

A detailed underwater photograph of a coral reef. On the left, two large, yellow, cone-shaped sponges with a porous, lattice-like structure dominate the foreground. To the right, there is a variety of coral, including a delicate, blue, feathery coral and a large, white, branching coral. Several bright orange crabs are visible on the reef, including a large one in the lower right and several smaller ones scattered throughout. The background is dark, suggesting a deep-sea environment.

# New Frontiers in Ocean Exploration

The E/V *Nautilus*, NOAA Ship *Okeanos Explorer*,  
and R/V *Falkor* 2018 Field Season

**GUEST EDITORS**

Nicole A. Raineault and  
Joanne Flanders

*Oceanography*

Vol. 32, No. 1, Supplement, March 2019

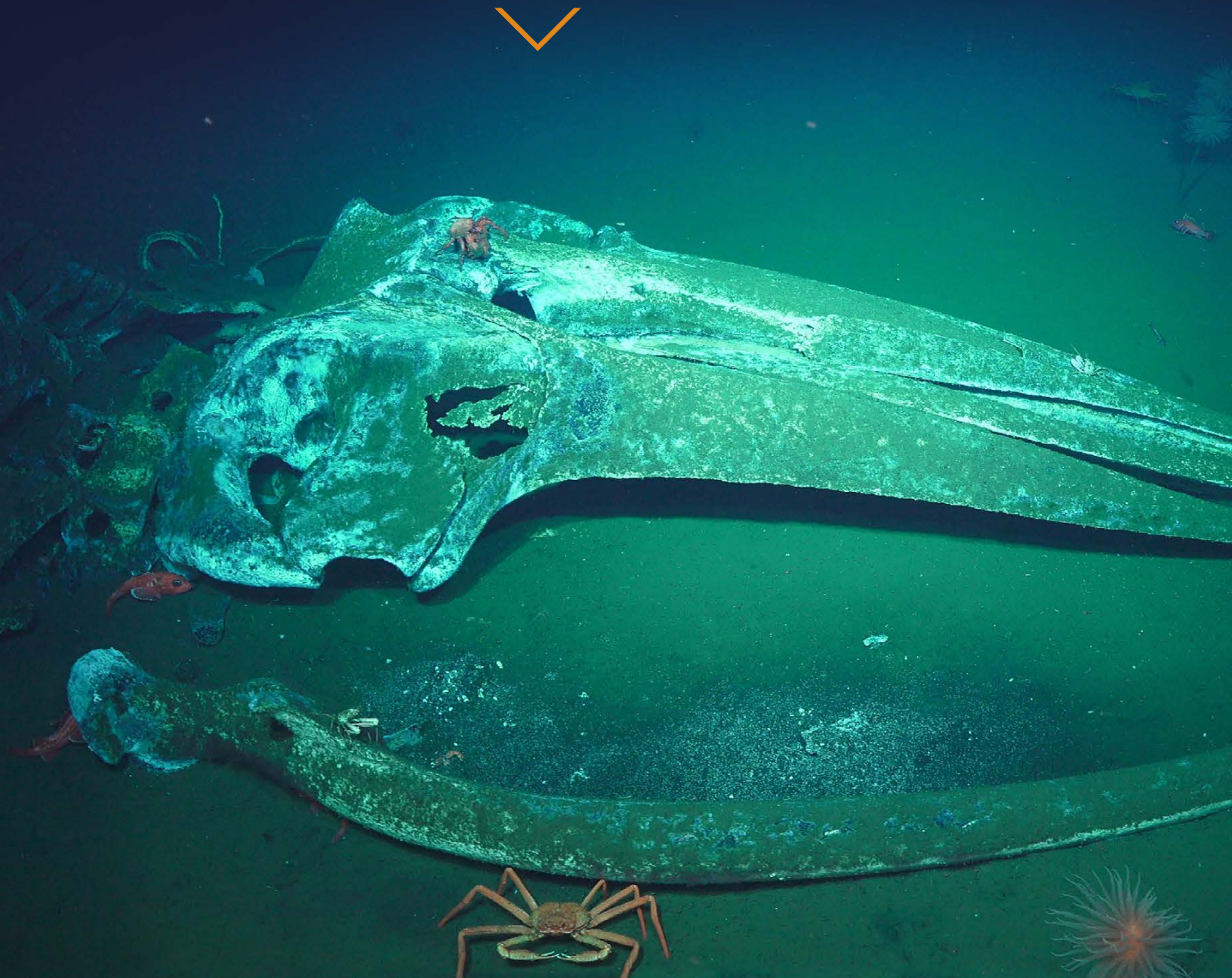
#### PREFERRED CITATION

Raineault, N.A., and J. Flanders, eds. 2019. New frontiers in ocean exploration: The E/V *Nautilus*, NOAA Ship *Okeanos Explorer*, and R/V *Falkor* 2018 field season. *Oceanography* 32(1), supplement, 150 pp., <https://doi.org/10.5670/oceanog.2019.supplement.01>.

#### FRONT COVER

A high-density habitat consisting of deep-sea sponge, coral, and squat lobsters on a previously unmapped and unexplored seamount in Papahānaumokuākea Marine National Monument. The photo was taken during E/V *Nautilus* cruise NA101. Image credit: D. Fornari (WHOI-MISO Facility) and OET

The R/V *Falkor* team dove on “Rosebud,” a whale fall that was placed by researchers off San Diego, California, in La Jolla Canyon. Researchers noted changes in composition and life forms around the location in a beautiful, exciting dive investigating ecosystems unique to whale falls. Image credit: SOI



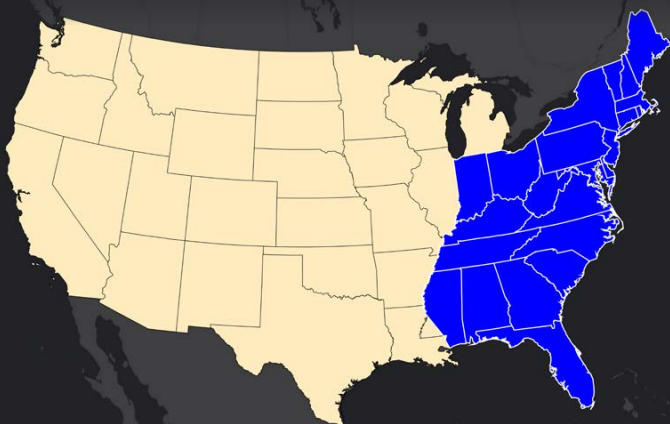
