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Ocean Exploration and Research

Cruise Report: EX-18-06 Windows to the Deep 2018 (ROV and Mapping)

Southeast U.S. Continental Margin

Charleston, SC to Norfolk, VA
(June 13, 2018 to July 2, 2018)

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Abstract

The deepwater areas offshore of Florida, Georgia, South Carolina, and North Carolina are some of the least explored areas along the U.S. East Coast. In 2018, NOAA and partners conducted a two-part expedition to map and characterize this area to support priorities put forward by the deep-ocean science and resource management communities. The primary objective of the expedition was to survey deepwater areas offshore of Florida, Georgia, South Carolina, and North Carolina in order to provide baseline data and information to support management and science needs. This two-part, 36-day telepresence-enabled expedition used the ship's deepwater mapping systems , NOAA's dual-body deepwater remotely operated vehicle (ROV), and a high-bandwidth satellite connection for real-time ship-to-shore communications. This cruise report details activities associated with the second leg of the *Windows to the Deep 2018: Exploration of the Southeast U.S. Continental Margin* expedition (EX-18-06). *Windows to the Deep 2018* was the first in a series of cruises that contributed to NOAA's Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) campaign, a major multi-year, multi-national collaborative field program focused on raising collective knowledge and understanding of the North Atlantic. During the expedition, 17 ROV dives were conducted, ranging in depth from 325 to 3,424 meters, to improve knowledge of unexplored areas within the U.S. Exclusive Economic Zone (EEZ) to inform management needs for sensitive habitats, maritime heritage sites, and potential resources. EX-18-06 also mapped 14,875 square kilometers of seafloor to extend bathymetric mapping coverage in the U.S. EEZ in support of Seabed 2030 and the NOAA Office of Ocean Exploration and Research goal to explore the U.S. EEZ. Additionally, 175 biological samples (new records, potential new species, dominant fauna, or to support trans-Atlantic connectivity studies) and 15 geological samples (to understand the geologic history and characterize habitat substrate) were collected. Data from this expedition will help to improve our understanding of the deep-ocean habitats of the U.S. continental margin and of the connections between communities throughout the Atlantic Basin.

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1. Introduction

By leading national efforts to explore the ocean and make ocean exploration more accessible, the NOAA Office of Ocean Exploration and Research (OER) is filling gaps in basic understanding of deep waters and the seafloor, providing deep-ocean data, information, and awareness. Exploration within the U.S. Exclusive Economic Zone (EEZ) and international waters as part of Seabed 2030 (https://www.ncei.noaa.gov/news/seabed-2030-map-gaps, last accessed November 2020) efforts to produce a bathymetric map of the world ocean floor by 2030 supports key NOAA, national, and international goals to better understand and manage the ocean and its resources.

Using the latest tools and technology, OER explores unknown areas of the deep ocean. NOAA Ship *Okeanos Explorer* is one such tool. Working in close collaboration with government agencies, academic institutions, and other partners, OER conducts deep-sea exploration expeditions using advanced technologies on *Okeanos Explorer*, mapping and characterizing areas of the ocean that have not yet been explored. Collected data about deep waters and the seafloor—and the resources they hold—establishes a foundation of information and fills gaps in the unknown.

All data collected during *Okeanos Explorer* expeditions adhere to federal open-access data standards and are publicly available shortly after an expedition ends. This ensures the delivery of reliable scientific data needed to identify, understand, and manage key elements of the ocean environment.

Exploring, mapping, and characterizing the U.S. EEZ are necessary for a systematic and efficient approach to advancing the development of ocean resources, promoting the protection of the marine environment, and accelerating the economy, health, and security of our nation. As the only federal program dedicated to ocean exploration, OER is uniquely situated to lead partners in delivering critical deep-ocean information to managers, decision makers, scientists, and the public, leveraging federal investments to meet national priorities.

1.1 Atlantic Seafloor Partnership for Integrated Research and Exploration

The *Windows to the Deep 2018: Exploration of the Southeast U.S. Continental Margin* (EX-18-05 and EX-18-06) expedition was the first in a series of cruises that contributed to NOAA's Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) campaign, a major multi-year, multi-national collaborative field program focused on raising collective knowledge and understanding of the North Atlantic. 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 (https://www.noaa.gov/sites/default/files/atoms/files/Leadership%20in%20Powering%20the%20American%20Blue%20Economy%20032320.pdf, last accessed November 2020), which, in addition to ocean exploration, are seafood production, tourism and recreation, marine transportation, and coastal resilience.

2. Expedition Overview

From June 13, 2018, to July 2, 2018, OER and partners conducted a two-part, telepresence-enabled ocean exploration expedition on *Okeanos Explorer* to collect critical baseline information and improve knowledge about unexplored and poorly understood deepwater areas offshore of Florida, Georgia, South Carolina, and North Carolina. EX-18-06 was part of a series of expeditions contributing to ASPIRE. Preceding OER cruises in this region include the Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) campaign, EX-14-03, and EX-18-05, cruises conducted under the banner of the Extended Continental Shelf Project (ECS; https://oceanexplorer.noaa.gov/about/what-we-do/extended-continental-shelf.html), and Windows to the Deep 2003. As such, EX-18-06 was designed to provide 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

The deepwater areas offshore Florida, Georgia, South Carolina, and North Carolina are some of the least explored areas along the U.S. East Coast. Though this region is home to millions of Americans and is experiencing some of the highest population growth rates in the U.S. (Conley et al., 2017), the offshore habitats are some of the least explored areas of the U.S. East Coast. The Southeast U.S. continental margin has some of the largest gaps in high-resolution ocean mapping data on the East Coast and limited previous observations via submersibles. These data gaps also include much of the Stetson-Miami Terrace Deepwater Coral Habitat Area of Particular Concern (HAPC) Fishery Management Area.

As part of the planning for this expedition, NOAA collaborated with the scientific and management community to assess the exploration needs and data gaps in unknown and poorly-known areas of the Southeast U.S. continental margin. NOAA incorporated the 2018 Call for Input (https://oceanexplorer.noaa.gov/okeanos/explorations/2018-

overview/input.html , last accessed November 2020) and priorities from resource managers to define the operating area for this expedition (**Figure 1**). Additional information about how OER blends input from stakeholders into campaign objectives and expedition priorities can be found in Cantwell et al.(2020). Data from this expedition helped to improve understanding of the deep-ocean habitats of the U.S. continental margin and of the connections between communities throughout the Atlantic Basin. Data from the expedition provided critical knowledge to inform deep-sea management plans for HAPCs, Marine Protected Areas (MPAs), and National Marine Sanctuaries; supported local scientists and managers seeking to understand and manage deep-sea resources; and supplied a foundation of information to stimulate subsequent exploration, research, and management activities.

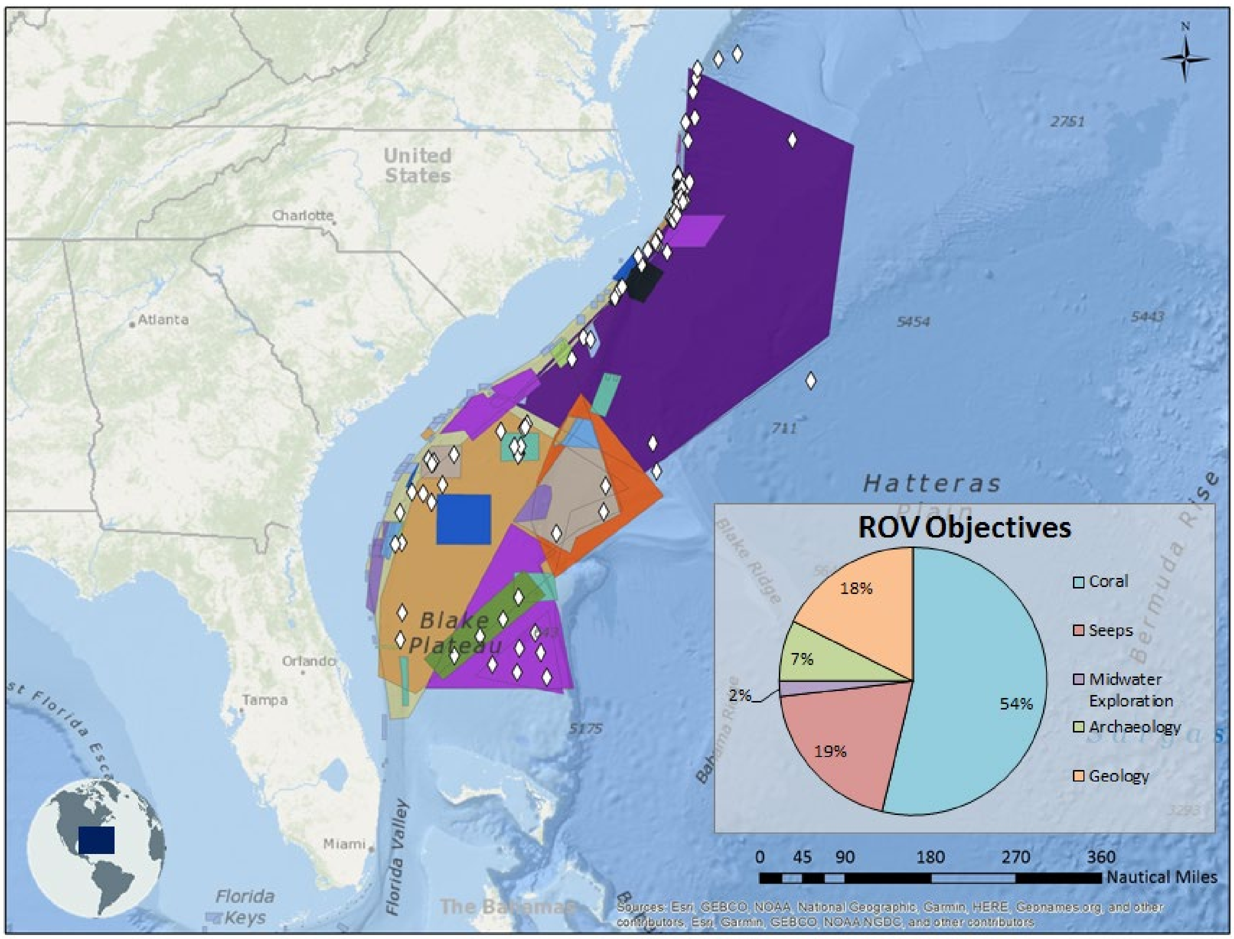

Figure 1: This map shows the different areas submitted for consideration as part of the OER's 2018 Call for Input in the Southeast U.S. Region. Each color represents a different submission for a mapping box and each white diamond represents a different ROV target proposal. Inset shows a breakdown of the priorities of submitted dive proposals. This input as well as

priorities from the SAFMC, NOAA DSCRTP, NOAA ONMS, BOEM and USGS informed a series of expedition goals for 2018 and 2019 NOAA Ship *Okeanos Explorer* missions.

This expedition also contributed to the ongoing NOAA collaboration with the National Marine Fisheries Deep-sea Coral Research and Technology Program's (DSCRTP's) Southeast Deep-sea Coral Initiative (SEDCI), the Office of National Marine Sanctuaries Maritime Heritage Program, the Bureau of Ocean Energy Management (BOEM), and the U.S. Geological Survey (USGS).

This two-part expedition used the ship's deepwater mapping systems (Kongsberg EM 302 multibeam sonar, Simrad EK60 and EK80 split-beam fisheries sonars, Knudsen 3260 chirp sub-bottom profiler sonar, and Teledyne Acoustic Doppler Current Profiler [ADCP]), NOAA's dual-body deepwater ROV, and a high-bandwidth satellite connection for real-time ship-to-shore communications. ROV dives included high-resolution visual surveys of water column and seafloor habitats as well as biological and geological sampling. Information about the first leg of this expedition (EX-18-05), which conducted 16 days of mapping on the Blake Plateau and Blake Escarpment, can be found in Lobecker et al. (2020).

2.2 Objectives

The expedition addressed science themes and priority areas put forward by NOAA scientists and resource managers, the South Atlantic Fishery Management Council (SAFMC), BOEM, USGS, and the broad ocean science community. The primary objective of the expedition was to survey deepwater areas offshore Florida, Georgia, South Carolina and North Carolina in order to provide baseline information to support management and science needs. Specifically, this expedition sought to:

- Acquire data on deepwater habitats in the Southeast and Mid-Atlantic U.S. continental margin to support priority science and management needs;
- Identify, map, and explore the diversity and distribution of benthic habitats, including fish habitats, deep-sea coral and sponge communities, chemosynthetic communities, and biological communities that colonize or aggregate around shipwrecks;
- Explore U.S. maritime heritage by identifying and investigating sonar anomalies as well as characterizing shipwrecks;
- Investigate biogeographic patterns of deep-sea ecosystems and connectivity across the Southeast U.S. continental margin for use in broader comparisons of deepwater habitats throughout the Atlantic Basin;

- Map, survey, and sample geologic features within the Southeast U.S. continental margin to better understand the geological context of the region and improve knowledge of past and potential future geohazards;
- Collect high-resolution bathymetry in areas with no (or lower quality) mapping data;
- Acquire a foundation of ROV, sonar, and oceanographic data to better understand the characteristics of the resident water column;
- Engage a broad spectrum of the scientific community and the public in telepresence-based exploration;
- Provide a foundation of publicly accessible data and information products to spur further exploration, research, and management activities.

3. Participants

The EX-18-06 expedition included mission personnel who participated in the expedition from on board NOAA Ship *Okeanos Explorer*, as well as shore-side science personnel who participated in the expedition remotely via telepresence technology. A list of participating personnel for EX-18-06 can be found in **Tables 1** and **2**.

3.1 At-Sea Mission Personnel

Table 1. Names, roles and affiliation of the mission team on board the NOAA Ship *Okeanos Explorer* during EX -18-06.

Name	Title	Affiliation
Kasey Cantwell	Expedition Coordinator	OER/ Maximus
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Leslie Sautter	Science Lead	College of Charleston/ University Corporation for Atmospheric Research (UCAR)
Derek Sowers	Mapping Lead	OER/Cherokee Nation Strategic Programs
Kevin Jerram	Mapping Watch lead	UCAR
Stephanie Bush	Sample Data Manager	Smithsonian Institution
Bobby Mohr	Global Foundation for Ocean Exploration (GFOE) Operations Manager	GFOE
Fernando Aragon	Engineering team	GFOE
Josh Carlson	Engineering team	GFOE
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Art Howard	Engineering team	GFOE
Roland Brian	Engineering team	GFOE
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3.2 Shore-Based Science Team

Table 2. Name, affiliation, email of the shore -based science team who participated in EX -18-06.

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4. Methodology

In order to accomplish its objectives, the expedition made use of:

(1) the 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 specimens, to help further characterize the deepwater fauna and geology of the region;

(2) the mapping systems (Kongsberg EM 302 multibeam sonar, Knudsen 3260 sub-bottom profiler, Kongsberg EK60 and EK80 split-beam sonars, and Teledyne ADCPs) to conduct mapping operations at night and when the ROV was on deck; and

(3) a high-bandwidth satellite connection to provide real-time ship-to-shore communications (telepresence).

4.1 ROV Surveys

ROV dive operations were conducted to support the expedition objectives, including characterizing deep-sea coral and sponge habitats, chemosynthetic communities at seeps, submarine canyons, and landslide or slump features. During each dive, the ROVs descended onto the seafloor and then moved from waypoint to waypoint, documenting the geology and biology of the area. Each ROV dive was approximately 8-10 hours long, conditions and logistics permitting. During EX-18-06, dives were primarily conducted during the day (operations described in detail by Quattrini et al., 2015, and Kennedy et al., 2019). Additional information about the general process of site selection, collaborative dive planning, scientific equipment on the ROVs, and the approach to benthic exploration can be found in Kennedy et al. (2019). At-sea and shore-based scientists identified each encountered organism to the lowest taxon possible based on data available during real-time assessment. Additionally, at-sea and shore-based scientists provided geological interpretations of the observed substrate throughout each ROV seafloor survey. These observations were recorded using the Ocean Networks Canada SeaTube software.

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. Specific transect depths were decided each day during ROV descent through an evaluation of the Simrad EK60 and EK80 data, ROV CTD data, and the acoustically-determined position of the deep scattering layer. Additionally, when seafloor depth allowed, a standard set of deeper transects were also completed at 900 m, 700 m, and 500 m. Transect length varied between 20 minutes to 50 minutes at each depth, depending on the specific objectives for water column exploration, conditions, and seafloor depth. Specific transect depths and times are noted in each Dive Summary (**Appendix A**).

