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Cruise Report: EX-17-08, Deep-Sea Symphony: Exploring the Musicians Seamounts (ROV/Mapping)

Remotely Operated Vehicle (ROV) and Mapping Exploration of the U.S. Exclusive Economic Zone (EEZ) in and around Hawai‘i and International Waters, Focusing on the Musicians Seamounts

September 6 to September 30, 2017
Honolulu, Hawai‘i, to Honolulu, Hawai‘i

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Abstract:

The *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition (EX-17-08), conducted by NOAA and partners, was a combined mapping and remotely operated vehicle (ROV) exploration as part of NOAA's Campaign to Address Pacific monument Science and Technology Needs (CAPSTONE), a multi-year foundational science effort to collect critical data and information in unknown and poorly-known deepwater areas in U.S. marine protected areas (MPAs) in the central and western Pacific Ocean. This two-part cruise, the last expedition in the CAPSTONE initiative, commenced on August 8, 2017, and concluded on September 30, 2017, focusing on these areas in and around the Musicians Seamounts and the Hawaiian Islands in order to increase the understanding of these deep-sea ecosystems in this region to support management decisions. The expedition used the ship's deepwater mapping systems to map over 85,000 km^2 of seafloor, including more than 50 seamounts and ridges. In addition, 22 ROV dives were conducted with over 360 hours dedicated to seafloor and midwater communities at depths 290 m to 3,854 m. Hundreds of animals were observed (many of which could be new species or records for the region), including 18 high-density coral and sponge communities, precious corals, and midwater species. In total, 178 samples (36 geological samples, and 142 biological samples) were collected for further analysis. Additionally, sonar anomalies were investigated as part of NOAA's Underwater Cultural Heritage (UCH) work. This report summarizes operations conducted during EX-17-08, presents data collected, and provides an overview of the initial findings.

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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 the Seabed 2030 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 NOAA Ship *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 NOAA Ship *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 to a systematic and efficient approach for 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 Expedition Background

The Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE), was a three-year effort designed to provide critical new information about the deepwater resources within the U.S. National Marine Monuments and Sanctuaries located throughout the Pacific. The primary goal of all NOAA Ship *Okeanos Explorer* expeditions during this campaign was to obtain baseline data and information of the poorly known deepwater areas and resources in these extensive marine protected areas (MPAs).

NOAA and partners conducted the final two cruises of the CAPSTONE effort, *Deep-Sea Symphony: Exploring the Musicians Seamounts* (EX-17-07 and EX-17-08), commencing on August 8, 2017, and completing on September 30, 2017. To meet the CAPSTONE objectives, this expedition collected critical data and information about unknown and poorly understood areas in and around the Musicians Seamounts.

Located northwest of the Main Hawaiian Islands (MHIs), the Musicians Seamounts are largely unexplored. Small portions of this 650-nautical-mile seamount chain have been previously mapped during transits, but the *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition conducted the first dedicated mapping operations and exploration using a remotely operated vehicle (ROV), to increase the understanding of the deep-sea ecosystems in this fascinating region that lies just outside of the U.S. EEZ.

As one of the closest seamount groups to the Hawaiian Islands, the Musicians Seamounts may serve as refuge for the transient fish populations that Hawaiʻi relies upon, provide additional habitat, and serve as a pool of genetic diversity for deep-sea coral populations known from the deep waters around the Hawaiian Islands. It is also important to characterize the habitats that lie on the borders of Papahānaumokuākea Marine National Monument (PMNM) in order to make informed management decisions and better understand the potential connectivity with the surrounding waters.

Additionally, exploring the Musicians Seamounts offered a unique opportunity to expand geological knowledge about fracture zones, hotspot volcanism, and how these features interact in areas where they coexist. Furthermore, this expedition filled in gaps in data regarding seamount geomorphology and manganese crust accretion.