# NOAA Ship *Okeanos Explorer* 2018 Ocean Mapping Achievements

By Derek Sowers, Michael P. White, Mashkoor Malik, Elizabeth Lobecker, Shannon Hoy, and Charles Wilkins

After three contiguous field seasons of remote expeditions in the Pacific Ocean, NOAA Ship *Okeanos Explorer* transited the Panama Canal in fall of 2017 to commence new exploration efforts in the Gulf of Mexico and the Atlantic Ocean. In 2017–2018, the ship boldly continued its tenth year of ocean mapping field operations in support of exploring and characterizing the US Exclusive Economic Zone and the world ocean, mapping almost 300,000 km<sup>2</sup> of seafloor (an area larger than the state of Arizona), while transiting a linear ship track distance of 53,374 km. That distance represents the equivalent of circumnavigating Earth at the equator 1.3 times. Six of the 12 expeditions summarized in this supplement to *Oceanography* were fully dedicated to 24-hour per day mapping exploration. For the remaining six combined ROV/mapping cruises, mapping operations typically comprised over 50% of the at-sea mission time.

## TEN YEARS OF OCEAN EXPLORATION MAPPING ACHIEVEMENTS

From 2008 to 2018, NOAA's Office of Ocean Exploration and Research—utilizing “America's Ship for Ocean Exploration,” *Okeanos Explorer*—has mapped a cumulative 1.79 million km<sup>2</sup> of seafloor with the ship's multibeam sonar. If projected over the contiguous United States, this area would cover about 23% of the land area of the country (blue area in figure). A majority of this work has been completed within the US Exclusive Economic Zone—host to America's hidden and still largely uncharacterized deep-sea habitats.