4.1.1 Science Annotations

Scientific observations were cataloged using SeaTube, the web-based annotation system developed by Ocean Networks Canada and used for NOAA ocean exploration expeditions, which enables searching and editing annotations, as well as browsing video. SeaTube allowed for a distributed science team to record observations from wherever they were participating, and instantly share those observations (Cantwell et al., 2020). This allowed for the generation of a common dataset in real-time, optimizing information sharing and the interdisciplinary nature of the resulting data.

By design, SeaTube allowed participating scientists to record all types of observational data, including biological identifications automatically linked to the World Register of Marine Species (WoRMS) database (WoRMS Editorial Board, 2020), geological and substrate observations, and operational notes such as when sampling is conducted, when the vehicles leave the seafloor, and any equipment malfunctions. SeaTube also automatically incorporates ROV environmental sensor data (e.g. CTD data) and vehicle position information.

At the conclusion of each OER ASPIRE expedition (2018-2022), a robust quality assurance/quality control (QA/QC) of the SeaTube annotations has been carried out by the France Lab at the University of Louisiana at Lafayette (supported by NOAA OER through UCAR), under the direction of Dr. Scott France. The QA/QC process for the data from EX-18-06 analyzed video and annotations from benthic exploration by updated misspellings and incorrect annotations, added missing annotations, and merged duplicate annotations. Animals were identified using WoRMs and the OER Benthic Deepwater Animal Identification Guide (https://oceanexplorer.noaa.gov/okeanos/animal_guide/animal_guide.html, last accessed September 17, 2020).

4.2 Specimen Collections

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 biological and geological collection boxes. The primary goal of sampling operations was to collect voucher specimens to be made publicly available to the science community so they could be used to characterize the site. For each collected specimen, the date, time, latitude, longitude, depth, salinity, temperature, and dissolved oxygen (DO) content were recorded at the time of collection. Geological samples were acquired for age dating and geochemical composition. Biological specimen 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, or rare morphotypes; specimens targeted to contribute to trans-Atlantic connectivity studies were also collected.

After vehicle recovery, specimens were examined for commensal organisms, labeled, photographed, and entered into a database containing all relevant metadata. Any commensal organisms found were separated from the primary specimen and processed separately as an "associate" sample. Geological samples were air dried and placed in rock bags. At the conclusion of the 2018 expeditions, these samples were shipped to the Marine and Geology Repository at Oregon State University (OSU), where they were photographed and entered into an online database (http://osu-mgr.org, last accessed November 2020). Thin and polished sections were made for each hard-rock sample and included in the database.

Biological samples were subsampled for inclusion in the Ocean Genome Legacy Project at Northeastern University (https://www.northeastern.edu/ogl/, last accessed November 2020) for future barcoding and DNA extraction. For this purpose, a small subsample, consisting of ~1 cm^2 of tissue, was removed from the original sample and processed using the OGL DNA extraction kit. All voucher specimens and subsamples from EX-18-06 have been delivered to the Smithsonian Institution National Museum of Natural History (NMNH) for long-term archival and public access through https://collections.nmnh.si.edu/search/iz/ (last accessed November 2020). Additionally, a second genomics sample was collected for the NMNH's Biorepository (https://naturalhistory.si.edu/research/biorepository, last accessed November 2020). 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 collected specimens, the remainder of the biological sample was preserved in 95% EtOH. For select taxa, vouchers or subsamples were preserved in buffered formalin per recommendation from taxa experts and guidance provided by the NMNH. Full details of the preservation of each biological sample can be seen in the metadata record associated with each specimen.

4.3 Seafloor Mapping

Mapping operations included Kongsberg EM 302 multibeam, Kongsberg EK60 and EK80 split-beam, Knudsen sub-bottom profiler, and ADCP data collection. The schedule of mapping operations included overnight transits and whenever the ROV was on deck. Lines were planned to maximize either edge matching of existing data or filling in of data gaps in areas where bathymetry coverage did not exist. In regions with no existing data, exploration transit lines were planned to optimize potential discoveries. Targeted mapping operations were conducted in the vicinity of: (1) the Stetson Miami Terance Deep Coral HAPC, (2) central Blake Plateau, and (3) in the vicinity of the North Carolina canyons and Currituck Landslide.

4.3.1 Multibeam Sonar (Kongsberg EM 302)

Multibeam seafloor mapping data were collected using the Kongsberg EM 302 sonar, which operates at a frequency of 30 kilohertz (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. When possible, transits were designed to maximize 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. Additionally, multibeam mapping operations were conducted directly over planned ROV dive locations in order to collect seafloor mapping data to help refine dive plans. Multibeam mapping operations collected data on seafloor depth (i.e., bathymetry), seafloor acoustic reflectivity (i.e., seafloor backscatter), and water column reflectivity (i.e., water column backscatter).

Background data used to guide exploratory mapping operations included mapping data collected during NOAA Ship *Okeanos Explorer* expeditions, notably cruises from the Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) campaign, EX-14-03, and EX-18-05 as well as ECS data. Dive planning and mapping operations were conducted using bathymetric grids created using all available bathymetry archived with the NOAA NCEI using NCEI's

Autogrid tool. Sandwell et al (2014) satellite altimetry data was also used to plan operations.

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 meters 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 in order to provide supplemental information about the sedimentary features underlying the seafloor. Specific sub-bottom profile surveys at 4-5 knots were conducted overnight while operating over the Currituck Landslide.

4.3.3 Split-beam Sonars (Simrad EK60 and EK80)

NOAA Ship *Okeanos Explorer* is equipped with three Simrad EK60 and one Simrad EK80 split-beam sonar transducers operated at frequencies of 18, 120, and 200 kHz for the EK60 and 70 kHz for the EK80. Though the *Okeanos Explorer* is equipped with a 38 kHz EK80; it was not functional during EX-18-06. These sonars were used continuously throughout the cruise 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 or schools of fish. These sonars can also help detect the presence of gaseous seeps emanating from the seafloor. EK60 and EK80 data were used during midwater transects of ROV dives to detect the depth of the deep scattering layers due to aggregations of biological organisms in the water column.

4.3.4 Acoustic Doppler Current Profiler (Teledyne Workhorse Mariner ADCP)

NOAA Ship *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.

4.3.5 Expendable Bathythermograph (XBT) Systems

Expendable bathythermographs (XBTs) were collected every six 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 (CTD)

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

4.4 Sun Photometer Measurements

OER gathers limited at-sea sun photometer measurements onboard NOAA Ship *Okeanos Explorer* in order to support a NASA-led, long-term research effort that assesses marine aerosols. Onboard personnel collected georeferenced sun photometer measurements on sunny days during the expedition in order to collect data to support the Maritime Aerosol Network (MAN) component of the Aerosol Robotic Network (AERONET). AERONET is a network of sun photometers which measure atmospheric aerosol properties around the world. MAN compliments AERONET by conducting sun photometer measurements on ships of opportunity in order to monitor aerosol properties over the global ocean. Sun photometer measurements were conducted as time allowed on cloud-free days.

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. NOAA's Administrative Order (NAO) 216-6A Companion Manual (https://www.nepa.noaa.gov/docs/NOAA-NAO-216-6A-Companion-Manual-01132017.pdf, last accessed November 2020) describes the agency's specific procedures for NEPA compliance. Among these is the need to review all proposed NOAA-supported field projects for their environmental effects. An Environmental Review Memorandum was completed for this survey, 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 for this expedition, as no extraordinary circumstances existed that required the preparation of an environmental assessment or environmental impact statement.

Informal consultation was initiated under Section 7 of the Endangered Species Act (ESA), requesting the NOAA National Marine Fisheries Service (NMFS) Protected Resources Division concurrence with OER's biological evaluation determining that NOAA Ship *Okeanos Explorer* operations conducted as part of ASPIRE, may affect, but are not likely to adversely affect, ESA-listed marine species. The informal consultation was completed on August 8, 2018 when OER received a signed letter from the Regional Administrator of the NMFS

Southeast Regional Office (SERO), stating that NMFS concurs with OER's determination that conducting proposed ASPIRE cruises are not likely to adversely affect ESA-listed marine species. OER has completed consultation with the NOAA Habitat Conservation Division on potential ASPIRE impacts of our operations to Essential Fish Habitat (EFH). They concurred that OER's operations would not adversely affect EFH provided adherence to the proposed procedures and their guidance stated in the letter. Copies of all environmental compliance are publicly available in EX-18-06 Project Instructions (Cantwell, 2018).

Additionally, OER received a Letter of Acknowledgement (LOA) from NMFS for operations in the Southeast Deepwater MPAs and areas deemed as a HAPC (**Appendix B**). A copy of the LOA can also be found in the EX-18-06 Project Instructions.

6. Expedition Schedule

EX-18-06 was planned for a total of 22 days at sea, from June 11 to July 2, 2018, departing from Charleston, SC, to Norfolk, VA. Departure was postponed due to a delay in fueling the ship and executed cruise dates were June 13 to July 2, 2018, totaling 20 days at sea for the cruise. There were 20 scheduled dives, with 17 dives achieved (**Tables 3** and **4**). Two dives were lost due to the fueling delay, and one was lost to a mechanical issue on June 18, 2020.

Table 3. Schedule of EX-18-06. All times are local (EDT) to the ship.

June - July						
SUN	MON	TUES	WED	THURS	FRI	SAT
3	4	5 Webinar for Educators @ 1600	6	7	8 Ship Tours Tri-Ship Hangout @ 1500	9

10	11 SAILING DELAYED UNTIL 6/12	12 *Okeanos Explorer* shifts to fuel pier @ 1430 Fueling @ 1930 -2400 Sailing delayed until 6/13	13 ***Okeanos Explorer*** **Departs Fuel Pier at 0930** Transit mapping to first dive site Pew Coral Group @ SS ECC @ 1445	14 **Dive 01:** Blake Escarpment North Reddit Ask Me Anything Live @ 1400-1600 Overnight mapping	15 **Dive 02:** Blake Ridge +Midwater Overnight mapping	16 **Dive 03:** Giant Bedforms SC Aquarium Live Stream event and on science line @ 1000 - 1400 Overnight mapping
17 **Dive 04:** Blake Escarpment South + Midwater Overnight mapping	18 **Dive Canceled, shift to mapping operations** NOAA Office of Habitat Conservation Open House at SS ECC @ 1145	19 **Dive 05:** Stetson Mesa South Overnight mapping	20 **Dive 06:** Stetson Mesa North NOAA NART at Inner Space Center (ISC) 1320 Nat Geo @ SS ECC 1530 Overnight mapping	21 **Dive 07:** Richardson Ridge Doseum testing @ 1400 PM Overnight mapping	22 **Dive 08:** Richardson Scarp Overnight mapping	23 **Dive 09:** Blake Ridge Wreck SC Aq Live Stream and on science line 1000 - 1400 PD Workshop @ Doseum 1530 Overnight mapping

24 **Dive 10:** Cape Fear (Lophelia Banks) Overnight mapping	**25** **Dive 11:** **South of** Pamlico Canyon (Shallow) Patriot's Point on Science Line 1000- 1400 Monitor NMS on Science Line @ 1215 and 1415 Overnight mapping	**26** **Dive 12:** Pamlico Inter-Canyon Ridge (Deep) +Midwater Weather Channel Interview. @ 1500 Intl. Maritime University of Panama @ UNH 1400 PM ET Overnight mapping	**27** **Dive 13:** "Big Dipper" Anomaly Patriot's Point on Science Line 1000 - 1400 Overnight mapping	**28** **Dive 14:** Hatteras Canyon Sea Grant Fellows at SS ECC @ 1330 Overnight mapping	**29** **Dive 15:** Keller Canyon +Midwater NC Museum @ 1300 Overnight mapping	**30** **Dive 16:** Pea Island SC Aq Live Stream and on science line @ 1000-1400 Overnight mapping
1 **Dive 17:** Currituck Overnight mapping	**2** **Okeanos Docks in Norfolk, VA** Ship tour: VA Sea Grant @ 1500	**3** Ship tour: MARCO @ 0900	**4** Holiday			

7. Expedition Map

EX-18-06 began in Charleston, SC, and ended in Norfolk, VA. **Figure 2** shows the locations of the expedition operations, which included ROV exploration and seafloor mapping along the Blake Plateau, Blake Escarpment, and North Carolina Canyons.

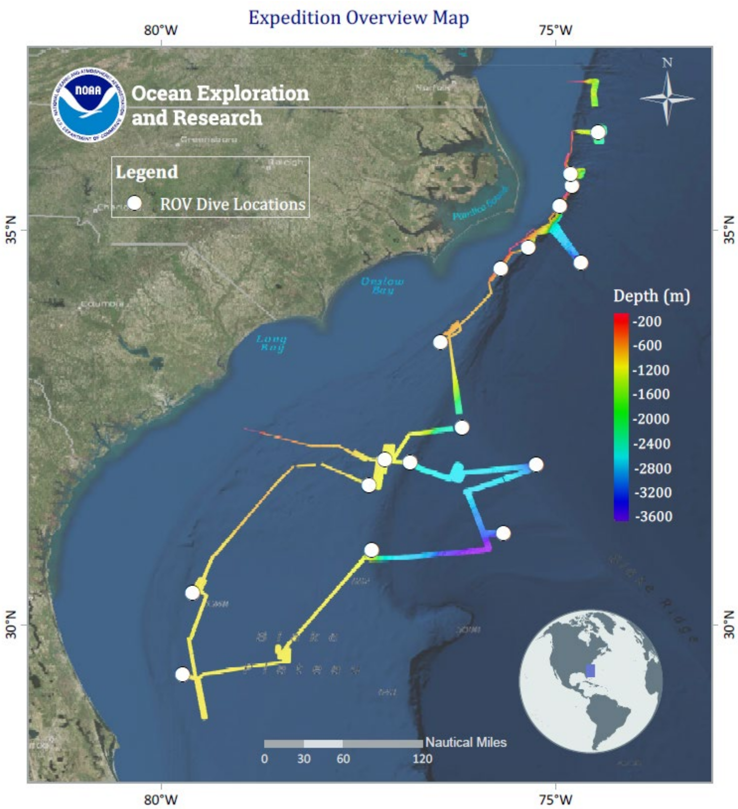

Figure 2. Map showing the locations of the 17 ROV dives and bathymetry data collected during EX-18-06.

8. Results

Depth ranges explored during ROV surveys were between 325 to 3,424 meters. During the 17 dives, the ROV spent a total of 96:55:46 hours on the bottom and 02:10:00 hours conducting water column exploration (**Table 4**).

Table 4. Summary information for the 17 ROV dives conducted during EX-18-06. Days with dedicated midwater exploration are highlighted in blue.

Date	Dive #	Site	Starting Depth (m)	Location	UCH	Water column transects?
11-Jun		DEPARTURE DELAYED	--	--	-	-
12-Jun		DEPARTURE DELAYED	--	--	-	-
13-Jun		Departed Charleston, SC	--	--	-	-

14-Jun	1	Blake Escarpment North	1736.0 m	32° 3.332' N ; 76°50.783' W	no	no
15-Jun	2	Blake Ridge + Midwater	3424.0 m	32° 1.561' N ; 75° 14.939' W	no	yes
16-Jun	3	Giant Bedforms	3358.0 m	31° 9.352' N ; 75° 39.655' W	no	no
17-Jun	4	Blake Escarpment South + Midwater	1321.0 m	30° 56.422' N ; 77° 19.825' W	no	yes
18-Jun	Dive Canceled	--	--	--	-	-
19-Jun	5	Stetson Mesa South	734.0 m	29° 21.906' N ; 79° 43.694' W	no	no
20-Jun	6	Stetson Mesa North	788.0 m	30° 23.916' N ; 79° 36.073' W	no	no
21-Jun	7	Richardson Ridge	873.0 m	31° 45.984' N ; 77° 21.869' W	no	no
22-Jun	8	Richardson Scarp	1006.0 m	32° 5.421' N ; 77°9.767' W	no	no
23-Jun	9	Blake Ridge Wreck	FOUO*	FOUO*	yes	no
24-Jun	10	Cape Fear (Lophelia Banks)	454.0 m	33° 34.591' N ; 76° 27.704' W	no	no
25-Jun	11	South of Pamlico Canyon	1716.0 m	34° 46.406' N ; 75° 20.8' W	no	no
26-Jun	12	Inter-Canyon Ridge	3470	35° 5.84' N ; 75° 1.454' W	no	no
27-Jun	13	"Big Dipper" Anomaly (Wreckless Scarp)	800 - 250	34° 30.393' N ; 75° 41.73' W	no	no
28-Jun	14	Hatteras Canyon	450	35° 17.921' N ; 74° 56.949' W	no	no
29-Jun	15	Keller Canyon + midwater	825	35° 33.325' N ; 74° 47.717' W	no	yes
30-Jun	16	Pea Island	550	35° 42.424' N ; 74° 48.62' W	no	no

1-Jul	17	**Currituck**	1850	36° 13.706' N ; 74° 27.875' W	no	no
2-Jul		RETURN TO PORT- NORFOLK, VA	--	--	-	-

*Location information from underwater cultural heritage dives (e.g. Dive 9) is for official use only (FOUO).