This two-part expedition to explore the Musicians Seamounts was composed of EX-17-07, a 24-hour mapping cruise to conduct reconnaissance and fill the significant mapping data gaps in the region (Lobecker et al, 2020), and EX-17-08, an ROV and mapping cruise to explore the newly mapped features and conduct the first-ever ROV exploration of habitats in the region. During EX-17-08, 24-hour operations were conducted consisting of daytime ROV dives and overnight mapping operations. The 22 ROV dives explored deep-sea coral and sponge habitats, bottomfish habitats, seamounts, and an investigation of habitats within the Murray Fracture Zone and areas of cultural heritage and marine archeological significance. Prior to EX-17-07, there was very little high-resolution multibeam mapping over Musicians Seamount chain. During EX-17-08, bathymetry coverage was expanded, building upon the work of the EX-17-07 cruise and leaving behind a rich legacy of publicly available data that reveals likely dozens of new features. This report focuses on data from EX-17-08, but additional information about EX-17-07 can be found in Lobecker et al 2020.

2. Objectives

NOAA Ship *Okeanos Explorer* cruises, in general, have a large number of objectives that can be categorized as being either scientific or programmatic in nature. Typically, science objectives are specific to a particular cruise or set of cruises, whereas programmatic objectives (i.e., operations, telepresence, data management, education, and outreach) are common to all cruises. Below are brief descriptions of the science and programmatic objectives for EX-17-08.

2.1 Science Objectives

The *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition (EX-17-07 and EX-17-08) addressed science themes and priority areas put forward by scientists and managers from NOAA, management agencies in the region, and the ocean science community. NOAA priorities for the expedition include a combination of science, education, outreach, and open data objectives that will support management decisions at multiple levels:

- Acquire data on habitats near the PMNM and U.S. EEZ boundaries to support priority science and management needs.
- Identify, map, and explore a diversity of benthic habitats and features—particularly vulnerable communities, such as high-density, deep-sea coral and sponge communities.
- Investigate biogeographic patterns of deep-sea ecosystems and connectivity across the Musicians Seamounts.
- Characterize seamounts within the upper extent of the Prime Crust Zone (PCZ), an area of the Pacific with the highest levels of commercially valuable deep-sea mineral deposits.
- Investigate the geology of the Musicians Seamounts and the Murray Fracture Zone to better understand the relationship between hotspot volcanism, mid-ocean ridges, and fracture zones.
- Explore U.S. maritime heritage by investigating sonar anomalies and characterizing World War II (WWII) era shipwrecks.
- Collect high-resolution bathymetry in areas with no (or low-quality) sonar data.
- Acquire a foundation of ROV, sonar, and oceanographic data to better understand the characteristics of the water column and the fauna that live there.
- Engage a broad spectrum of the scientific community and public in telepresence-based exploration, and provide a foundation of publicly accessible data and information products to spur further exploration, research, and management activities.

2.2 Programmatic Objectives

a) *Mapping and ROV and Operations*

Mapping objectives during each NOAA Ship *Okeanos Explorer* cruise are to collect high-resolution acoustic data. Data were collected from all four types of sonars on the ship: EM 302 multibeam, EK60 echo sounder, 3.5 kHz subbottom profiler (SBP), and Acoustic Doppler Current Profilers (ADCPs). Mapping data were acquired during transits, as well as on specific targets identified by the science team. Data from these systems were processed as quickly as possible in order to generate daily mapping products that supported ROV operations. Data quality was expected to be high, as a result of proper instrument maintenance, careful planning of the surveys, and appropriate calibration of the instruments. For example, standard operating procedure for the multibeam sonar is to obtain sound velocity profiles at regular intervals—no longer than six hours—using expendable bathythermographs (XBTs).