## IMPROVEMENTS IN OCEAN MAPPING

Each field season of exploratory ocean mapping work brings new opportunities to upgrade equipment, software, procedures, and collaborations to improve methodologies aboard *Okeanos Explorer*. Over the past year, the mapping team implemented Sound Speed Manager, an open-source, user-friendly application for importing, editing, and exporting sound speed profile data, a fundamental requirement for obtaining high-quality multibeam sonar data (Masetti et al., 2017a; [Figure 1](#)). This application enables mappers to utilize historical salinity and temperature data from the World Ocean Atlas to improve ship-collected sound speed profiles and generate synthetic profiles when physical sampling is not possible. The software also provides an easy interface for editing and comparing oceanographic profiles of the water column and exporting GIS files or tables of all casts completed during a cruise—all of which streamlines record keeping. The application is often used in combination with SmartMap, a web GIS that helps

Figure 1. Sound Speed Manager enables the user to generate quick and easy plots for comparing water column sound speed profiles during a cruise. (a) An example of three expendable bathythermograph profiles plotted for day 15 of the November 2018 cruise off-shore Puerto Rico, with depth on the y-axis and sound speed on the x-axis. (b) A quick Google Earth export from Sound Speed Manager of all sound speed casts completed during the cruise.

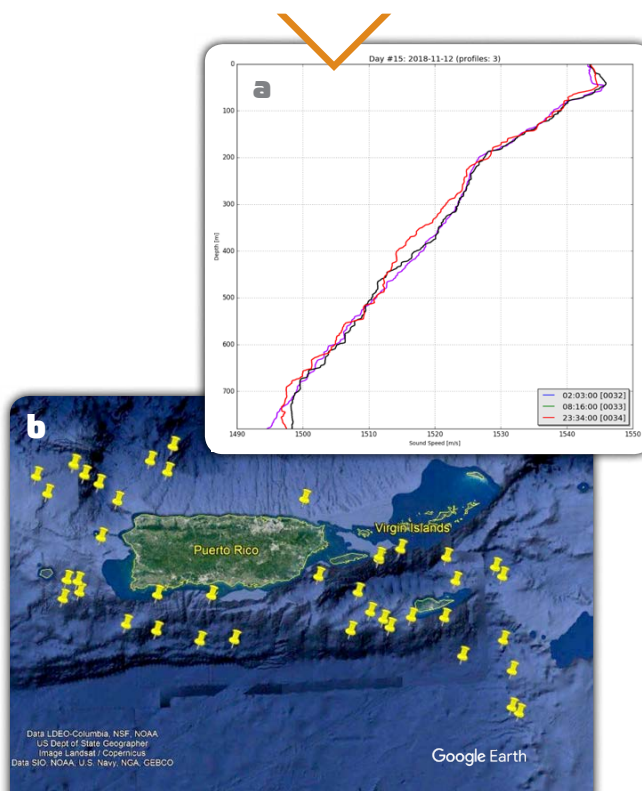
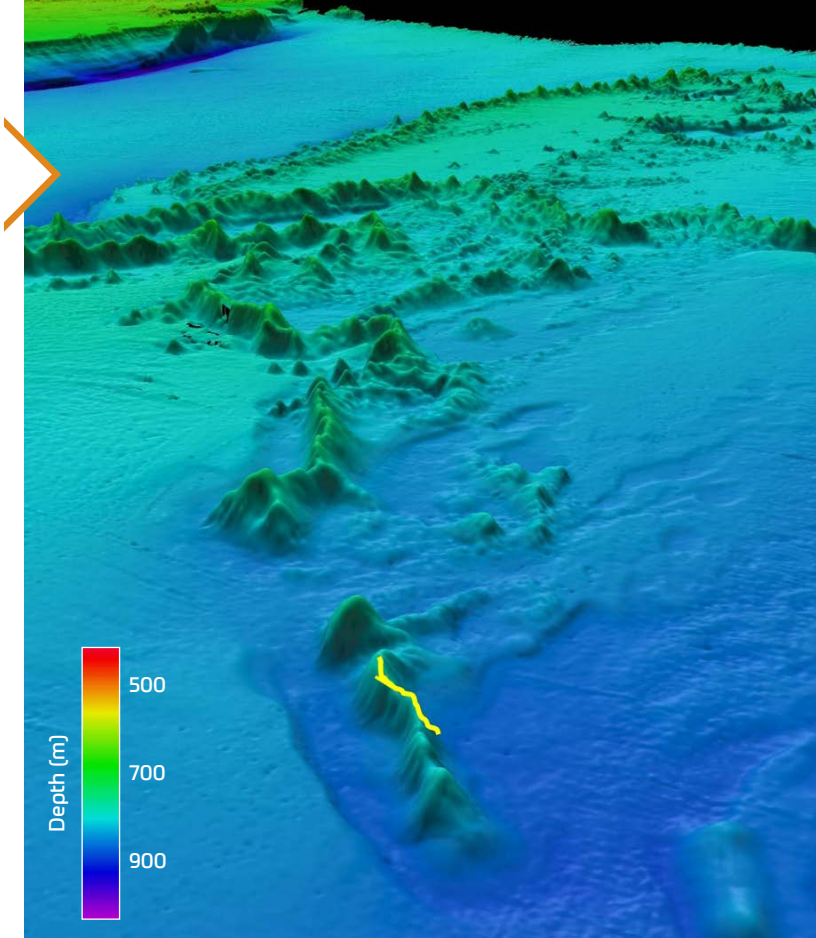


