/a	20210619	165500	39.375	-72.078	1,241	34.985	4.406	8.122

Dive #	Site Name	Sample#*	Sample ID	Preser-vative	Collection Rationale	Date (yyyymmdd)	UTC Time (hhmmss)	Latitude (dd)	Longitude (dd)	Depth (m)	Salinity (ppt)	Temper-ature (C)	Dissolved Oxygen (mg/l)
6	Caryn Seamount	EX2103_D06_02G_A03	Bryozoa	95% EtOH	n/a	20210619	165500	36.669	-67.929	3,785	35.016	2.532	8.304
8	Toms Canyon	EX2103_D08_02B	Hydrozoa	5% Formalin	Characteristic of Site	20210623	180050	36.669	-67.929	3,785.	35.016	2.532	8.304
9	Hudson Steep	EX2103_D09_01B	Anthomastus	95% EtOH	Connectivity Study	20210624	155118	36.669	-67.929	3,785	35.016	2.532	8.304
9	Hudson Steep	EX2103_D09_03B	Antipatharia	95% EtOH	Connectivity Study	20210624	183704	39.375	-72.078	1,257	34.986	4.326	8.152
9	Hudson Steep	EX2103_D09_02G_A02	Actiniaria	95% EtOH	n/a	20210624	180241	39.375	-72.078	1,257	34.986	4.326	8.152
9	Hudson Steep	EX2103_D09_02G_A03	Porifera	95% EtOH	n/a	20210624	180241	39.375	-72.078	1,257	34.986	4.326	8.152
9	Hudson Steep	EX2103_D09_02G_A01	Dendrophylliidae	95% EtOH	n/a	20210624	180241	39.375	-72.078	1,241	34.985	4.406	8.122
9	Hudson Steep	EX2103_D09_03B_A01	Ophiuroidea	95% EtOH	n/a	20210624	183704	36.669	-67.929	3,791	35.065	2.451	8.306

*Biological sample numbers with "_A##" indicate associate samples.

7.2.1 Sample Repositories

The following repositories archive samples collected during OER expeditions on *Okeanos Explorer*.

Biological Samples

Invertebrate Zoology Collections
National Museum of Natural History
Smithsonian Institution, Museum Support Center
MRC 534, 4210 Silver Hill Road, Suitland, MD 20746

DNA Samples

Biorepository
National Museum of Natural History
Smithsonian Institution, Museum Support Center
4210 Silver Hill Road, Suitland, MD 20746

Geological Samples

Marine and Geology Repository
Oregon State University
Burt 346, Corvallis, OR 97331-5503

7.3 Acoustic Operations Results

During EX-21-03, multibeam mapping operations results included 2,403 linear km mapped and 9,822 km^2 covered (6,209 of these in U.S. waters) (Hoy et al., 2021).

A crossline was run on June 20, 2021, as shown in **Figure 2**, and the results are presented in **Table 9**.