ROV objectives were to obtain high-quality video and sensor data on exploration targets to achieve the science objectives. This most often involved surveying benthic habitats and features in priority areas (e.g., deep corals and related benthic ecosystems, canyons, and seamounts), as

well as occasionally surveying in midwater for water column organisms. Benthic surveys were not only used to characterize the habitats in each target area but also to ground-truth the acoustic data with visual data (i.e., video). In 2015, the ROV was fitted with hydraulically-activated sample boxes that permitted ROV pilots to collect limited geological and biological specimens.

b) *Telepresence*
Telepresence objectives were to provide real-time, high-quality video and audio during ROV dives to as wide a shoreside audience as possible. This audience included the general public, students, and researchers—the latter of whom were either passively watching or actively participating in the dives via teleconference or instant messaging. Telepresence was used to help achieve the science objectives by extending the science team well beyond those actually onboard the ship. Telepresence also helped to achieve the expedition's education and outreach objectives through live ship-to-shore events.

c) *Data Management*
Data management objectives were to collect, process, distribute, and archive cruise data as quickly and efficiently as possible. Effective data management provided a foundation of publicly accessible information products to spur further exploration, research, and management activities; it also stimulated interest in the deep-sea environment and the excitement of exploration. Each year, new methods and new equipment, such as video encoders, are tried and tested in an effort to improve data management activities.

d) *Education and Outreach*
Education and outreach objectives included the engagement of the general public in ocean exploration through live video and a variety of other web-based products, both during and after each cruise. Web content included topical essays written before the cruise, daily updates, mission logs, highlight videos, still imagery and mapping products—all of which are posted on the OER website (http://oceanexplorer.noaa.gov/okeanos/welcome.html). Additional activities including live telepresence events and an in-port event that included ship tours, presentations, workshops, and other events, helped to expand the reach of this expedition.

3. List of Participants

EX-17-08 included at-sea mission personnel as well as shore-based science personnel who participated remotely via telepresence technology. See Table 1 for the at-sea mission personnel and Table 2 for the shore-based personnel who supported this expedition.

Table 1: *Full list of at-sea mission personnel for EX-17-08.*

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Table 2: *Shore-based personnel participated from remote exploration command centers (ECCs) and from their home institutions at various locations around the world.*

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4. Methodology

In order to accomplish its objectives, the expedition made use of NOAA Ship *Okeanos Explorer*'s:

(1) two-body ROV system—ROVs *Deep Discoverer* (*D2*) and *Seirios*—to conduct daytime seafloor surveys, as well as to collect limited numbers of specimens to help further characterize the deepwater fauna and geology of the region;
(2) mapping systems—Kongsberg EM 302 multibeam sonar, Knudsen 3260 SBP, Kongsberg EK60 split-beam fisheries sonars, and Teledyne ADCPs to conduct nighttime mapping operations and when the ROV was on deck; and
(3) high-bandwidth satellite connection for real-time ship-to-shore communications.

4.1 ROV seafloor surveys

ROV dive operations were conducted to support the expedition objectives, including characterizing a diversity of benthic habitats (like those for bottomfishes and precious corals), features (such as high-density, deep-sea coral and sponge communities), and seamounts (specifically those within the upper extent of the PCZ); investigating the geology of the Musicians Seamounts and the Murray Fracture Zone, as well as the biogeographic patterns of deep-sea ecosystems and connectivity across the Musicians Seamounts; and exploring U.S. maritime heritage (by investigating sonar anomalies and characterizing WWII-era shipwrecks). Dive sites were chosen using high-resolution bathymetry data, when available. With the exception of one site (the USS *Baltimore*), all chosen dive locations were previously unexplored. The USS *Baltimore*'s position was confirmed by the *Pisces V* submersible during a test dive in August 2017.

During each dive, the ROVs descended onto the seafloor and then moved from waypoint to waypoint, documenting the geology and biology of the area. At-sea and shore-based scientists identified each encountered organism to the lowest possible taxon. For this purpose, scientists used the online pilot version of the OER Benthic Deepwater Animal Identification Guide (http://oceanexplorer.noaa.gov/okeanos/animal_guide/animal_guide.html), as well as the online Hawai'i Undersea Research Lab (HURL) animal guide (https://www.soest.hawaii.edu/HURL/HURLarchive/guide.php). At-sea and shore-based scientists provided geological interpretations of the observed substrate throughout each ROV seafloor survey. Additional information about the general process of site selection, collaborative dive planning, scientific equipment on the ROVs, and the approach to benthic exploration used during CAPSTONE expeditions can be found in Kennedy et al. (2019). Details about ROV seafloor surveys conducted during this expedition can be found in Section 7.1.