Figure 2. Linear ridge features discovered offshore due east of Savannah, Georgia, at about 800 m depth. During the 2018 Windows to the Deep expedition, ROVs explored one of these features (dubbed “Richardson Ridge”) that was found to be densely covered in *Lophelia pertusa* deep-sea corals. The dive track on the ridge feature is shown in yellow (4x vertical exaggeration).

surveyors evaluate the impact of oceanographic temporal and spatial variability on hydrographic surveys (Masetti et al., 2017b). Sound Speed Manager and SmartMap are two of several free applications found within the HydrOffice framework (<https://www.hydrooffice.org>) created through a collaborative effort of the University of New Hampshire's Joint Hydrographic Center and NOAA.

Another significant improvement to both mapping equipment and procedures involved the adoption of automated EK60 sonar calibration methods on *Okeanos Explorer*. Calibration of EK60 split-beam fisheries sonars involves suspending a metal sphere beneath the ship and moving it around within the sonar's beam to collect measurements of the strength of the echoes from the sphere. This arduous task must be done several times per year on five different transducers in order to ensure high data quality. NOAA fisheries vessel scientists developed customized equipment and software to remotely control fishing pole downriggers that move the sphere within the sonar beam. *Okeanos Explorer* has adopted this technology and was able to successfully fabricate auto calibration gear in-house and calibrate the ship's EK60 sonars with it during a shakedown cruise in the spring of 2018. This improvement is expected to decrease the amount of time and effort needed to complete the calibration.

Several improvements to ocean mapping systems aboard *Okeanos Explorer* are planned for 2019. Two Simrad EK80 wideband transceivers (38 and 70 kHz) are scheduled for installation. Wideband sonars use a frequency-modulated (chirp) signal to both send and receive a broader range of frequencies than narrowband sonars. The new wideband transceivers will enable OER to serve as a data gathering testbed for this new advancement in split-beam sonar technology and to explore the advantages of wideband EK80 data over narrowband EK60 data that the ship has been collecting since 2008. Wideband transceivers will provide improved range resolution of targets in the water column (Demer et al., 2017), may be useful in discriminating “acoustic signatures” of various water column targets (because acoustic response for many targets exhibits frequency dependence), and have proven useful in identifying prominent thermohaline layers in the water column where these features exist (Stranne et al., 2017). The ship will also benefit from an equipment upgrade to enable improved syncing of multiple sonars to avoid interference while maximizing data resolution.



## MAPPING PARTNERSHIPS IN ACTION

Mapping priorities for the year were driven strongly by OER's commitment to strategic marine mapping and research collaborations with a diversity of national and international partners. For each of these initiatives, maps of the unknown ocean serve as baselines upon which further characterization work can be done. In addition to the primary driver of the ASPIRE campaign (see pages 74–75), mapping work completed during the last field season directly supported the following efforts.