8.1 Science Summary

During the *2018 Windows to the Deep: Exploration of the Southeast U.S. Continental Margin* expedition, 17 ROV dives allowed visual exploration of several geologic and biogenic features (described below in section 8.1.1.). Over the course of these dives, the team was able to visually observe seafloor features identified by the mapping efforts that were part of the expedition, including a variety of habitat types for benthic and mobile fauna. Many exciting biological observations were made, including high-density and high-diversity coral and sponge communities, commercially important species in new areas, dramatic predation events, mating, juveniles utilizing habitat, species at deeper depths or wider geographic distributions than previously known, associations between corals and/or sponges with other species, sightings of rare species, and marine debris at most dive sites. Many of these observations may guide future research. Highlights of the biology observed during the ROV dives are given below (Section 8.1.2), grouped by geologic feature type. More comprehensive lists of species and behaviors observed can be found in the individual Dive Summaries (https://www.ncei.noaa.gov/waf/okeanos-rov-cruises/ex1806/, last accessed November 2020).

8.1.1 Geology

During EX-18-06, a variety of seafloor substrates and geologic features were encountered. These include intra-slope terraces, deep terrace and sediment plains, giant bedforms, coral mounds, shelf-edge rocky ledges, submarine canyon slopes, and mud cliffs, each of which is described and summarized below.

Intraslope Terraces

Dive 01 – Blake Escarpment North
Dive 04 – Blake Escarpment South
Dive 08 – Richardson Scarp

Three dives were conducted along the outer reaches of the Blake Plateau, where the relatively flat-lying strata outcrop as depths descend toward the Blake Escarpment. The edges of these strata form stair-step like areas, where rock exposure often results in hard-bottom substrate. Dives 01, 04, and 08 each began at the foot of a terraced feature identified using the high-resolution multibeam sonar. Backscatter imagery for these dive sites showed high intensity, indicating relatively hard substrate. On each dive, very low-sloped pelagic mud seafloor was found at the base of the features, with intermittent rock slab outcrops at the terrace steps. These rocks were most commonly composed of interbedded indurated/semi-lithified pelagic muds, which broke easily. They were mostly comprised of clays and silts, likely of biogenic origin. Many exposed surfaces were coated with what appears to be FeMn crust.

The outcropping rocks were sometimes in-place with steep slopes at the edges of the terrace. In nearly all areas, rock slabs served as excellent substrate promoting habitat for numerous species of soft corals and sponges (**Figure 3**), as well as many mobile organisms (e.g. squat lobsters). In contrast, the flat-lying mud seabed areas were less densely populated, with lower diversity. Few corals were observed in the mud areas. Dive 04 included an impressive vertical rock wall with many exposed layers of varying strata. Many small Mn nodules were observed on the flat step areas of Dive 08, and a vertical wall with 31 m of relief hosted several large corals and sponges (**Figure 3**). Varying degrees of induration and encrustation by FeMn oxides determine the rocks' resistance to erosion, the terracing and the angle of the slope, and the concentrations of organisms.

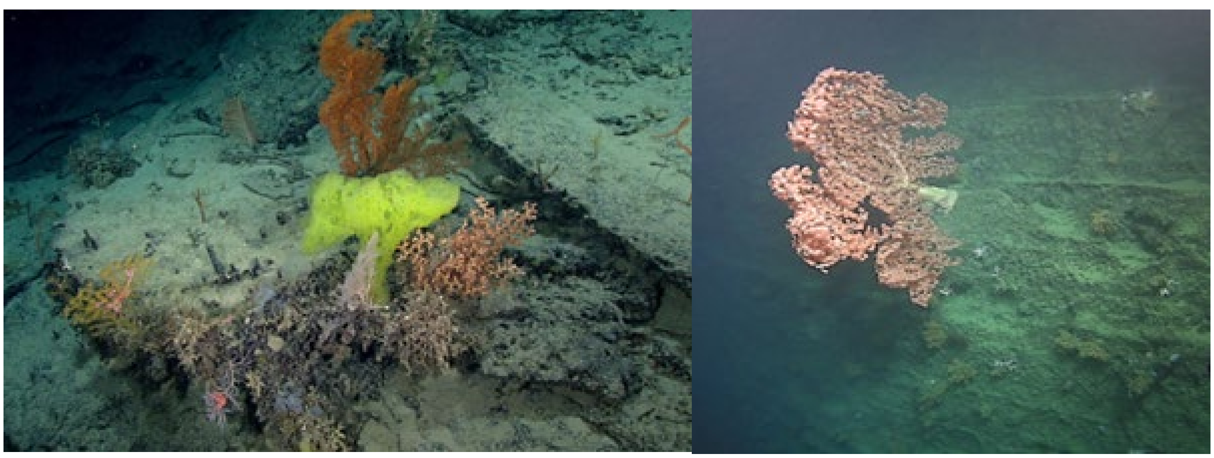

Figure 3 : Dive 04 – Blake Escarpment South, various species of corals and sponges on the outcrops of the portion of the Blake Escarpment surveyed.

Deep Terrace and Sediment Plains

Dive 02 – Blake Ridge
Dive 09 – Blake Ridge Wreck

High-resolution bathymetry showed this region as a gently sloped, moderately terraced landscape. Although backscatter surfaces showed this dive site lying within a large area of high intensity, much of the site was low slope and covered with mud, often with large areas of gravel that appeared to be FeMn-encrusted. Tabular mudstones that tilted beneath the muds supported numerous large sponges (**Figure 4**). Likely, the mud was underlain by this hard substrate and the sonar penetrated the sediment veneer, generating the high intensity return. Gravel was often concentrated in the lee of large sponges, and indicate episodes of significant current velocities.

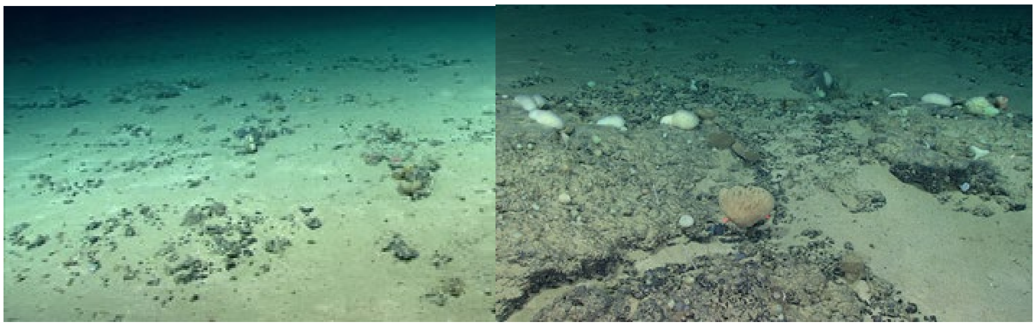

Figure 4 : Dive 02 – Examples of the benthic environment on Blake Ridge.

The Blake Ridge Wreck (Dive 09) was located on an extremely flat, featureless plain of mud. No ripples or other bedforms were observed that would indicate persistent currents affected the area. Wreck artifacts and a pile of conch shells (**Figure 5**, left) showed little burial, indicating low sediment accumulation rates. Ruts made by the DSV *Alvin* several years ago looked extremely fresh and unchanged. The surface of the anchor chain was still exposed (**Figure 5**). Additional information about this dive can be f ound in the Dive Summary.

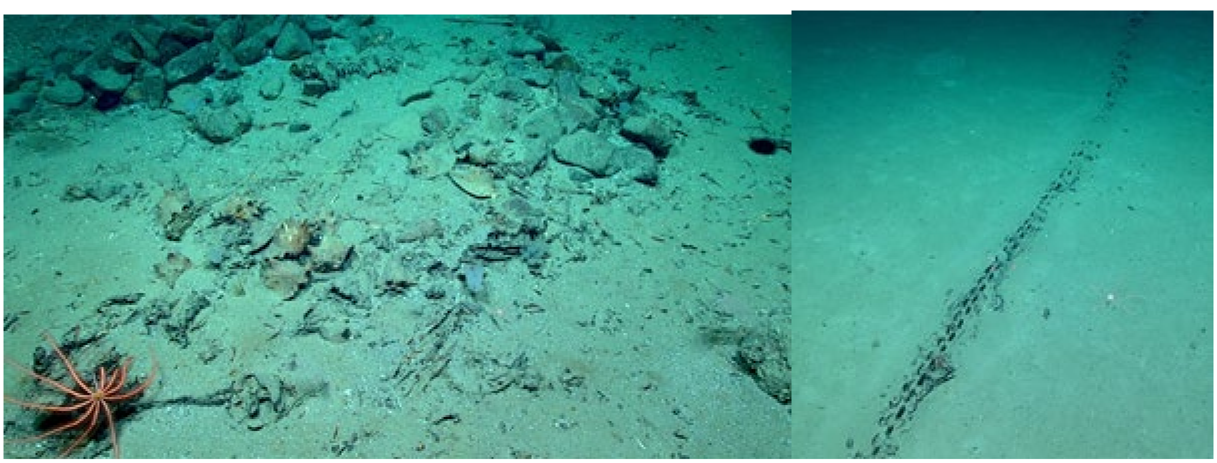

Figure 5 : Artifacts from the Blake Ridge wreck wrest on soft sediment, likely mud (left). The artifacts are indicative of a vessel sailing in the first half of the 19th century, possibly 1830s or 1840s. At the end of the dive, the vehicles followed the end of the anchor chain (right) until it was time to begin recovery.

Giant Bedforms

Dive 03 – Giant Bedforms

This dive was within a huge region south of the Blake Ridge, characterized by enormous undulating bedforms where wavelengths of bedforms exceed 800 m. Sediments collected were stiff and cohesive. Clay-sized particles (likely $CaCO_3$ nannofossils) abounded (estimated at >80%), with planktonic foraminifera dominating the silt -size fraction (**Figure 6**, left). One portion of a bedform sloped at least 70° and exhibited ripples from horizontal currents moving along the wall (**Figure 6**, right). No rock outcrops were observed, and few organisms were seen. The few sessile organisms encountered clung to sunken balls of Sargassum. Large pitted and scoured areas suggested evidence of beaked whale feeding.

Figure 6: Foraminifera collected during Dive 03 imaged by the digital microscope onboard *Okeanos Explorer* (left) and a landscape view of the ripples observed on the seafloor (right).

Coral Mounds

Dive 05 – Stetson Mesa South
Dive 06 – Stetson Mesa North
Dive 07 – Richardson Ridge
Dive 10 – Cape Fear (Lophelia Banks)

Four different dive sites with coral mounds were explored, three of which were on the Blake Plateau (Dives 05, 06, and 07), and one (Dive 10) was in the Cape Fear Lophelia Banks Deepwater Coral HAPC Fishery Management Area. The Blake Plateau mounds are representative of thousands of similar features mapped during EX-14-02 and EX-18-05. These mounds typically have ~100 m of relief, with crests at depths between 600 and 700 m. They exhibit gradual to steep slopes ranging 15 to 30°.

All mounds explored during EX-18-06 were strongly influenced by the Gulf Stream, due to the proximity of the dive sites to the axis of the Gulf Stream. Even Richardson Ridge, located well east of the current's usual path, was experiencing significant flow due to the stream axis' bending/meandering.

All four coral mound sites were comprised of thick accumulations of dead coral rubble, the remaining skeletal framework of old *Lophelia pertusa* stony coral. This skeletal framework provided the complex, hard substrate that is an ideal habitat for a high diversity of organisms that both live attached to the framework, and within the cave-like areas beneath. At the shallowest points of the Blake Plateau mounds visited during Dives 05, 06, and 07, thriving communities of *L. pertusa* were encountered, and current velocities were strongest. However, on the slopes and swales between crests, and on two deeper adjacent mounds explored during Dive 05, few living colonies were observed, and moderate currents were encountered.

In some areas of the Blake Plateau, the mounds were oriented in a chain-like arrangement, while in other areas they were individually situated. Richardson Ridge (Dive 07) is a chain of mounds that has been modified by significant erosion from slumping, resulting in steep (>30º) walls. Learning that these elongate, steep ridge areas were actually coral mounds was a significant finding, as similar features occur in many areas of the region in addition to the rounded mounds seen throughout Stetson Mesa. The amount of live coral observed at the crest of the Richardson Ridge chain-like mound was quite high compared to other coral mounds visited (**Figure 7**).

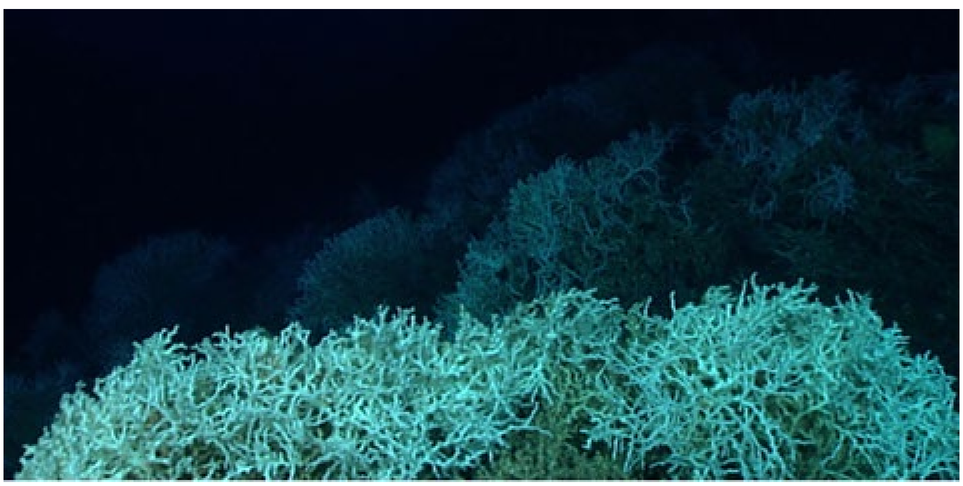

Figure 7: Dive 07 at Richardson Ridge shows an example of the live coral discovered at the top of the mound features.

Dive 10 explored the Northwest flank of Lophelia Bank, which had not been explored previously. This mound was significantly shallower, and the dive crested at 375 m water depth. Although the mound's structure was built by *L. pertusa* stony coral, the flank visited on Dive 10 had nearly no living *L. pertusa*. Instead, abundant, lush carpets of orange anemones dominated the high points of the ridge-like mound area (**Figure 8**).

Figure 8 : The dive at Cape Fear (Lophelia Banks) revealed significant and dense secondary colonialism of the dead *Lophelia* structures.

Coarse-grained calcareous sediments were found infilling the skeletal framework. The sediment matrix included shell remains of planktonic microfauna, including pteropods and foraminifera (**Figure 9**). Little fine grain material is able to deposit in this environment due to the high current velocities. The coral rubble appeared to armor the flanks and portions of mound crests, while making excellent substrate for growth of coral and sponge communities.

Figure 9: Planktonic microfauna, including pteropods and foraminifera, retrieved from Dive 06, imaged by the digital microscope onboard *Okeanos Explorer*.

Shelf-Edge Rocky Ledges

Dive 13 – "Big-Dipper Anomaly" (Wreckless Scarp)

Initially, this dive was planned to identify a potential WWII wreck that had been targeted by marine archaeologists, based on previously-mapped, high-backscatter returns that were coincident with a large high-relief structure at the edge of the continental shelf. Additional multibeam tracklines verified and enhanced the site's image and also showed anomalous sonar returns in the water column immediately above the site. However, no wreck was found, but instead a steep scarp with slopes 20-50° was found, exhibiting many layers of outcropping rocks. These rocks provide habitat for a rich diversity of fish and invertebrate organisms (**Figure 10**). Marine debris (aluminum cans, fishing gear) was observed throughout the site.