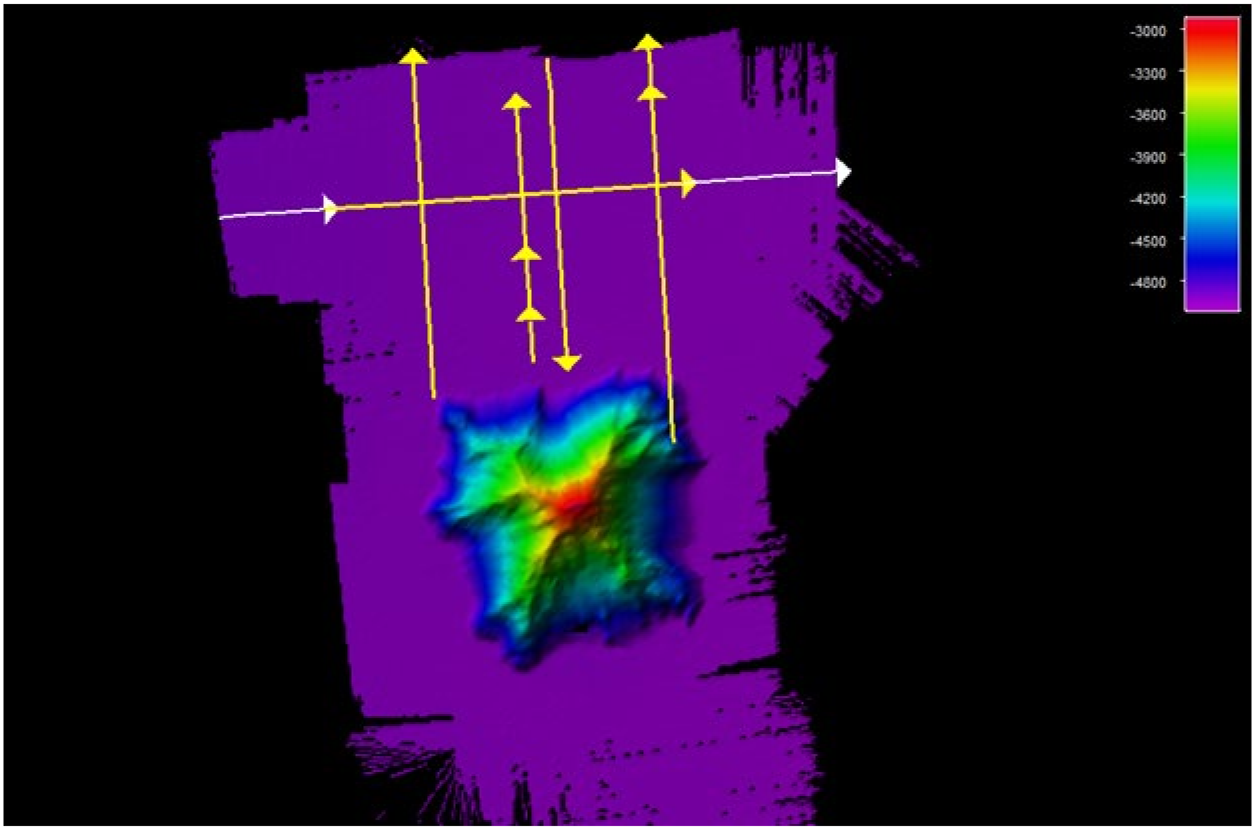

Figure 2. EX-21-03 crossline (shown in yellow) used for comparison against the bathymetric grid generated via orthogonal multibeam survey lines.

Table 9. Results of crossline analysis

Statistic	Value
Number of points of comparison	1,057,869
Grid cell size (m)	100
Difference mean (m)	0.158
Difference median (m)	0.367
Difference standard deviation (m)	4.459
Difference range (m)	[-55.23, 109.61]
Mean + 2* standard deviation (m)	9.075
Median + 2* standard deviation (m)	9.284
Data mean (m)	-4,926.641

Statistic	Value
Reference mean (m)	-4,926.799
Data z-range (m)	[-4,989.55, -3,558.98]
Reference z-range (m)	[-4,963.78, -3,572.23]
Order 1 error limit (m)	64.0503
Order 1 # rejected	4
Order 1 p-statistic	0.000004
Order 1 survey	ACCEPTED

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

Additional information about the mapping conducted during EX-21-03, including data quality assessments, is in the EX-21-03 mapping data report (Hoy et al., 2021).

7.3.1 Acoustic Operations Data Access

Multibeam Sonar (Kongsberg EM 304)

The multibeam dataset for the expedition is archived at NCEI and accessible through their Bathymetric Data Viewer. To access these data, click on the Search Bathymetric Surveys button, select "NOAA Ship Okeanos Explorer" from the Platform Name dropdown menu, and "EX2103" from the Survey ID dropdown menu. Click OK, and the ship track will appear on the map. Click the ship track for options to download data.

Sub-Bottom Profiler (Knudsen Chirp 3260)

The sub-bottom profiler was not run during any of EX-21-03's ROV dive operations, but generally was operated during multibeam mapping operations. These data are archived at NCEI and accessible through the Trackline Geophysical Data Viewer. To access these data, select "Subbottom Profile" under Marine Surveys and click on Search Marine Surveys. In the pop-up window, select "EX2103" in the Filter by Survey IDs dropdown menu. Click OK, and the ship track will appear on the map. Click the ship track for options to download data.