### Southeast Deep Coral Initiative

OER continues to be a key collaborator on the Southeast Deep Coral Initiative (<https://oceanexplorer.noaa.gov/explorations/17sedci/background/sedci/sedci.html>) led by NOAA's National Centers for Coastal Ocean Science. This effort is collecting new scientific information about the distribution, abundance, and diversity of deep-sea coral ecosystems within the Caribbean, Gulf of Mexico, and South Atlantic Bight. Mapping work and ROV exploration completed by *Okeanos Explorer* in this region has been fundamental to providing baseline information on the location of corals and the environmental conditions that support coral habitats (Figure 2). This information is being directly used to improve habitat prediction models for deep-sea corals and inform ocean management decisions.

## DEEP SEARCH

OER is providing both financial support for, and allocation of *Okeanos Explorer* sea days to, the DEEP SEARCH project (see pages 104–105). Two *Okeanos Explorer* cruises were dedicated to mapping and ROV exploration within DEEP SEARCH priority areas off the southeast US coast.

## Atlantic Seabed Mapping International Working Group

The Atlantic Seabed Mapping International Working Group (ASMIWG) emerged as an implementation group for the Atlantic Ocean Research Alliance formed between Canada, the European Union, and the United States, which resulted from the Galway Statement on Atlantic Ocean Cooperation signed in May 2013. ASMIWG is leveraging resources to collaboratively map the North Atlantic Ocean and has identified high-priority areas to pursue ship-based mapping surveys. *Okeanos Explorer* completed the first focused survey of one of these priority areas (see pages 88–89), and OER is planning extensive exploration work in the North Atlantic for 2019.

## Seabed 2030

Seabed 2030 is an initiative led by the Nippon Foundation and the General Bathymetric Chart of the Oceans (GEBCO), with the goal of producing a publicly accessible definitive map of the world ocean by 2030 (<https://seabed2030.gebco.net/>). With the vast majority of the world's deep ocean remaining unmapped by modern surveying methods, all *Okeanos Explorer* mapping data are substantially contributing to this global effort.

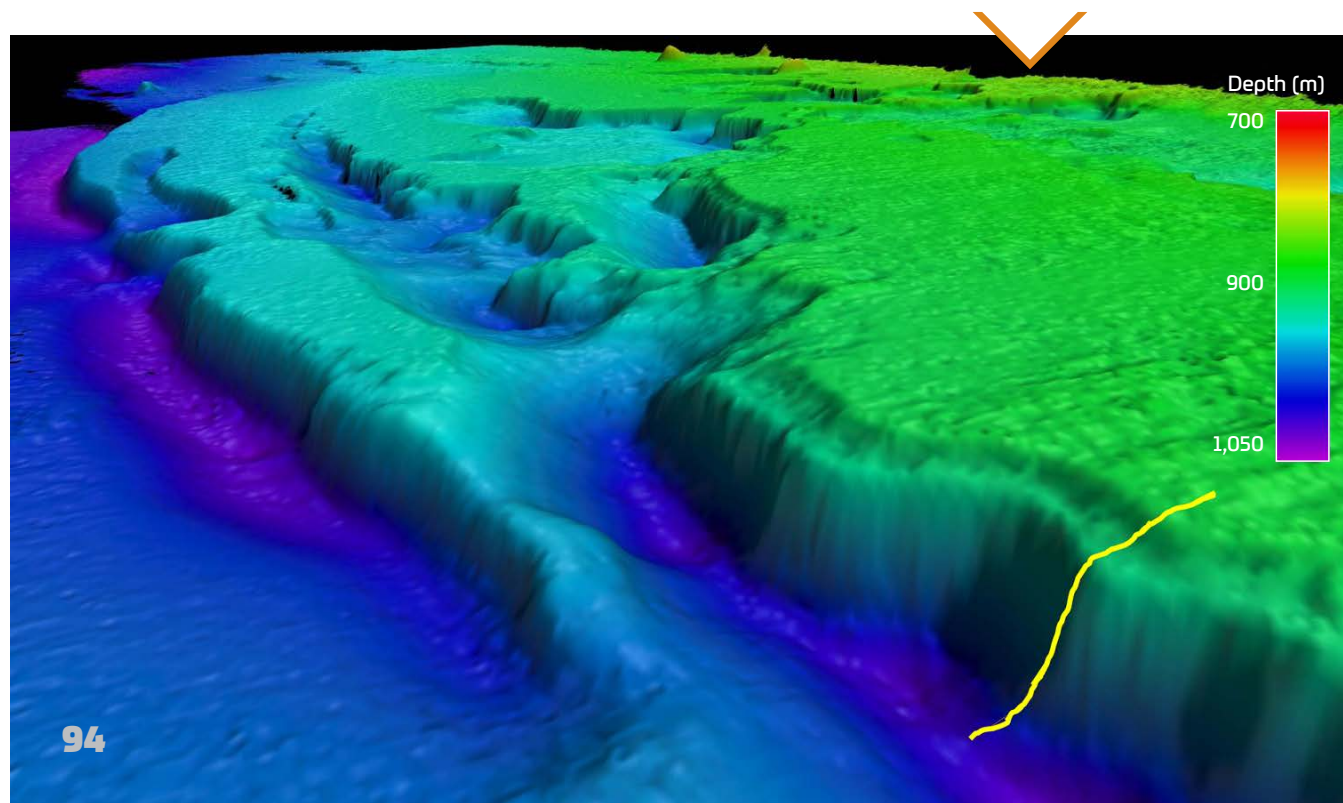
## NASA's Visible Infrared Imaging Radiometer Suite