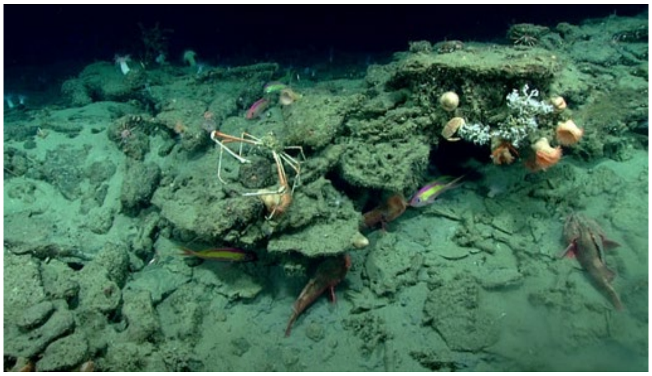

Figure 10: Dive 13 revealed numerous layers of outcropping rocks, but no shipwreck.

Submarine Canyon Slopes

Dive 11 – South of Pamlico Canyon
Dive 12 – Inter-Canyon Ridge
Dive 14 – Hatteras Canyon
Dive 15 – Keller Canyon
Dive 16 – Pea Island

Five dives were located on steep slopes within and between submarine canyons along the North Carolina continental slope, with dive depths ranging from 340 to 1,700 m. Substrate throughout these dives was consistently clay/silt particles (mud), comprised mostly of calcareous microfossils with increasing terrigenous material in shallower areas. No rock or hard-bottom substrate was encountered; however, some areas showed significant compaction that allowed for steeply sloped seabed (**Figure 11**, left). Numerous deep burrows with surrounding mounded areas were the only features on the steeply sloped dive track (**Figure 11**, right).

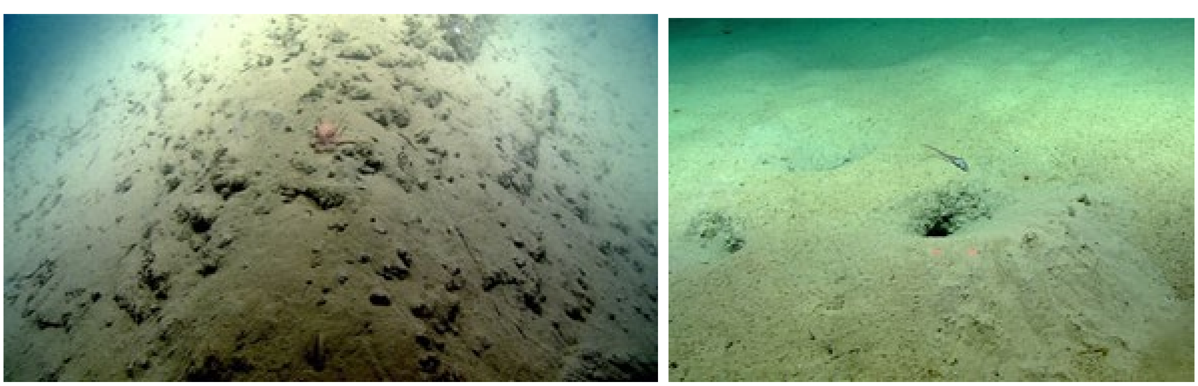

Figure 11: Characteristic landscape view of seafloor surveyed at Keller Canyon (left), and example of the deep burrows that were observed throughout Dive 12 at Inter-Canyon Ridge (right).

Bacterial mats indicative of methane gas seeps (**Figure 12**, left) were seen on Dive 14 – Hatteras Canyon, Dive 15 – Keller Canyon, and Dive 16 – Pea Island (**Figure 13**). Active methane seep bubbling was observed at Hatteras Canyon (Dive 14) and Pea Island (Dive 16), although venting was not vigorous (**Figure 12**, right).

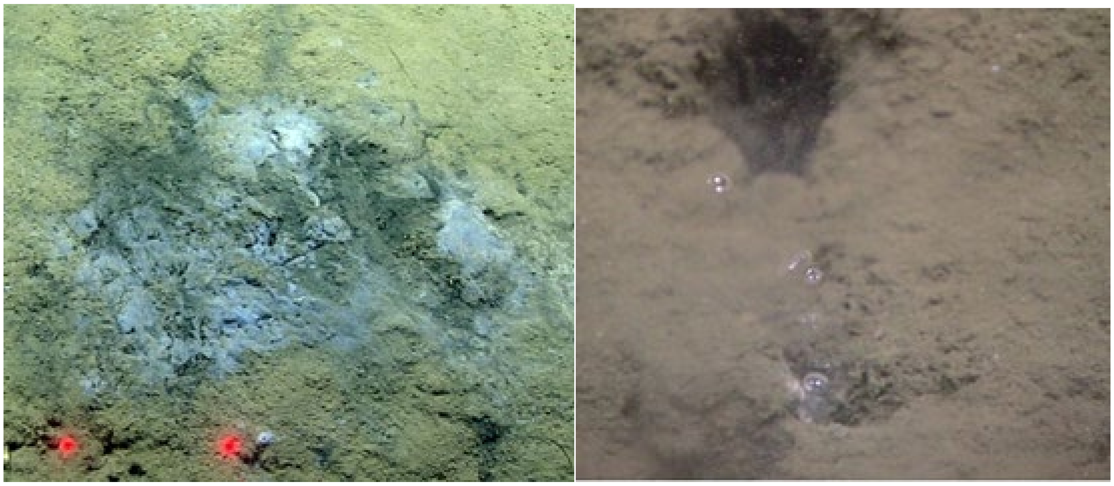

Figure 12: Bacterial mats observed at Hatteras Canyon (left) and diffuse venting at Pea Island (right) were examples of evidence of seep activity observed during EX-18-06.

Pea Island appeared to be the most active of the five sites visited, as evidenced by the high-density of white bacterial mats, with underlying anoxic (black) sediments (**Figure 13**).

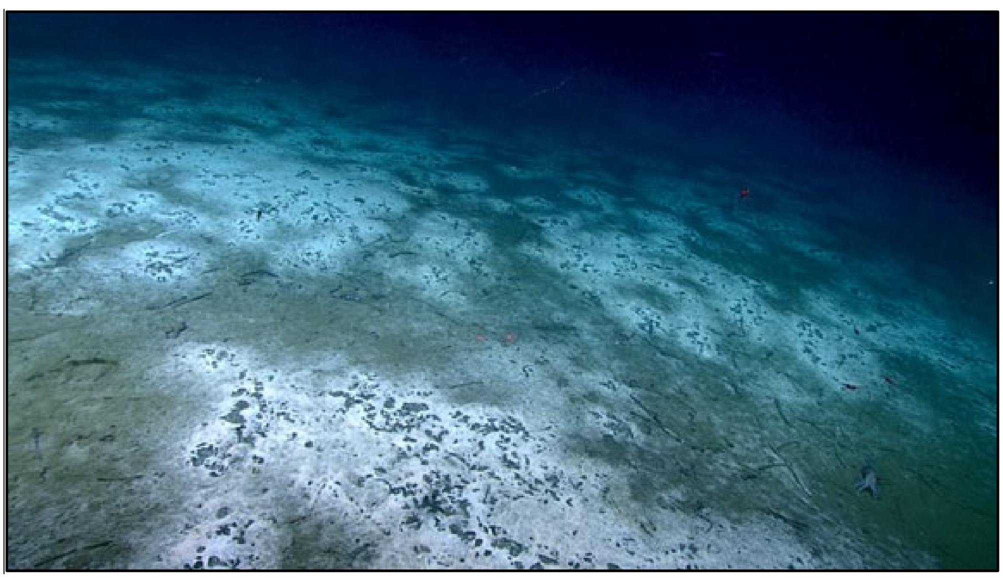

Figure 13: Dive 16 explored bacterial mat communities at Pea Island.

Mud Cliffs

Dive 17 – Currituck

This dive explored the lower headwall of the portion of continental margin associated with the Currituck Landslide feature that has not yet failed. The target was a vertical wall with relief of nearly 100 m.

The sediment plain at the cliff's base had scattered, individual rocks (potentially dropstones or ballast), that were effective hard-ground for many organisms, some of which were not seen elsewhere during the dive (**Figure 14**, left). At the base of the wall, large blocks formed an apron of debris (**Figure 14**, right). Attempts to collect a rock sample failed, as the "rock" was actually cohesive, unconsolidated muds which disintegrated in the ROV's manipulator arm claw.

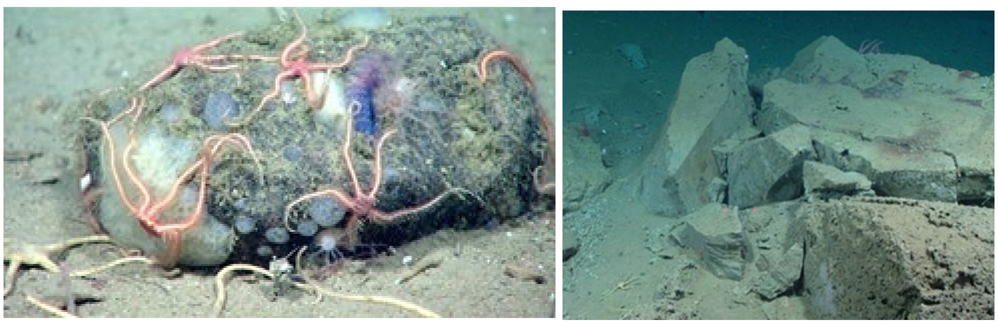

Figure 14: Examples of rocks observed during Dive 17.

The vertical segments of the wall displayed surprisingly smooth, flat, sheared areas, with angular edges (**Figure 15**). Continued 'rock' sampling attempts verified that the entire cliff was composed of these cohesive fine-grained sediments. Despite the lack of lithified rock, numerous organisms, such as brisingid sea stars took full advantage of the relatively hard substrate of the blocky muds.

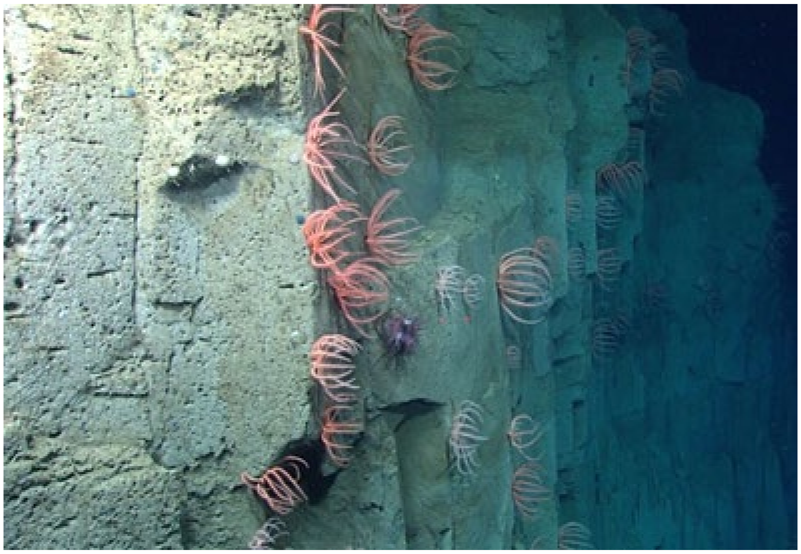

Figure 15: The vertical segments of the portion of the wall explored during Dive 17 at Currituck were composed of smooth, flat sheared areas, with angular edges.

8.1.2 Biology

During EX-18-06, there were many biological organisms observed during the ROV dives. These are grouped by substrate. The following sections - *Intra-slope Terraces*, *Deep Terrace*, *Sediment Plains and Giant Bedforms*, and Coral Mounds, detail the biological observations made during ROV exploration.

Intraslope Terraces

Dive 01 – Blake Escarpment North
Dive 04 – Blake Escarpment South
Dive 08 – Richardson Scarp

The three dives at intraslope terraces (escarpments) traversed two major habitat types that were inhabited by different fauna: soft sediment plains (mud) at the base of escarpments, and intermittent rock slabs on or near escarpment walls. Generally, echinoderms such as brittle stars, sea stars, and pancake urchins, along with sea pens and cerianthid tube anemones, were observed in the mud habitat, though at the Blake Escarpment North, the bamboo octocoral *Acanella* sp. and sea pens were present (**Figure 16**).

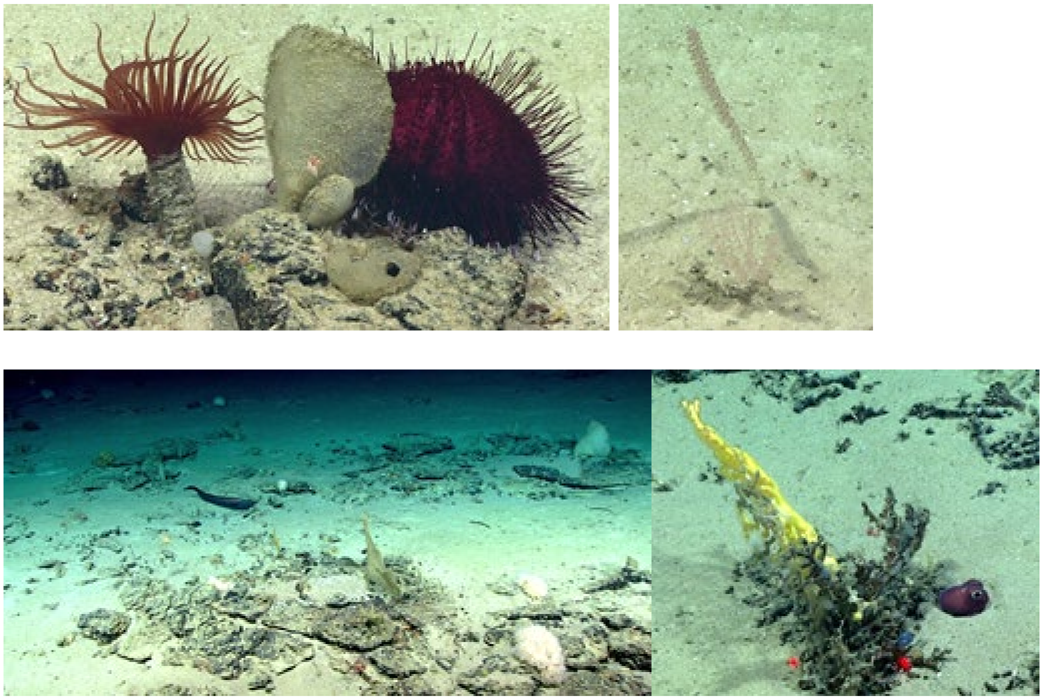

Figure 16: Organisms inhabiting soft sediment areas near bases of intra-slope terraces: (upper left – Dive 01) A cerianthid tube anemone extends into the sediment next to a small rock with attached sponges, a hermit crab, and a mobile pancake urchin (*Hygrosoma* sp.); (upper right – Dive 01) the bamboo octocoral *Acanella* sp. and a sea pen living in soft sediment habitat; (middle left – Dive 01) low-relief rock slabs were colonized by a variety of demosponges and a stalked crinoid; (middle right – Dive 04) the yellow scleractinian coral *Enallopsammia rostrata* was attached to coral rubble, which also hosted a crinoid, hermit crab and a blue encrusting sponge. A bobtail squid (Family Sepiolidae) is partially buried in the sediment next to the coral, and a skeleton of *Desmophyllum dianthus* is seen in the upper right of the image.

Nearly all exposed rock provided suitable habitat for corals and sponges. The highest diversity of antipatharian black corals and octocorals occurred at the southern portion of the Blake Escarpment (Dive 04), making this dive a highlight of the expedition. At least seven antipatharian genera were observed on rocky substrate at the base and wall of the escarpment (**Figure 17**), whereas only one or two antipatharian genera were observed at the other escarpment sites. Octocoral diversity was also high at this site, with at least 11 genera observed, which was about double the number observed at the other escarpment sites. Octocoral species belonging to the Chrysogorgiidae and the Alcyoniidae (*Anthomastus* spp. and/or *Pseudoanthomastus* spp.) were present at all escarpment sites. Species belonging to the genus *Paragorgia* were seen on Dive 01 (*P. johnsoni* with a brittle star associates, **Figure 16**) and Dive 08 where several large *P. arborea* grew horizontally from the steep scarp face (**Figure 18**). A large skeleton, likely from *P. arborea*, was also seen at the Richardson scarp (**Figure 18**). Isidid bamboo octocorals were observed during Dives 01 and 04, where they became more abundant toward the crest of the escarpment on the latter dive. The colonial scleractinian corals *Solenosmilia variabilis* and *Enallopsammia rostrata*, along with the solitary coral *Desmophyllum dianthus* also occurred at this southern portion of the Blake Escarpment (**Figure 17**; Dive 04) yet were absent from the deeper Northern Blake Escarpment (Dive 01). Sponge species differed between the North and South Blake Escarpment sites as well, with demosponge species dominating at the northern site and hexactinellid glass sponges dominating the south site, including a species, *Tretopleura*, that was not seen elsewhere on the expedition (**Figure 17**). Although scleractinian corals were not abundant at the Richardson Scarp site (Dive 08), it is noteworthy that both *S. variabilis* and *L. pertusa* were both present and co-occurred (see **Figure 18**).