Split-Beam Sonars (Simrad EK60 and EK80)

EK60 and EK80 water column data for EX-21-03 are archived at NCEI and available through the Water Column Sonar Data Viewer. To access these data, click on the Additional Filters button, deselect “All” next to Survey ID, and select “EX2103” from the Survey ID list. Click OK, and the ship track will appear on the map. Click on the ship track for options to download data.

Acoustic Doppler Current Profilers (Teledyne Marine Workhorse Mariner and Teledyne Ocean Surveyor ADCPs)

For information on the ADCP data collected aboard *Okeanos Explorer*, contact ncei.info@noaa.gov.

7.4 Conductivity, Temperature, and Depth Measurements

CTD profile data from EX-21-03 are archived at NCEI and available through OER’s Digital Atlas. To access these data, click on the Search tab, enter “EX2103” in the Enter Search Text field, and click Search. Click on the point that represents EX-21-03 to access data options. In the pop-up window, select the Data Access tab for a link to download the CTD profile data.

ROV CTD data from EX-21-03 can be found on the EX-21-03 pages of the Okeanos Explorer ROV Expeditions website. To access these data, click on the 2021 Expeditions tab at the top of the page and then click on the link to 2021 ROV Shakedown (ROV and Mapping) – EX2103.

7.5 Engagement

EX-21-03 engaged with audiences around the world, opening a window of understanding into the deep sea. Highlights are listed below:

- Live video feeds received over 48,500 views, and web content received approximately 1,970 visits during EX-21-03.
- Over 77 news/web articles covered EX-21-03. Stories appeared in national and local media outlets and on websites throughout the country. A story written by the Associated Press was picked up by a number of affiliated outlets (including the *Washington Post*), and another story ran in all 28 of the McClatchy-owned news outlets. In addition, a local story from Norfolk, Virginia’s WTKR featured a video interview with the expedition coordinators. All of this coverage amplified the impact of the expedition, increasing the audience reached.
- Conducted two live interactions with National Science Bowl finalists and an interaction with teachers across the nation.
- A web article was written about the *Humaitá* (ex-USS *Muskallunge*) discovery on Dive 11 (Delgado et al., 2021).

8. Summary

- 11 successful dives, on soft bottom, seamounts, canyons, and a maritime heritage site. The deepest depth reached with ROV *Deep Discoverer* was 4,780 m. These dives included the first ROV exploration of Caryn Seamount and four ROV dives on mid-Atlantic canyons (Toms, Hudson, Uchupi).
- Discovered the wreck of the World War II-era submarine *Humaitá* (ex-USS *Muskallunge*) using the sonar systems.
- Mapping operations included sub-bottom transects of the Currituck landslide, acoustic imaging of the upper water column while transiting the Gulf Stream, and an EK60/EK80 split-beam survey at the head of Hudson Canyon.
- ROV shakedown work included testing and calibration of new ROV motor controllers, auto position software, lighting system, hydraulic system, ME-20 low-light camera, high-definition ancillary ROV cameras, and sector scanning sonar.
- Trained the entire ROV team in the pilot, co-pilot, and navigator roles.
- Installed and tested the telepresence wet lab equipment, including a sampling camera that can take high-definition images and stream content simultaneously.
- Optimization by the satellite engineers made the VSAT's connection speedy and reliable, allowed for new mission abilities, including Google Meet, Zoom, and Wi-Fi calling on -an iPhone.
- Oversaw the first live trial of SeaTube v3 with Ocean Networks Canada.
- Conducted the first live trial of the remote sample data manager system.
- Several ROV expedition standard operating procedures were developed for the mapping lead, expedition coordinator, science leads, and SeaTube at sea.
- Conducted two live interactions with National Science Bowl finalists, an interaction with teachers across the nation, and two interviews with news outlets.
- Tested sending select high-resolution videos to shore for the Outreach and Engagement Division to use in their public engagement.
- Trained the *Okeanos Explorer* wardroom on ROV deployment and recovery, aft control, and new dynamic positioning system.
- Developed man overboard procedures for a scenario where someone falls in during ROV launch/recovery.