In 2018, *Okeanos Explorer* provided a platform for collecting essential ship-based measurements needed to calibrate the Visible Infrared Radiometer Suite (VIIRS) satellite ocean color measurements (<https://jointmission.gsfc.nasa.gov/viirs.html>). VIIRS provides remote-sensing data that are critical for assessing broadscale sea surface temperatures, harmful algae blooms, risk to coral habitats, ocean productivity, and weather forecasts.

## CRITICAL MAPPING SUPPORT OF SUCCESSFUL ROV DIVE OPERATIONS

With half of the expeditions last year spent as joint ROV/mapping cruises, mapping data played a critical role in ensuring safe and effective ROV dive operations. Interesting features (e.g., seamounts, mounds, canyons, potential shipwrecks) identified through mapping efforts typically serve as the primary basis for selecting ROV dive targets (Figure 3). Mapping team support is particularly important when the need arises to change a dive site at the last minute due to unfavorable wind, weather, or current conditions. This happened with some regularity for ROV dives in the vicinity of the strong Loop Current in the Gulf of Mexico and in the Gulf Stream current offshore of the southeast US

Figure 3. ROV planning scene for Dive 8 (Richardson Scarp) of the 2018 Windows to the Deep expedition offshore of the southeast US coast. This dive track (yellow line) was mapped the night before the dive was conducted, with the science team selecting the biggest and steepest slope in the area to examine the geology and maximize chances to observe attached fauna on hard substrates.



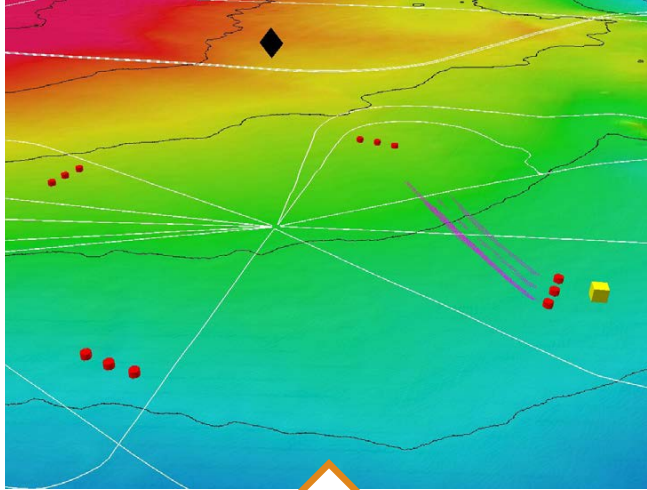


Figure 4. Three-dimensional ROV planning scene for an archaeology dive in the Gulf of Mexico in 2018. The yellow square represents the archaeological dive target in close proximity to mooring anchor points (red circles) and anchor chains (shown in pink, as picked from multibeam water column backscatter data) for a floating oil rig (black diamond). Oil pipeline routes are shown as white lines, with 250 m bathymetric contours shown as black lines. This visualization was built using QPS Fledermaus marine GIS software.