Figure 17: The vertical walls and ledges at the Blake Escarpment South site (Dive 04) were home to a variety of corals, sponges, and the occasional mobile species, such as crabs and/or fishes: (upper left) the scleractinian corals *Solenosmilia variabilis* and *Desmophyllum dianthus*, octocorals, and glass sponges grew underneath a ledge at the crest of the scarp, while a large black coral (*Leiopathes* sp.) grew above the ledge; (upper right) black corals, octocorals, and a large glass sponge colonized the top

of the scarp; (middle left) a *Chaceon* sp. crab moves along the top of the scarp wall that is colonized by corals and sponges; (middle right) balcony-like ledges provided habitat for octocorals and *Solenosmilia* sp. stony corals; (lower left) large, branching hexactinellid glass sponges, such as this *Tretopleura* sp., were common on the flat rocky area above the scarp; (lower right) an ophidioid cusk eel (*Diplacanthapoma* sp.) swam under a ledge at the crest of the scarp, where *Solenosmilia* sp. and *Desmophyllum* sp. stony corals reside.

While Dive 04 revealed the highest coral diversity among the escarpment dives, Dive 08 had unique fauna, such as cladorhizid carnivorous sponges, *Membranipora* sp. bryozoans, and *Plumarella* sp. octocorals (**Figure 18**). Given that this dive was the shallowest of the escarpment dives (~1,000-870 m), it is likely influenced by warmer Gulf Stream waters instead of colder Western Boundary Undercurrent waters that influence the deeper escarpments, which may explain the faunal differences. A mating pair of red crabs was observed under a rock ledge, along with several instances of lithodid and *Chaceon* sp. crab species feeding on other crabs or fish (**Figure 18**).

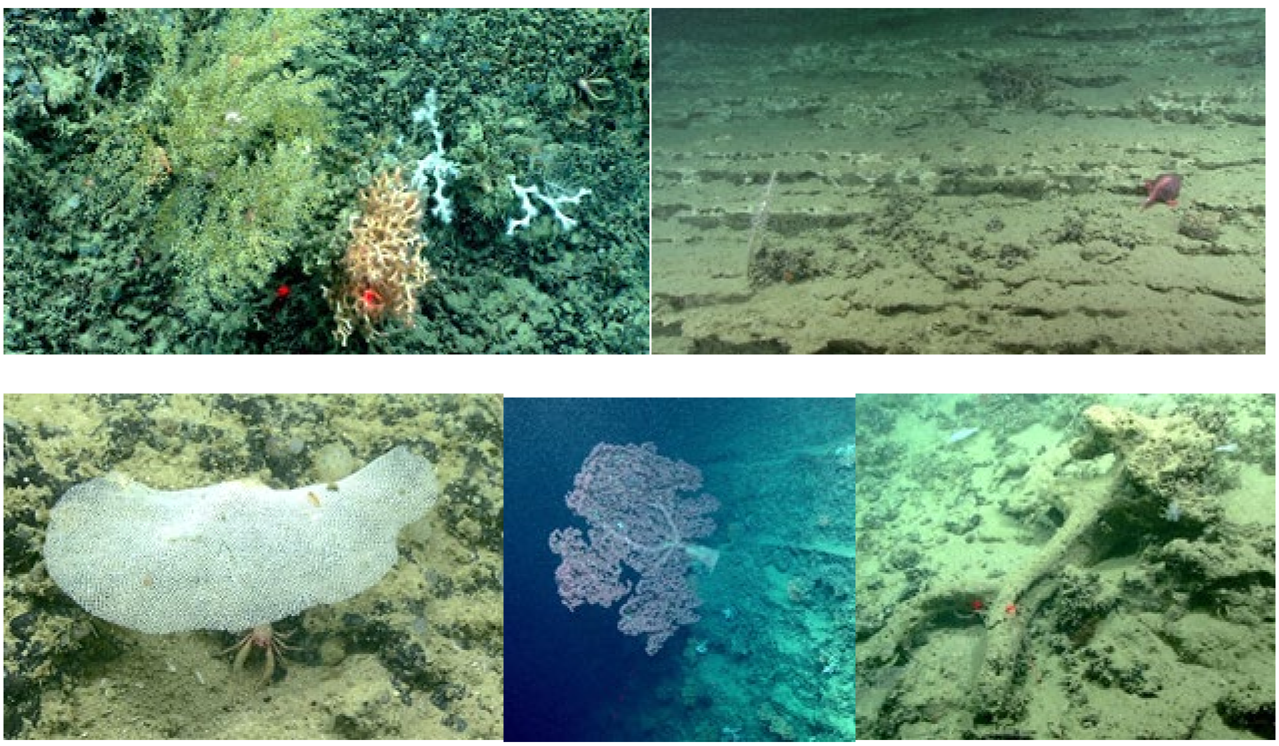

FIgure 18: Unique fauna and behaviors were observed at R ichardson Scarp (Dive 08): (upper left) the scleractinian corals *Solenosmilia variabilis* (orange) and *L. pertusa* (white) were observed on the scarp wall, along with the yellow octocoral, *Anthothela* sp., and several squat lobsters; (upper right) carnivorous cladorhizid sponges (*Chondrocladia* sp., lower left of this image) were common, along with fan -shaped bryozoans (*Membranipora* sp., middle left of this image); (middle right)) a *Paragorgia arborea* bubblegum coral grew vertically from the steep scarp wall, and a large skeleton of *P. arborea* was observed; (bottom left) a pair of mating *Chaceon* sp. crabs seen under a ledge; (bottom right) a *Chaceon* sp. crab eating a portion of another crab (Dive 08), with a Synaphobranchid eel which appeared to be investigatin g potential feeding opportunities.

Deep Terrace, Sediment Plains, and Giant Bedforms

Dive 02 – Blake Ridge
Dive 03 – Giant Bedforms
Dive 09 – Blake Ridge Wreck

Three ROV dives were completed over mostly sedimented benthic environments in deeper waters (> 2,500 m). Of these, the Blake Ridge (Dive 02) had the highest coverage of hard substrate, consisting of tabular mudstones and gravel that was colonized by demosp onges (e.g. *Phakellia* sp. and *Geodia* sp.), glass sponges, as well as several unbranched *Convexella* sp. octocorals, and a stalked tunicate (**Figure 19**). The fauna living on soft sediment was typical for the habitat type and depth, including many stalked orga nisms such as tunicates and sponges (**Figure 20**), along with a xenophyophore. Many of these organisms had the algae *Sargassum* sp. wrapped around their stalks, which was likely hung up as it drifted with bottom currents. Mobile fauna included the abyssal rat tail (*Coryphaenoides* sp.), along with a variety of echinoderms, including a feather star belonging to the family Antedonidae that may be a new depth record (**Figure 21**). Many depressions or grooves in the sediments were observed on Dives 02 and 03 (along wth the sedimented plains below the Blake Escarpment on Dive 01), and the science team postulated they may have been carved by beaked whales (see Auster and Watling, 2010; Marsh et al., 2018).

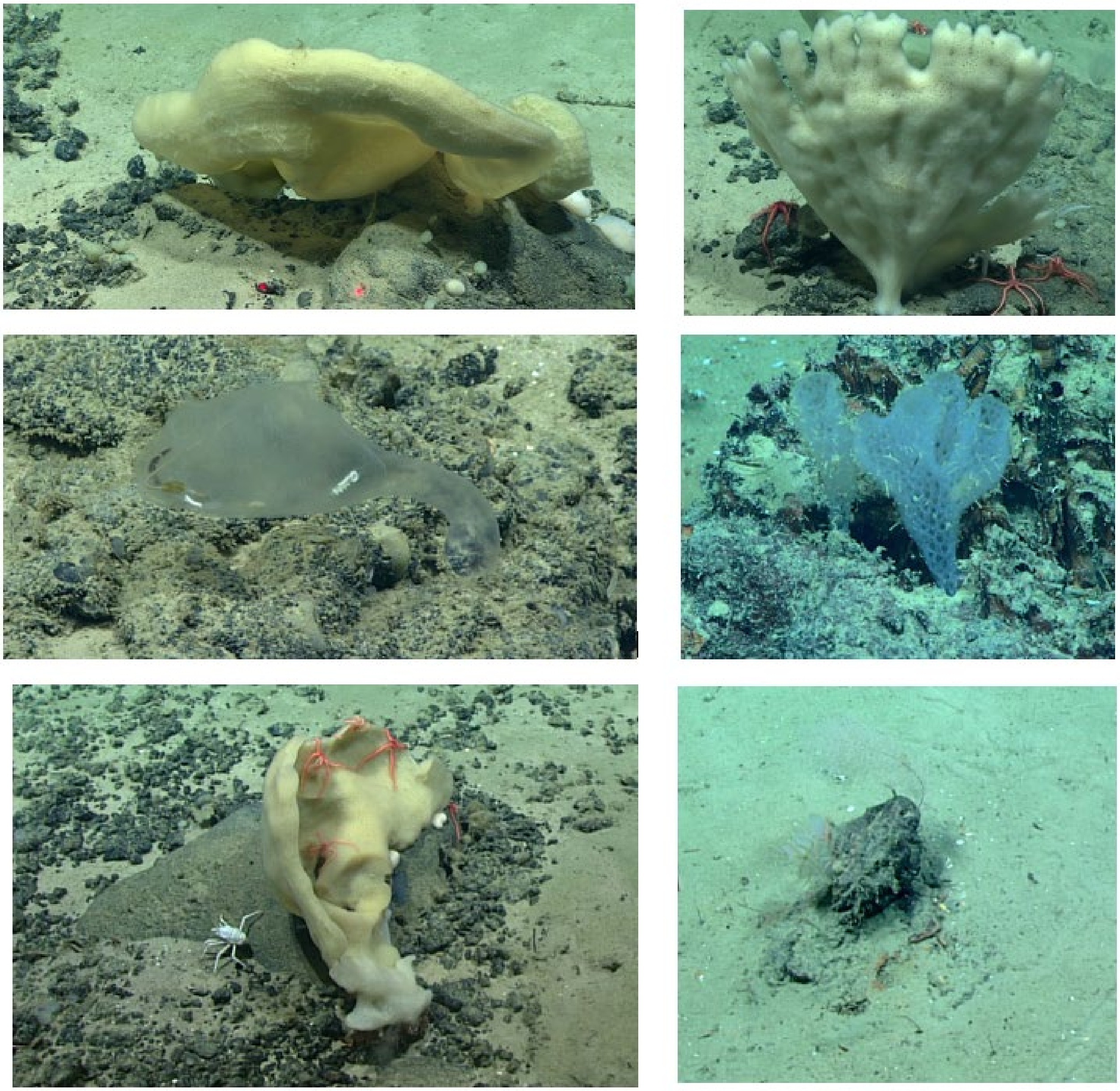

Figure 19: During dives to deep terraces and sediment plains, sponges, stalked tunicates, and *Chrysogorgia* sp. octocorals lived attached to the limited hard substrate available: (upper left, right and lower left – Dive 02) *Phakellia* sp. demosponges were common, often with associated fauna such as brittle stars; (middle left – Dive 02) a stalked tunicate attached to small rocks; (middle right – Dive 09) hexactinellid glass sponges; (lower right – Dive 09) *Chrysogorgia* sp. octocorals were among the sessile organisms observed at the Blake Ridge Wreck.

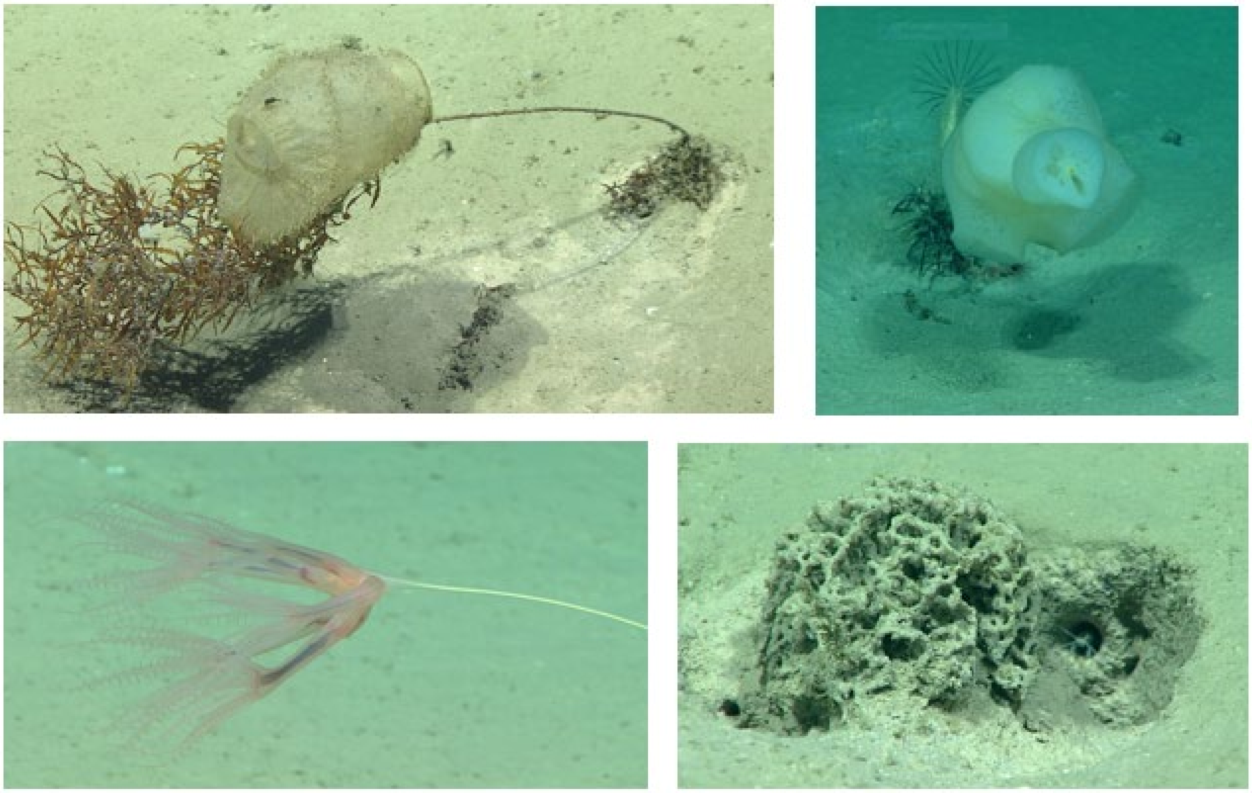

Figure 20 : Soft sediment benthic organisms at the Giant Bedforms site (Dive 03) included many stalked organisms such as sponges (upper images), sea pens (lower left, *Umbelulla* sp.), along with others, such as the xenoph yophore (lower right). The stalks often 'caught' drifting *Sargassum* sp. seaweed that sinks to the benthos over time. Xenophyophores are single celled organisms that make tests (houses) out of sediment. There was a small amphipod living in a mud tube to the right of the xenophyophore.