9. References

Candio, S., Hoy, S., Jerram, K., Wilkins, C., Copeland, A., Lobecker, M., Sowers, D. (2021). NOAA Ship Okeanos Explorer Mapping Readiness Report 2021. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/qbjz-m470

Delgado, J., Damour, M., Catsambis, A., Brennan, M., Hoyt, J., Caporaso, A., Horrell, C., Jones, D. (2021). Exploring History: Humaitá (ex-USS Muskallunge). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://oceanexplorer.noaa.gov/okeanos/explorations/ex2103/features/history/history.html

Dornback, L.M. (2021). Project Instructions: EX-21-03, 2021 ROV Shakedown (ROV & Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/pqm9-7n61

Hoy, S., Wilkins, C., and Baechler, N. (2021). Mapping Data Acquisition and Processing Summary Report: EX-21-03 2021 ROV Shakedown. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/jc1h-3x19

Kennedy, B.R.C., Cantwell K., Malik M., Kelley, C., Potter, J., Elliott, K., Lobecker, E., Gray, L.M., Sowers, D., White, M.P., France, S.C., Auscavitch, S., Mah, C., Moriwake, V., Bingo, S.R.D., Putts, M., and Rotjan, R.D. (2019). The unknown and the unexplored: Insights into the Pacific deep-sea following NOAA CAPSTONE expeditions. Front. Mar. Sci. 6:480. https://doi.org/10.3389/fmars.2019.00480

NOAA Office of Ocean Exploration and Research. (no date). Summary Report for the Atlantic Seafloor Partnership for Integrated Research and Exploration Science Planning Workshop. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://oceanexplorer.noaa.gov/explorations/aspire/aspire-workshop-report.pdf

Quattrini, A.M., Nizinski, M.S., Chaytor, J.D., Demopoulos, A.W.J., Roark, E.B., et al. (2015). Exploration of the canyon-incised continental margin of the northeastern United States reveals dynamic habitats and diverse communities. PLoS One 10:e0139904. https://doi.org/10.1371/journal.pone.0139904

Sowers, D. (2021). NOAA Ship Okeanos Explorer FY21 Field Season Instructions. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. https://doi.org/10.25923/83ze-r686

Appendix A: EX-21-03 Shore-Based Science Team Members

Table A1. EX-21-03 shore-based science team members

First	Last	Email	Affiliation
Megan	Cromwell	megan.cromwell@noaa.gov	NOAA National Centers for Environmental Information
Susan	Gottfried	susan.gottfried@noaa.gov	NOAA National Centers for Environmental Information
Jonathan	Jackson	jonathan.jackson@noaa.gov	NOAA National Centers for Environmental Information
Anna	Lienesch	anna.s.lienesch@noaa.gov	NOAA National Centers for Environmental Information
Madalyn	Newman	madalyn.newman@noaa.gov	NOAA National Centers for Environmental Information
Nick	Beaseo	nickbezio@gmail.com	University of Maryland
Mike	Brennan	mike.brennan@searchinc.com	Search, Inc.
Alicia	Caporaso	Alicia.Caporaso@boem.gov	Bureau of Ocean Energy Management
Jason	Chaytor	jchaytor@usgs.gov	United States Geological Survey
Alan	Collins	allen.collins@noaa.gov	NOAA and National Museum of Natural History
James	Delgado	james.delgado@searchinc.com	SEARCH, Inc.
Upasana	Ganguly	upasana.ganguly1@louisiana.edu	University of Louisiana at Lafayette
Quinn	Girasek	quinn.girasek@noaa.gov	NOAA Office of Ocean Exploration and Research
Steve	Haddock	haddock@mbari.org	Monterey Bay Aquarium and Research Institute
Noelle	Helder	noelle.helder@noaa.gov	NOAA Office of Ocean Exploration and Research
Joe	Hoyt	joe.hoyt@noaa.gov	NOAA National Marine Sanctuaries
Dhugal	Lindsay	dhugal@jamstec.go.jp	JAMSTEC
Asako	Matsumoto	amatsu@gorgonian.jp	Chiba Institute of Technology
Thomas	Morrow	thomas.morrow@bc.edu	Boston College

First	Last	Email	Affiliation
Kenneth	Sulak	jumpingsturgeon@yahoo.com	United States Geological Survey
Michael	Vecchione	vecchiom@si.edu	NOAA and National Museum of Natural History
Kelsey	Viator	ksviator2000@gmail.com	University of Louisiana at Lafayette
Les	Watling	watling@hawaii.edu	University of Hawaiʻi at Manoa