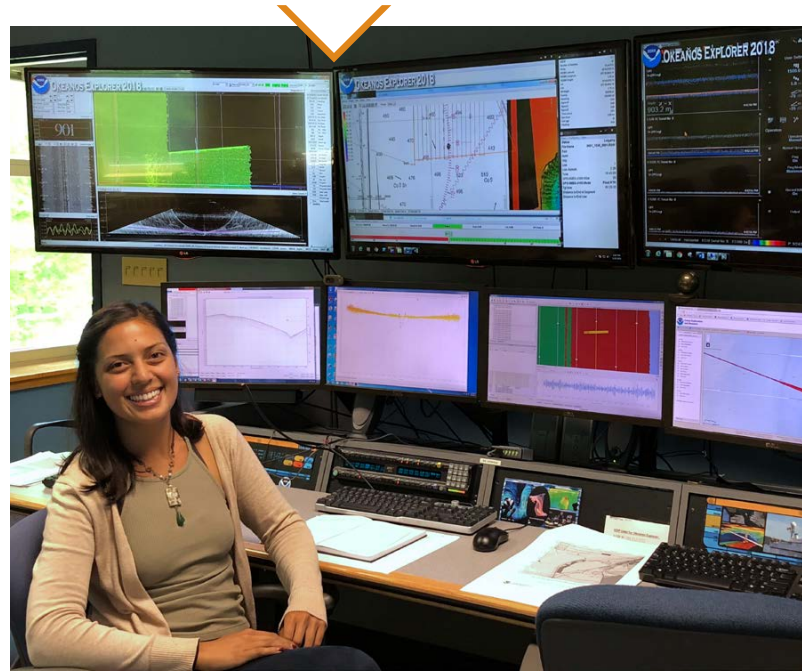
coast. Mapping data are quickly utilized to generate a new dive location plan to meet the desired scientific objectives while optimizing ship and ROV orientations relative to wind and current.

Careful use of mapping data is particularly important when planning an ROV dive in the vicinity of morphological features or anthropogenic structures with the potential to entangle or damage the ROVs. Dives are planned to avoid known (charted) subsea cable routes and other man-made obstructions (Figure 4), as well as confined canyons that could be hazardous in the event of equipment or power failures.

## ADVANCING THE TELEPRESENCE MAPPING PARADIGM

OER continued to explore the benefits of telepresence-enabled mapping (“telemapping”) cruises on *Okeanos Explorer*. A robust computer network and a high-bandwidth ship-to-shore satellite connection enables the OER mapping team to lead mapping cruises from shore. Data collection is overseen at sea by a small team of experienced survey contractors, while high-level planning and decision-making can be handled by the onshore expedition coordinator. Using computer networks and specialized software at the Exploration Command Center at the University of New Hampshire, multibeam data sets are downloaded from the ship for onshore data cleaning and processing that has historically been done at sea. Onshore students (see Explorer-in-Training program information on pages 114–115) stand watch to monitor the ship’s sonar

Figure 5. Explorer-in-Training Mikia Weidenbach stands watch, ready to process multibeam sonar data on shore during the mapping leg of the 2018 Windows to the Deep expedition.



performance in real time (Figure 5), as well as to post-process multibeam, subbottom, and water column sonar data to generate value-added mapping products that can be shared rapidly with the broader scientific community. Successful telemapping surveys were conducted in this manner for the ship’s long transit from Hawai’i to Panama, and for a mapping cruise off the southeast US coastline in support of DEEP SEARCH project priority areas.

Given the success of these efforts, telemapping operations have been prototyped and can now be replicated on other offshore or shore-based scientific platforms with comparable satellite bandwidth and data sharing capabilities. Live streaming of sonar acquisition screens provides real-time monitoring of survey operations, while processed sonar files (and derivative products such as cleaned bathymetric grids) are produced on shore and made publicly available within 24 to 48 hours of data collection. This paradigm has great potential to expand the number of shoreside participants in a mapping survey by providing exceptional educational opportunities for marine scientists, ocean mappers, and interested citizen scientists. While ocean mapping is often somewhat of a “behind the scenes” aspect of ocean exploration, telemapping could provide a mechanism for engaging more people and delivering mapping products to scientists more quickly and directly than has been conventionally possible.