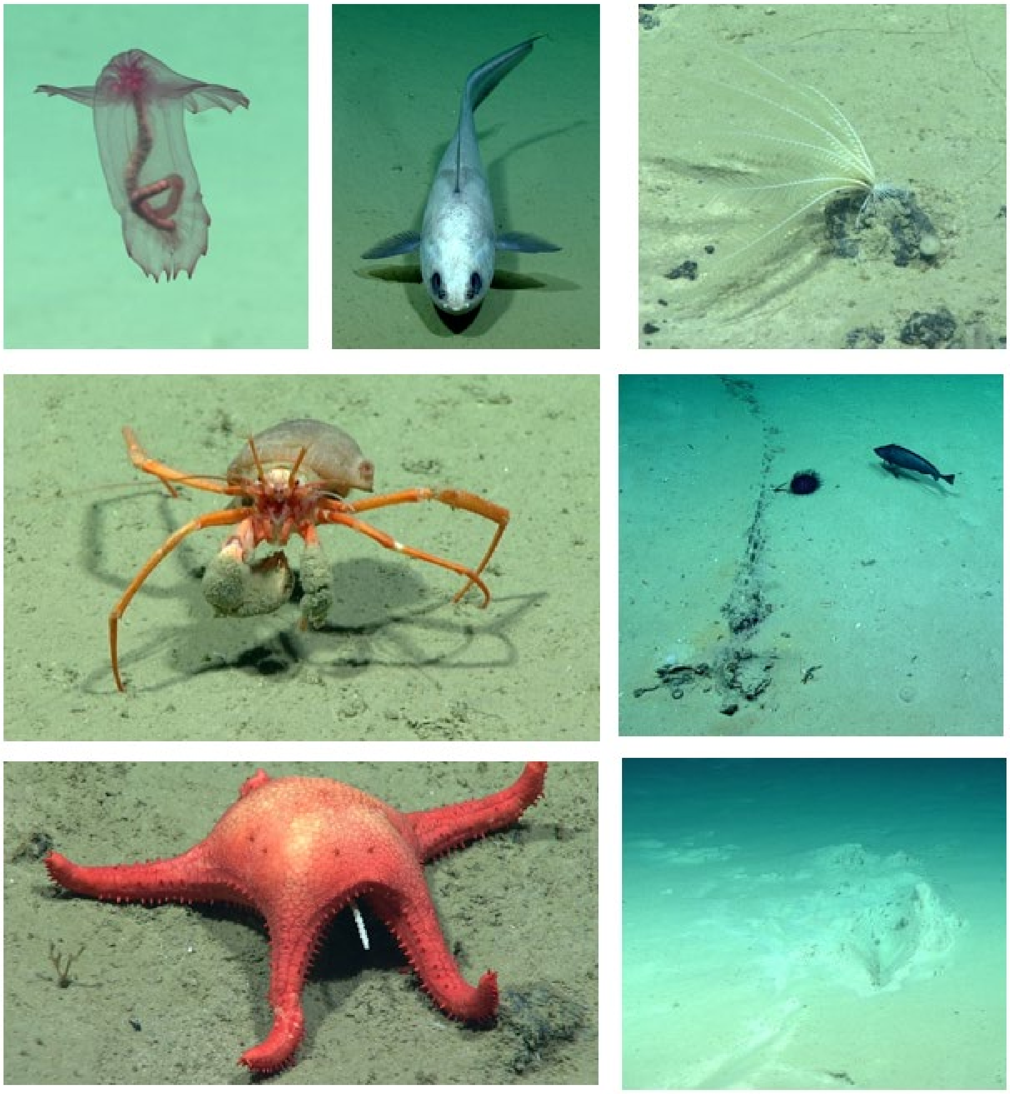

Figure 21: A variety of mobile organisms were seen at the deep terraces and sediment plains: (upper left – Dive 03) a swimming holothurian; (upper middle – Dive 03) abyssal rattail (*Coryphaenoides* sp.); (upper right – Dive 02) a crinoid (possibly *Thaurmatometra* sp., Family Antedonidae) on a small rock; (middle left – Dive 03) a hermit crab with a symbiotic anemone living on the gastropod shell it carried; (middle right – Dive 09) a black abyssal rattail and a pancake urchin (*Hygrosoma* sp.) were seen next to the anchor chain at the Blake Ridge Wreck; (lower left – Dive 02) a sea star (*Evoplosoma* sp.) consuming a small unbranched octocoral (*Convexella* sp.); (lower right – Dive 03) one of many grooves observed in the sediment that may have been carved by beaked whales.

Coral Mounds

Dive 05 – Stetson Mesa South
Dive 06 – Stetson Mesa North
Dive 07 – Richardson Ridge
Dive 10 – Cape Fear/Lophelia Banks

A highlight of the expedition was documenting the biogenic nature of coral mounds, formed mainly by the scleractinian coral *L. pertusa*, at the Stetson Mesa (Dives 05 and 06) and at Richardson Ridge (Dive 07). These dives revealed typical biogenic coral habitat in which mound flanks were covered in dead coral rubble, often forming habitat for sponges, brittle stars, asteroid sea stars, sea urchins, solitary corals, and octocorals (**Figure 22**), while the mound crests were comprised of a higher live coral coverage (**Figure 23**). Extrapolating from the mapping data that revealed an extensive number and coverage of mounds, the extent of coral habitat off the Southeastern U.S. coast is likely much greater than appreciated in the past. Most of the coral mounds in the Stetson Mesa region are within the boundaries of the Coral Habitat Area of Particular Concern (CHAPC), which is valuable information for the SAFMC that established the protections. Stylasterids were present only at the site furthest south on the Stetson Mesa (Dive 05). Learning that the elongate, steep Richardson Ridge is comprised of linear coral mounds is a significant finding, given that these features cover an extensive area. The amount of live coral at Richardson Ridge was quite high compared to other coral mounds visited, including some of the largest living *L. pertusa* and *Madrepora oculata* colonies observed on the expedition (**Figure 23**). A sharp temperature spike and oxygen decrease was noted as ROV *Deep Discoverer* approached the bottom (approximately 800 m) at the Richardson Ridge site—water column anomalies not seen elsewhere. A sponge species not known from the northwestern Atlantic, *Dercitus* sp. (**Figure 22**) was observed at Stetson Mesa South and is likely a range extension from the Northeastern Atlantic. Golden crabs (*Chaceon fenneri*) were encountered at the Stetson Mesa South and Richardson Ridge sites; at the latter, an individual sat underneath a large *M. oculata* colony (**Figure 23**). Several instances of predation were observed at the coral mound sites, including several sea stars (*Gilbertaster caribbaea*) eating *Plumarella* sp. octocorals (Dive 07), plus a herd of *Cidaris* sp. pencil urchins feeding upon sunken *Sargassum* sp. surface algae (Dive 10).

Figure 22: The coral rubble that covered the flanks of coral mounds made good habitat for various organisms: (upper left – Dive 07) a hexactinellid glass sponge, orange solitary corals and an alcyonacean soft coral live attached to *L. pertusa* coral rubble; (upper right – Dive 06) a recently described species of hagfish (*Eptatretus lophliae*) that lives in *L. pertusa* rubble was seen multiple times at Stetson Mesa North; (middle left – Dive 06) several large black encrusting sponges (possibly *Dercitus* sp.) grew over coral rubble substrate at Stetson Mesa North; (middle right – Dive 07) several of the sea star *Gilbertaster caribbaea* were seen consuming *Plumarella* sp. octocorals, and this individual had small pink amphipods on its oral surface; (bottom left – Dive 10) live (white) *L. pertusa* coral plus dead coral matrix that hosts sessile (anemones, octocorals) and mobile (*Eumunida picta* squat lobsters, *Cancer* sp. crab, *Echinus* sp. sea urchin) fauna at Cape Fear; (bottom right – Dive 10) a herd of *Cidaris* sp. pencil urchins was observed consuming Sargassum.

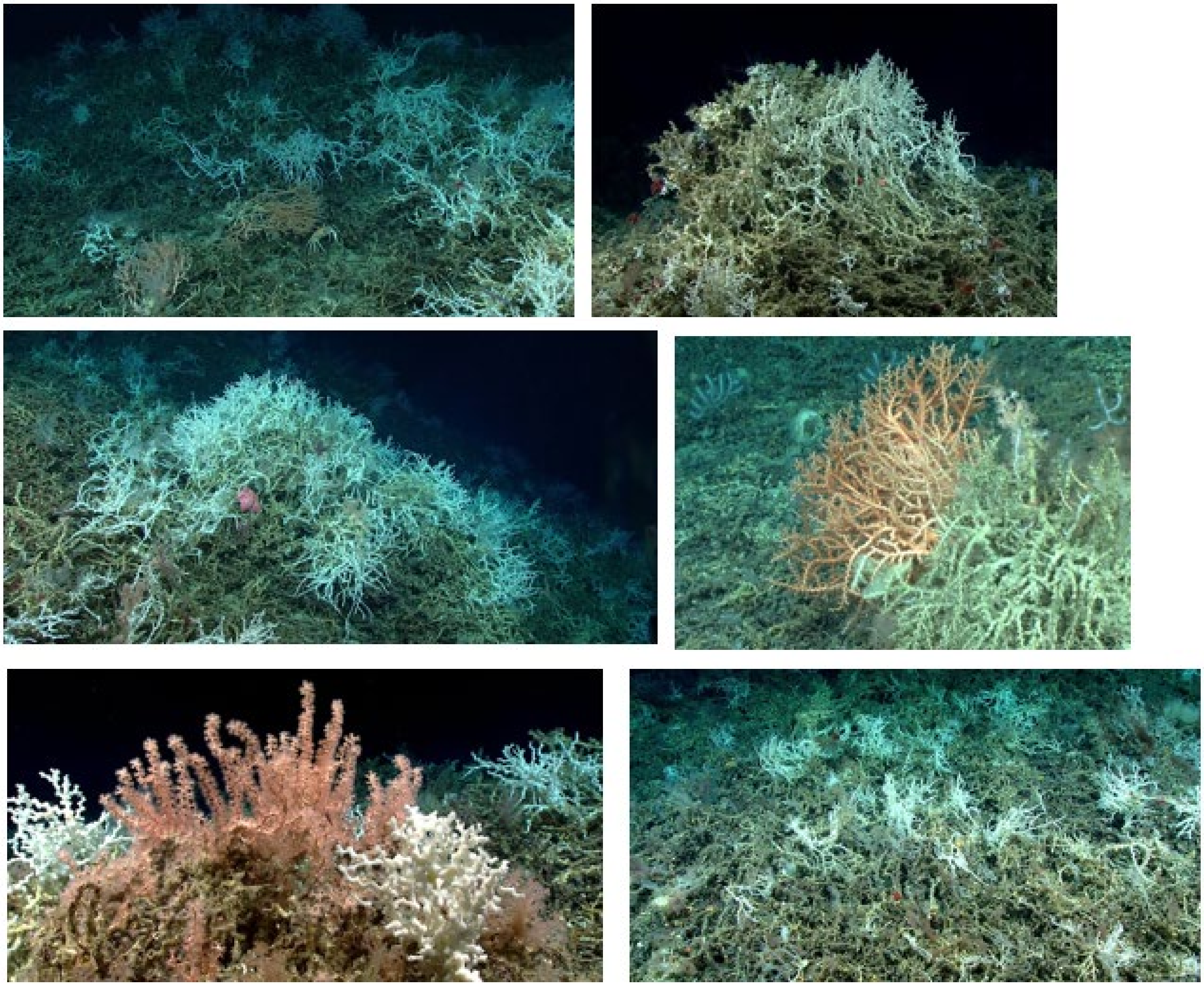

Figure 23: Mound crests had the high live coral abundance: (upper left – Dive 07) a golden crab (*Chaceon fenneri*) sits underneath a colony of *M. oculata* and is surrounded by *L. pertusa*; (upper right – Dive 05) at the Stetson Mesa South dive, the deeper mounds were comprised of *Enallopsammia profunda*, such as this large colony; (middle left – Dive 07) live *L. pertusa* plus the sea star, *Chondraster grandis*, at Richardson Ridge; (middle right – Dive 06) orange *M. oculata* at Stetson Mesa North; (lower left – Dive 07) an octocoral (left), *L. pertusa* and a soft coral (right) at Richardson Ridge; (lower right – Dive 06) a mixture of live (white) and dead *L. pertusa* coral matrix at Stetson Mesa North.

The northernmost coral mound visited, Cape Fear, had fewer corals present and lower coverage by live coral relative to those at Stetson Mesa and Richardson Ridge. For example, there were no sightings of the stony corals *M. oculata* or *Enallopsammia profunda,* nor the octocorals *Plumarella* sp. and *Anthomastus* sp. seen at other coral mounds. However, encounters with fishes were the highest at Cape Fear, including many seen at other mounds (e.g. coral hake *Laemonema melanurum*, *Nezumia* sp. rattails, and scorpionfish (*Trachyscorpia* sp. and/or *Helicolenus* sp.), plus others such as conger eels, greeneye, and oreo. The most conspicuous fishes were wreckfish (*Polyprion americanus*) that followed the ROV for most of the dive (**Figure 24**). Both catsharks and dogfish were seen here as well. It was notable that several neonate chimaera (possibly *Chimaera bahamensis*) were seen at the Stetson Mesa South site (Dive 05), and two of the recently described *Lophelia* sp. associated hagfish, *Rubicundus lopeliae*, were seen hiding within the dead coral matrix at the Stetson Mesa North site.

Figure 24: Mobile fauna seen at coral mounds included cartilaginous fishes such as sharks, rays and chimaera, fishes, and octopus: (upper left – Dive 05) one of several neonate chimaera seen at Stetson Mesa South; (upper right – Dive 10) a school of large wreckfish (*Polyprion americanus*) followed the ROV throughout the dive at Cape Fear; (middle right – Dive 07) an oreo (*Neocyttus* sp.) at Richardson Ridge; (middle right – Dive 10) a catshark (*Scyliorhinus meadi*) at Cape Fear; (lower left – Dive 05) a juvenile octopus (*Muusoctopus* sp.) at Stetson Mesa; (lower right – Dive 07) a goosefish (*Lophiodes beroe*) swam towards the ROV at Richardson Ridge.

8.2 Specimen Collections

A total of 213 samples were collected during the expedition, including 15 geological samples, 53 primary biological samples, 145 associated samples, and 161 biological subsamples. In addition, 28 water samples were collected, but were compromised in the sampling process and were not retained. See **Table 5** for additional details.

Table 5. Inventory of primary samples collected during EX-18-06. Water samples are denoted as their sequential Niskin sample bottle. Several opportunistic samples were collected (e.g. polychaete worm caught on ROV skid after ROV recovery; see dive summaries and sampling data base for additional information) and lack collection information, and as such are noted as collected at 00:00:00. .

Sample ID	Identification	Date	Time collected (UTC)	Latitude	Longitude	DEPTH
D2_DIVE01_SPEC01BIO	Demospongiae	20180614	17:17:13	32.053953	-76.846137	1684.1122
D2_DIVE01_SPEC02BIO	*Paragorgia* sp.	20180614	17:32:25	32.053846	-76.846077	1684.6169
D2_DIVE01_SPEC03GEO	Mudstone	20180614	17:55:25	32.054008	-76.845956	1684.4858
D2_DIVE01_SPEC04BIO	*Paramuricea* sp.	20180614	19:22:59	32.053367	-76.846804	1682.2085
D2_DIVE02_SPEC01BIO	Bryozoa	20180615	16:13:29	32.012609	-75.259884	3393.9973
D2_DIVE02_SPEC02BIO	Demospongiae	20180615	17:02:37	32.012544	-75.260696	3380.315
D2_DIVE02_SPEC03BIO	*Geodia pachydermata*	20180615	17:22:24	32.012571	-75.261017	3378.5292
D2_DIVE02_SPEC04BIO	Demospongiae	20180615	17:26:42	32.012519	-75.26091	3378.6068
D2_DIVE02_SPEC05BIO	Tunicata	20180615	17:54:13	32.013568	-75.260712	3371.3282
D2_DIVE02_SPEC06GEO	Mudstone	20180615	18:06:00	32.012513	-75.261533	3364.7663
D2_DIVE03_SPEC01GEO	Mud	20180616	14:33:26	31.158637	-75.661643	3341.8809
D2_DIVE03_SPEC02BIO	Pyuridae	20180616	16:41:39	31.161298	-75.662147	3338.32
D2_DIVE04_SPEC01BIO	*Stauropathes* sp.	20180617	13:57:02	30.940135	-77.328591	1321.1468
D2_DIVE04_SPEC02BIO	*Bathypathes* sp.	20180617	14:06:38	30.940167	-77.328545	1321.0438
D2_DIVE04_SPEC03WAT	Niskin 01	20180617	14:06:38	30.940167	-77.328545	1321.0438
D2_DIVE04_SPEC04WAT	Niskin 02	20180617	14:06:38	30.940167	-77.328545	1321.0438
D2_DIVE04_SPEC05WAT	Niskin 03	20180617	14:06:38	30.940167	-77.328545	1321.0438

D2_DIVE04_SPEC06GEO	Mudstone with FeMn crust	20180617	14:29:29	30.939978	-77.328862	1315.4665
D2_DIVE04_SPEC07BIO	Thouarella sp.	20180617	14:56:42	30.940089	-77.32916	1308.8407
D2_DIVE04_SPEC08GEO	Mudstone with FeMn crust	20180617	17:56:20	30.94089	-77.330088	1249.6294
D2_DIVE04_SPEC09BIO	*Leiopathes* sp.	20180617	19:01:08	30.941433	-77.330136	1247.232
D2_DIVE04_SPEC10WAT	NISKIN 04	20180617	19:06:27	30.941492	-77.330117	1248.0084
D2_DIVE04_SPEC11WAT	NISKIN 05	20180617	19:07:22	30.941485	-77.330079	1247.8595
D2_DIVE04_SPEC12BIO	Hexactinellida	20180617	19:19:36	30.941601	-77.330366	1247.6492
D2_DIVE05_SPEC01BIO	*Eunicella* sp.	20180619	14:38:13	29.36738	-79.729007	731.4581
D2_DIVE05_SPEC02GEO	Coral rubble	20180619	17:07:31	29.3693	-79.728255	732.8897
D2_DIVE05_SPEC03BIO	Duva florida	20180619	17:44:38	29.369924	-79.728433	711.7008
D2_DIVE05_SPEC04BIO	*Pseudoanthomastus sp.*	20180619	17:48:49	29.369917	-79.728425	711.7302
D2_DIVE05_SPEC05BIO	*Swiftia* sp.	20180619	18:36:25	29.370349	-79.728555	710.9001
D2_DIVE06_SPEC01BIO	*Pheronema* sp.	20180620	15:48:40	30.403807	-79.598518	778.6093
D2_DIVE06_SPEC02BIO	Primnoidae	20180620	16:30:41	30.404078	-79.599096	760.1131
D2_DIVE06_SPEC03BIO	*Geodia pachydermata*	20180620	18:07:30	30.405028	-79.600939	737.2063
D2_DIVE06_SPEC04BIO	?*Dercitus* sp.	20180620	19:55:14	30.405274	-79.601697	717.5974
D2_DIVE07_SPEC01BIO	*Madrepora oculata*	20180621	21:22:30	31.770105	-77.363953	787.5425
D2_DIVE07_SPEC02BIO	*Lophelia pertusa*	20180621	21:26:34	31.77029	-77.364102	788.2545
D2_DIVE07_SPEC03GEO	Coral rubble	20180621	22:06:47	31.770492	-77.363978	763.7358
D2_DIVE08_SPEC01GEO	Rock	20180622	13:40:51	32.092937	-77.159524	1005.8107
D2_DIVE08_SPEC02BIO	Bryozoa	20180622	14:05:34	32.092969	-77.159643	1003.5104
D2_DIVE08_SPEC03GEO	Laminar rock	20180622	14:45:57	32.093182	-77.1605	992.5203
D2_DIVE08_SPEC04BIO	*Plumarella* sp.	20180622	17:37:27	32.093415	-77.161969	893.4168
D2_DIVE08_SPEC05BIO	Cup coral	20180622	18:42:45	32.093367	-77.163444	883.8004
D2_DIVE08_SPEC06BIO	Carnivorous sponge	20180622	19:00:35	32.093328	-77.163712	880.619
D2_DIVE10_SPEC01BIO	Hydroid or black coral	20180624	16:47:05	33.575155	-76.466167	403.0861
D2_DIVE10_SPEC02BIO	?Hydrozoan	20180624	18:04:18	33.574137	-76.46517	386.2568

D2_DIVE10_SPEC03GEO	Coral rubble and sediment (scoop)	20180624	18:11:03	33.574132	-76.465174	386.2496
D2_DIVE10_SPEC04BIO	Echinoidea	20180624	18:14:21	33.574131	-76.465169	386.2704
D2_DIVE10_SPEC05BIO	Octocorallia	20180624	18:28:49	33.574153	-76.465094	386.5529
D2_DIVE10_SPEC06BIO	*Vazella*sp.	20180624	19:37:55	33.573424	-76.465073	373.7453
D2_DIVE10_SPEC07WAT	Niskin 1	20180625	19:43:38	33.5734	-76.46497	373.2964
D2_DIVE10_SPEC08WAT	Niskin 2	20180626	19:43:38	33.5734	-76.46497	373.2964
D2_DIVE10_SPEC09WAT	Niskin 3	20180627	19:43:38	33.5734	-76.46497	373.2964
D2_DIVE10_SPEC10WAT	Niskin 4	20180624	20:07:58	33.573229	-76.464944	374.8254
D2_DIVE10_SPEC11WAT	Niskin 5	20180624	20:08:28	33.573233	-76.464945	374.5799
D2_DIVE11_SPEC01BIO	Pennatulacea	20180625	19:00:25	34.777781	-75.348627	1518.9859
D2_DIVE11_SPEC02BIO	Ophiuroidea and sediment	20180625	19:05:12	34.777788	-75.348624	1518.9956
D2_DIVE12_SPEC01BIO	Pennatulacea	20180626	19:52:43	35.099121	-75.021217	1167.8837
D2_DIVE13_SPEC01GEO	Rock slab	20180627	15:41:34	34.503391	-75.696815	328.7031
D2_DIVE13_SPEC02BIO	Octocoral	20180627	17:11:43	34.503054	-75.697614	330.9269
D2_DIVE13_SPEC03BIO	Corallimorpharia	20180627	17:44:08	34.503267	-75.697919	339.4103
D2_DIVE13_SPEC04WAT	Niskin 1	20180627	19:04:50	34.50337	-75.696934	328.7345
D2_DIVE13_SPEC05WAT	Niskin 2	20180627	19:05:29	34.503359	-75.696949	328.8377
D2_DIVE13_SPEC06WAT	Niskin 3	20180627	19:05:58	34.503364	-75.696919	328.8729
D2_DIVE13_SPEC07BIO	Actinaria	20180627	19:58:36	34.503273	-75.696749	332.0862
D2_DIVE13_SPEC08WAT	Niskin 4	20180627	20:00:12	34.503269	-75.69675	332.1828
D2_DIVE13_SPEC09WAT	Niskin 5	20180627	20:01:19	34.503273	-75.696765	332.1353
D2_DIVE14_SPEC01GEO	sediment scoop	20180628	17:32:35	35.293175	-74.950651	338.4775
D2_DIVE14_SPEC02WAT	Niskin 1	20180628	19:55:51	35.291572	-74.951047	307.6159
D2_DIVE14_SPEC03WAT	Niskin 2	20180628	19:56:13	35.291617	-74.951012	307.4643
D2_DIVE14_SPEC04WAT	Niskin 3	20180628	19:57:02	35.291631	-74.95104	306.9568
D2_DIVE15_SPEC01BIO	Nemertea	20180629	16:04:29	35.556363	-74.793044	581.8866
D2_DIVE15_SPEC02BIO	Alcyonacea	20180629	18:31:54	35.557047	-74.793192	540.5147

D2_DIVE15_SPEC03WAT	Niskin 1	20180629	20:41:47	35.557632	-74.792592	499.6779
D2_DIVE15_SPEC04WAT	Niskin 2	20180629	20:42:54	35.557648	-74.792579	499.4365
D2_DIVE15_SPEC05WAT	Niskin 3	20180629	21:20:17	35.555837	-74.792737	399.9913
D2_DIVE15_SPEC06WAT	Niskin 4	20180629	21:21:24	35.55582	-74.792719	400.1848
D2_DIVE15_SPEC07WAT	Niskin 5	20180629	21:52:59	35.554024	-74.792818	300.1984
D2_DIVE15_SPEC08BIO	*Nemichthys curvirostris*	20180629	0:00:00			
D2_DIVE16_SPEC01WAT	Niskin 1	20180630	13:28:53	35.707763	-74.81288	519.0819
D2_DIVE16_SPEC02BIO	Gastropoda	20180630	14:09:36	35.707253	-74.812212	491.0589
D2_DIVE16_SPEC03WAT	Niskin 2	20180630	14:22:46	35.707068	-74.812047	482.0935
D2_DIVE16_SPEC04WAT	Niskin 3	20180630	15:28:05	35.706396	-74.812206	465.0885
D2_DIVE16_SPEC05BIO	*Hyalinoecia*sp.	20180630	16:33:39	35.705964	-74.813075	442.3708
D2_DIVE16_SPEC06WAT	Niskin 4	20180630	17:05:01	35.705808	-74.813361	433.3929
D2_DIVE16_SPEC07WAT	Niskin 5	20180630	19:56:54	35.70327	-74.815697	354.3729
D2_DIVE16_SPEC08BIO	*Sergestes*sp.	20180630	0:00:00			
D2_DIVE16_SPEC09BIO	Myctophidae	20180630	0:00:00			
D2_DIVE16_SPEC10BIO	*Nemichthys curvirostris*	20180630	0:00:00			
D2_DIVE16_SPEC11BIO	Paralepididae	20180630	0:00:00			
D2_DIVE16_SPEC12BIO	Hyperiidae	20180630	0:00:00			
D2_DIVE17_SPEC01BIO	*Chrysogorgia*sp.	20180701	15:13:55	36.230062	-74.465283	1867.9242
D2_DIVE17_SPEC02BIO	*Acanella* sp.	20180701	15:35:51	36.230078	-74.46529	1866.8335
D2_DIVE17_SPEC03GEO	Sediment	20180701	16:49:37	36.230294	-74.465788	1825.1813
D2_DIVE17_SPEC04GEO	Burrow cast	20180701	18:12:26	36.230158	-74.466344	1786.8456
D2_DIVE17_SPEC05GEO	Small rock from sediment plain	20180701	19:30:42	36.23014	-74.4689	1753.4258
D2_DIVE17_SPEC06BIO	Polychaeta	20180701	0:00:00			

8.2.1 Sample Repositories

Details for all repositories that have archived specimens from EX-18-06 can be found below:

- Invertebrate Zoology Collections, National Museum of Natural History, Smithsonian Institution, Museum Support Center, MRC 534, 4210 Silver Hill Road, Suitland, MD 20746
  Website: https://invertebrates.si.edu/LoanPolicy.html (last accessed Nov. 2020)
- Biorepository, National Museum of Natural History, Smithsonian Institution, Museum Support Center, 4210 Silver Hill Road, Suitland, MD 20746
  Website: https://naturalhistory.si.edu/research/biorepository (last accessed Nov. 2020)
- Ocean Genome Legacy Center, Northeastern University, 430 Nahant Road, Nahant, MA 01908
  Website: https://www.northeastern.edu/ogl/ (last accessed Nov. 2020)
- Marine and Geology Repository, Oregon State University
  Burt 346, Corvallis, OR 97331-5503
  Website: http://osu-mgr.org/noaa-ex/ (last accessed Nov. 2020)

8.3 Accessing ROV Data

Data from this expedition is available through OER's Digital Atlas: https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm (last accessed November 2020). To specifically access data from this expedition, use the "Enter Search Text" feature on the "Search" tab, type in "EX1806" in the text box available, and click on the Search button. Click on the dot that represents the expedition (the map will center around this dot), which will provide options for data access. ROV dive data organized by dive can be found here: https://service.ncddc.noaa.gov/rdn/oer-rov-cruises/ex1806 (last accessed November 2020).

8.4 Seafloor Mapping

Table 6. Mapping Statistics for EX -18-06.

EM 302 Linear Kilometers Mapped	3,764
EM 302 Square Kilometers Mapped	14,875

Number of XBT Casts	95

A summary of mapping operations conducted on EX-18-06 can be found in **Table 6** and multibeam bathymetry data coverage from EX-18-06 is shown in **Figure 2**. The schedule of operations included overnight transit mapping and mapping operations whenever the ROVs were on deck (Table 3). In areas with existing data, focused mapping operations edge matched existing data and targeted potential seafloor features withi n the satellite bathymetry.

Mapping operations included Kongsberg EM 302 multibeam, Simrad EK60 and EK80 split-beam, Knudsen sub-bottom profiles, and Teledyne ADCP data collection. XBTs were collected approximately every 2-4 hours and applied in real time using SIS software. Sound speed at the sonar head was determined using sound speed from a flow through TSG.

Much of the mapping was conducted along transit lines to ROV dive sites; however, in places where time allowed, focused surveying was completed over areas lacking multibeam data.

The ADCPs were always turned off for general mapping operations due to noticeable interference between the Ocean Surveyor 38kHz ADCP, the Workhorse 300kHz ADCP and the EM 302 multibeam. This interference has been documented during previous cruises.

During normal mapping operations, data were collected with the EM 302, EK60 and EK80, and sub-bottom profiler. During ROV operations, both ADCPs were turned on to provide information on currents in the vicinity of each dive site. Also, during ROV operations, the EK60 and EK80 were turned on to better understand the interaction between the ROVs and biology in the water column.

Additional information about the mapping conducted during EX-18-06, including data quality assessments, can be found in the EX-18-06 mapping data report (Sowers et al., 2020).

8.4.1 Mapping Data Access

Multibeam Sonar (Kongsberg EM 302)

The multibeam dataset for the expedition is archived at NCEI and accessible through their Bathymetric Data Viewer (https://maps.ngdc.noaa.gov/viewers/bathymetry/ , last accessed

November 2020). To access these data click on the "Search Bathymetric Surveys" button, select "NOAA Ship OKEANOS EXPLORER" from the Platform Name dropdown menu, "NOAA Office of Ocean Exploration and Research" from the Source Institution dropdown menu, and select "EX1806" from the Survey ID dropdown menu. Click the OK button and the ship track for the expedition will appear on the map. Click on the ship track for options to download the data.

Sub-Bottom Profiler (Knudsen Chirp 3260)

The sub-bottom profiler was not run during any of EX-18-06's ROV dive operations, but generally was operated during multibeam mapping operations. Geophysical data for the area covered by the expedition are archived at NCEI and accessible online through their Geophysical Data Viewer (https://maps.ngdc.noaa.gov/viewers/geophysics/, last accessed November 2020). To access these data, select "Subbottom Profile" under Marine Surveys and click on the "Search Marine Surveys" button. In the pop-up window, select "EX1806" in the Filter by Survey ID dropdown menu. Click the OK button and the ship track for the expedition will appear on the map. Click on the ship track for options to download data.

As of writing of this report (December 4, 2020), these data are part of a backlog of data with the NOAA Archives and are not currently available on the Geophysical Data Viewer. Data can be accessed through OER data request form (https://docs.google.com/forms/d/e/1FAIpQLSdBLvbtStVhGrDO3Ugn_sNJpgR1Yy-e-DaUU3TIqGjg07ITNg/viewform?formkey=dHAycC1MYndJb0hTdGRaYXAzVTVBdWc6MA&fromEmail=true, last accessed December 2020) until the data are made available through the archive.

Split-beam Sonars (Simrad EK60 and EK80)

These sonars were used continuously throughout the cruise during both overnight mapping operations and daytime ROV operations. EK60 and EK80 water column data for the expedition are archived at NCEI and available through their Water Column Sonar Data Viewer (https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html, last accessed November 2020). To access these data, click on the Additional Filters button, deselect "All" next to the Survey ID, and select "EX1806" from the Survey ID list. Click the OK button and the ship track for the expedition will appear on the map. Click on the ship track for options to download data.

Acoustic Doppler Current Profiler (Teledyne Marine Workhorse Mariner ADCP)

ADCP data for the expedition were collected at each ROV dive location, are archived at NCEI, and are available through their Global Ocean Currents Database (https://www.nodc.noaa.gov/gocd/sadcp_oer_inv.html, last accessed November 2020). Access these data by searching the table for the cruise identification number, "EX1806."

Sun Photometers Measurements

Sun photometer measurements are available through NASA's MAN (https://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html, last accessed November 2020). Access these data by searching the table for "2018," "Okeanos Explorer," and "North Atlantic Ocean." Click on the links to download the data. (Note: There may be more than one entry for *Okeanos Explorer* in a region in a given year.) Additional information can be found in **Appendix C**.

Other Oceanographic Data

Additional oceanographic data from this expedition are archived at NCEI, and can be found using the following link: https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0195408# (last accessed November 2020). These include data acquisition from shipboard sensors such as navigational data, meteorological data (wind), and oceanographic data (bathythermograph, sound velocity probe, thermosalinograph). Additional data include Profile Data (ASVP, CTD, and XBT), raw and processed CTD data, event logs, images, ROV ancillary data, and specimen data.

8.5 Engagement

EX-18-06 engaged with audiences around the world, opening a window of understanding into the deep sea. Highlights are listed below:

- Live video feeds received over 245,700 views, and web content received 17,400 visits during EX-18-06.
- Six ship tours, one Reddit Science "Ask Me Anything" session, 16 live interactions, and 18 live streaming events were conducted to engage over 8,670 people from a diversity of audiences (see **Table 3** for details about these and other similar events).
- Over 80 news/web articles covered EX-18-06. Stories about the expedition appeared in national and local media outlets and on websites throughout the country, including the front page of Charleston's *Post and Courier*. Several outlets published multiple stories about the expedition. International audiences were also engaged with articles in French, Italian, Spanish, Russian, Chinese, Indian, Cambodian, and

Vietnamese, as well as several articles by news outlets in the United Kingdom. This coverage amplified the impact of the expedition, increasing the audience reached.

9. Summary

The *Windows to the Deep 2018: Exploration of the Southeast U.S. Continental Margin* expedition (EX-18-05 and EX-18-06) was a two-part, 36-day, telepresence-enabled expedition to collect critical information and acquire data on priority exploration areas identified by the ocean management and scientific communities. This expedition involved exploration of a diversity of features across the Southeast U.S. continental margin with mapping and ROV operations targeting areas with potential to host deep-sea coral and sponge communities, maritime heritage sites, a landslide feature, and water column sonar anomalies of possible cold seeps where gas bubbles emanate from the seafloor. Mapping data collected during this expedition filled major data gaps in the region. This expedition also marked over 400 ROV dives (https://oceanexplorer.noaa.gov/okeanos/explorations/ex1806/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1806/dailyupdates/june20/media/dive.html, last accessed November 2020) for NOAA Ship *Okeanos Explorer.*

The expedition conducted 17 ROV dives, ranging in depth from 325 to 3,436 meters, to improve knowledge of unexplored areas within the U.S. waters and in deepwater areas previously mapped for the U.S. ECS project to inform management needs for sensitive habitats, maritime heritage sites, and potential resources. Data collected can be used to increase understanding of deep-sea ecosystem connectivity across the Atlantic basin. Major accomplishments of this expedition are summarized below:

- Collected 175 biological (53 primary and 122 associates) and a total of 38 geological specimens (15 primary and 23 associates). Biological specimens were representatives of new records, potential new species, dominant fauna, or were collected to support trans-Atlantic connectivity studies. Geological samples will be used to better understand the geologic history of this region, as well as to characterize habitat substrate.
    - Collected six biological samples to support trans-Atlantic connectivity studies including *Geodia pachydermata*, *Bathypathes* sp., *Leiopathes* sp., *Anthomastus sp.*, *Lophelia pertusa,* and *Pheronema sp.*
- Revealed one of the largest areas of deep-sea coral reef habitat that has been discovered in U.S. waters to date. Through both mapping and visual surveys, this expedition added substantial evidence that the numerous mounds on the Stetson Mesa offshore of Florida and Georgia appear to be the slow accumulation of *Lophelia pertusa* coral skeletal material over hundreds of thousands of years. This expedition only explored three mounds, but all were rich with live coral stands at their crests.

- Conducted ROV dives and mapping operations in two areas managed by the SAFMC—the Stetson Miami Terrace Deep Coral HAPC and Cape Fear Lophelia Banks MPA.
    - When coupled with EX-18-05, this expedition mapped over 7,400 square kilometers and conducted three dives in the Stetson Miami Terrace Deep Coral HAPC that revealed high-density coral communities at each site. Two of these communities were also highly diverse.
    - Conducted an ROV dive in the Cape Fear MPA, documenting several large wreckfish (*Polyprion americanus*), a commercially important species managed by the SAFMC.

- Discovered a high diversity of deep-sea corals and sponges on low relief, intraslope terraces (terraced features between a depth of 1,000 to 4,000 meters) along the Blake Escarpment in areas with no previous exploration.

- Explored two potential archeological sites to support the BOEM and NOAA maritime heritage programs.
    - Characterized the Blake Ridge Wreck and collected data that were used by BOEM to make a 3D photogrammetry model. This wreck was originally discovered by a team from Duke University in 2015 and is likely an early 19th century wreck.
    - Conducted targeted overnight mapping operations to search for other potential shipwrecks in an area suspected to contain many due to the World War II Battle of the Atlantic, as well as merchant ships lost at sea along the busy trade routes of the U.S. East Coast. Dive 13 investigated a sonar anomaly, dubbed "Big Dipper," with very strong backscatter, roughly the size and shape of a ship known to have sunk in the area offshore North Carolina; ROV imagery revealed that this site was not a shipwreck, but instead a biologically diverse rocky habitat that was home to a significant concentration of fish and corals.
    - Additional review of the mapping data collected during this expedition is currently ongoing by the marine archaeology community which may provide additional targets for future expeditions in the region.

Located and characterized deep-sea coral, sponge, and chemosynthetic communities.

- Documented three dive sites with high biological diversity and six medium diversity sites. Six dive sites had high biological abundance/density or high biomass.

- Observed deep-sea corals and sponges on every dive except one, which was a dedicated gas seep exploration dive.

- Conducted two dives that targeted water column anomalies. Both dives identified evidence of methane seepage, with bacterial mats and fauna typically associated with chemosynthetic habitats and active bubble seepage in this region.

- Observed several potential new species, recorded significant depth and geographic range extensions for several fish and coral species, and documented the presence of commercially important species —including red crab (*Chaceon quinquedens*) and golden crab (*Chaceon fenneri*)—in areas not previously investigated.

Characterized water column habitats using acoustics, visual observations, and emerging technologies.

- Conducted midwater exploration at depths ranging from 300 to 950 meters during three dives to investigate the diversity and abundance of the largely unknown pelagic fauna.
- Made multiple observations of a species of medusa jellyfish (*Cyanea* sp.) in the deep waters above Keller Canyon. This species is typically observed in shallow waters, which raises new questions about shallow and deepwater connectivity in the area.

Extended bathymetric mapping coverage in the U.S. EEZ and international waters in support of Seabed 2030.

- Mapped more 14, 875 square kilometers.
- EX-18-06 and EX-18-05 made new insights into this region, including the discovery of previously unknown intraslope terraced feature; newly mapped karstic features on the northern portion of the Blake Plateau; unusually flat seafloor terrain when compared to predictions made by satellite altimetry on the southern Blake Plateau; and numerous likely biogenic ridges and mounds offshore Florida, Georgia, and South Carolina. Due to their size, these features cannot be resolved from satellite data and were only revealed in detail using the ship-mounted multibeam sonar.

Collected mapping data and conducted ROV dives to support enhanced predictive capabilities for vulnerable marine habitats and submarine geohazards.

- Discovered numerous areas of deep-sea coral and sponge habitat, which has not only improved our understanding of this region, but has habitat modeling implications that may apply to many other places in the world.
- Conducted one ROV dive on the toe of the Currituck landslide feature, one of the largest submarine landslides on the U.S. East Coast, to better understand past submarine geohazards.

Engaged over 140 scientists, resource managers, and students, which is a record high for *Okeanos Explorer* missions.

- Participants were from 21 U.S. states as well as international scientists from Russia, Portugal, Japan, and Norway.

Documented several rarely observed predation events. Highlights included:

- An Atlantic Midshipmen (*Porichthys plectrodon*) opportunistically grabbing a barracudina in the family Paralepididae as it swam by during the dive at Pea Island.
- A lithodid crab ripping a brittle star apart along a sedimented ridge south of Pamlico Canyon.
- Inter-species predation activity between two crabs (*Neolithodes* sp. and *Chaceon* sp.) along a scarp feature in the Richardson Hills area.

Engaged with audiences around the world, opening a window of understanding into the deep sea.

- Conducted six ship tours for 66 people, including tours for the SAFMC, the Mid-Atlantic Regional Council on the Ocean, Virginia Sea Grant, NOAA partners, South Carolina Aquarium, Patriots Point Naval and Maritime Museum staff, and students from the College of Charleston.
- Conducted 16 live interactions, 18 live streaming events at partner locations, and a Reddit Science 'Ask Me Anything'. Over 8,670 people were engaged during these events.
- Over 75 news articles covered the expedition. Stories about the expedition appeared in national media as well as local outlets in landlocked areas and on both coasts, including the front page of Charleston's *Post and Courier*. Several outlets published multiple stories about the expedition. International audiences were also engaged with articles in French, Italian, Spanish, Russian, Chinese, Indian, Cambodian, and Vietnamese, as well as several articles by news outlets in the United Kingdom.
- Live video feeds received over 245,700 views during the expedition. Web content received 17,400 visits during the second leg of the expedition, with more than 54,000 additional views coming in the weeks immediately following the cruise, largely due to exposure on social media and subsequent media interest.

Data collected during this expedition are intended to inform initial exploration of the areas visited and includes multibeam, single beam, sub-bottom, ADCP, XBT, CTD, and DO profiles; surface oceanographic and meteorological sensors; video and imagery; and physical specimens. All data from this expedition are publicly available through national archives. The OER website (oceanexplorer.noaa.gov) provides a direct link to the expedition data archive.

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11. Appendices

11.1 Appendix A: Dive Summaries

Dive Summaries and associated ROV data from EX-18-06 can be found here: https://service.ncddc.noaa.gov/rdn/oer-rov-cruises/ex1806

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5505
http://sero.nmfs.noaa.gov

MAY 14 2018 F/SER25:FH

Mr. Craig Russell
NOAA Office of Ocean Exploration and Research (OER)
Seattle, WA 98115

Dear Mr. Russell:

This letter of acknowledgement (LOA) recognizes the activities outlined in your May 9, 2018, request as scientific research in accordance with the definitions and guidance at 50 CFR 600.10 and 600.745(a). As such, the proposed activities are not subject to fishing regulations at 50 CFR 622 developed in accordance with the Magnuson-Stevens Fishery Conservation and Management Act. This LOA is effective from date of issuance through December 31, 2019.

NOAA Fisheries understands primary operations aboard the NOAA Ship *Okeanos Explorer* will take place throughout federal waters of the South Atlantic and U.S. Caribbean in areas deeper than 250 m. OER anticipates supporting up to seven cruises between 2018 and 2019 that will be some combination of mapping and remote operating vehicle (ROV) operations. Specifically, these efforts will (1) survey deep-sea coral ecosystems using ROV, (2) map deep-water habitats using multi-beam echosounders, and (3) sample the physical and chemical properties of the water column. From May 22 through June 6, 2018, NOAA OER will conduct a seafloor and water column mapping cruise (EX-18-05) to collect data to help improve fundamental understanding in this region and to facilitate ROV dive planning. During the second leg of this expedition (EX-18-06), ROV and mapping operations will be conducted during the expedition's second cruise (EX-18-06) from June 11 to July 2, 2018, at depths ranging from 250 m to approximately 4,000 m. Mapping and ROV targets for operations in the Southeast include, but are not limited to unexplored areas of the Blake Plateau, Blake Ridge, Blake Escarpment, submarine canyons offshore North Carolina, submerged cultural heritage sites in the region, areas predicted to be suitable habitat for deep sea corals and sponges, inter-canyon areas, and gas seeps. The combined dives will enable scientists and managers to have a better understanding of the diversity and distribution of deep water habitats in this region, and enable informed resource management decisions.

Project participants covered under this LOA include: Kasey Cantwell, Eric Johnson, Elizabeth Lobecker, Rosemary Abbitt, Craig Russell, and Alan Leonardi. Copies of this LOA and the scientific research plan for the project should be onboard the vessel during all sampling activities. This LOA is separate and distinct from any permit or consultation required by the Marine Mammal Protection Act, Endangered Species Act, or any other applicable law.

Please send a copy of any cruise report or other publications resulting from the scientific research activity to me and to the Director, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149-1003.

Sincerely,

STRELCHECK.ANDREW.J.1365863152

Digitally signed by STRELCHECK.ANDREW.J.1365863152
Date: 2019.06.06 08:29:50 -04'00'

for Roy E. Crabtree, Ph.D.
Regional Administrator

Enclosure

cc: F/SEFSC, F/EN3

11.3 Appendix C: NASA Maritime Aerosols Network Survey of Opportunity

NASA Maritime Aerosols Network Survey of Opportunity

Survey or Project Name
Maritime Aerosol Network

Lead POC or Principle Investigator (PI & Affiliation)
POC: Dr. Alexander Smirnov

Supporting Team Members Ashore
Alexander Smirnov (NASA)

Supporting Team Members Aboard (if required)
N/A

Activities Description(s)(Include goals, objectives and tasks)
The Maritime Aerosol Network (MAN) component of AERONET provides ship-borne aerosol optical depth measurements from the Microtops II sun photometers. These data provide an alternative to observations from islands as well as establish validation points for satellite and aerosol transport models. Since 2004, these instruments have been deployed periodically on ships of opportunity and research vessels to monitor aerosol properties over the World Oceans.

11.4 Appendix D: Acronyms

ADCP—Acoustic Doppler Current Profiler
ACUMEN—Atlantic Canyons Undersea Mapping Expeditions
AERONET—Aerosol Robotic Network
ASPIRE—Atlantic Seafloor Partnership for Integrated Research and Exploration
ASVP—Automated Sound Velocity Profiler
BOEM—Bureau of Ocean Energy Management
BSEE—Bureau of Safety and Environmental Enforcement
$CaCO_3$—Calcium carbonate
CHAPC—Coral habitat area of particular concern
CIOERT—Cooperative Institute for Ocean Exploration, Research & Technology
CNES—National Centre for Space Studies (*French: Centre national d'études spatiales*)
CTD—Conductivity, temperature, and depth
DCEL—NOAA Deep Coral Ecology Laboratory
DNA—Deoxyribonucleic acid
DO—Dissolved oxygen
DSCRTP—NOAA Deep Sea Coral Research and Technology Program
DSV—Deep-submergence vehicle
ECC—Exploration Command Center
ECS—Extended Continental Shelf
EEZ—Exclusive Economic Zone
EFH—Essential Fish Habitat
EPP—NOAA Educational Partnership Program
ESA—Endangered Species Act
EtOH—Ethyl alcohol, or ethanol
FAU—Florida Atlantic University
FeMn—Ferromanganese
FOUO—For official use only
FSU—Florida State University
GFOE—Global Foundation for Ocean Exploration
GIS—Geographic Information Systems
HAPC—Habitat areas of particular concern
ISC—Inner Space Center
JAMSTEC—Japan Agency for Marine-Earth Science and Technology
kHz—Kilohertz
LOA—Letter of Acknowledgement
LSU—Louisiana State University
LSS—Light scattering spectroscopy

MAN—Maritime Aerosol Network
MBARI—Monterey Bay Aquarium Research Institute
MPA—Marine Protected Area
MSU—Mississippi State University
MUSC—Medical University of South Carolina
NAO—NOAA Administrative Order
NASA—National Aeronautics and Space Administration
NASEM—National Academies of Sciences, Engineering, and Medicine
NCCOS—NOAA National Centers for Coastal Ocean Science
NCEI—NOAA National Centers for Environmental Information
NEPA—National Environmental Policy Act
NGI—Northern Gulf Institute
NMFS—NOAA National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
NOS—NOAA National Ocean Service
OER—NOAA Office of Ocean Exploration and Research
ONMS—NOAA Office of National Marine Sanctuaries
ORP—Oxygen reduction potential
OSU—Oregon State University
PIFSC—NOAA Pacific Islands Fishery Science Center
QA/QC—Quality assurance/quality control
RAS—Russian Academy of Sciences
ROV—Remotely operated vehicle
SAFMC—South Atlantic Fisheries Management Council
SBNMS—Stellwagen Bank National Marine Sanctuary
SEDCI—NOAA Southeast Deep Coral Initiative
SEFSC—NOAA Southeast Fisheries Science Center
SERO—NOAA NMFS Southeast Regional Office
SIO—Scripps Institution of Oceanography
SIS—Seafloor Information Software
TSG—Thermosalinograph
UCAR—University Corporation for Atmospheric Research
UCH—Underwater Cultural Heritage
UH—University of Hawai'i at Mānoa
ULL—University of Louisiana at Lafayette
UNH—University of New Hampshire
USDA—U.S. Department of Agriculture
USGS—U.S. Geological Survey

USNM—National Museum of Natural History
WHOI—Woods Hole Oceanographic Institution
WoRMS—World Register of Marine Species
WWII—World War II
XBT—Expendable bathythermographs