4.2 Specimen collections

A limited number of geological and biological samples were collected on the seafloor using the manipulator arms and biological and geological collection boxes on ROV *D2.* 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 specimen collections targeted samples 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, or dominant species in the area.

Once specimens were brought back onto the deck of the ship, they were examined for commensal organisms, labeled, photographed, and inventoried into a database containing all relevant metadata. When possible, any commensal organisms found were separated from the sample and processed separately. If commensal organisms could not be separated without causing damage to either sample, they were preserved together. Geological samples were air dried and placed in rock bags. These samples were shipped to the Marine Geology Repository at Oregon State University (OSU) at the conclusion of the expedition, where they were analyzed in the laboratory for their chemical composition and geologic age. Biological samples were processed for DNA extractions using a kit provided by the Ocean Genome Legacy (OGL). 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. The remainder of the biological sample was preserved in 95% ethanol. Additionally, several samples had subsamples taken and preserved in 10% buffered formalin for future histological examinations, with all but one of the subsamples transferred to 70% ethanol after three days. Details about the specimens collected during this expedition can be found in Section 7.3.

All DNA samples were sent to OGL for DNA sequencing and storage, whereas the biological specimens preserved in ethanol and formalin were sent to the National Museum of Natural History (USNM), Smithsonian Institution (SI), for taxonomic identification and permanent storage. Some corals and sponges may also be subsampled and provided to the Bernice Pauahi Bishop Museum in Honolulu, Hawai‘i.

Additional information about accessing data collected during this expedition, including samples, can be found in Appendix A.

4.3 Seafloor mapping

Mapping operations included EM 302 multibeam, EK60 singlebeam, Knudsen SBP, and ADCP data collection. The schedule of operations included overnight transit mapping and mapping whenever the ROV was on deck. Lines were planned to maximize either edge matching of existing data or data gap filling in areas where existing bathymetry coverage existed. In regions with no existing data, exploration transit lines were planned to optimize potential discoveries. Details about seafloor mapping conducted during this expedition can be found in Section 7.2.

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 kHz. Multibeam mapping operations were conducted during all overnight transits between ROV dive sites, which were designed to maximize coverage over seafloor areas with no previous high-resolution mapping data whenever feasible. Overnight surveys were also completed in some 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).

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. 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.

4.3.3 Split-beam Sonars (Kongsberg EK60)

NOAA Ship *Okeanos Explorer* is equipped with five Kongsberg EK60 split-beam sonar transducers operated at frequencies of 18, 38, 70, 120 and 200 kHz. These sonars were used continuously (aside from the 38 kHz, which interferes with the multibeam during mapping operations) throughout the cruise during both overnight mapping operations and daytime ROV operations. The sonars provided calibrated target-strength measurements on 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. Data collected using the EK60 sonars 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). However, only the 300 kHz ADCP was operational during this expedition. This ADCP had a reliable range of approximately 60 meters throughout the expedition and provided information on the speed and direction of currents underneath the ship. It was used throughout ROV dives to support safe deployment and recovery of the vehicles.

4.3.5 Expendable Bathythermograph (Lockheed Martin Sippian Deep Blue XBT)

The Lockheed Martin Sippican Deep Blue XBT probe was deployed to obtain sound velocity profiles to help calibrate the multibeam system and ensure accurate bathymetric mapping. XBTs were collected every three to six hours at an interval defined by prevailing oceanographic conditions to correct multibeam data for changes in sound speed in the water column, and were applied in real time using Seafloor Information Software (SIS). Sound speed at the sonar head was determined using a Reson sound velocity probe (SVP)-70, and salinity measurements near the transducers were taken using the ship's flow-through thermosalinograph (TSG).

4.4 Sun Photometer Measurements

OER gathers limited at-sea measurements aboard NOAA Ship *Okeanos Explorer* in order to support a National Aeronautics and Space Administration (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. More information about this NASA Survey of Opportunity can be found in Appendix C.

4.5 Education and Outreach Activities

One of OER's primary goals is to encourage and inspire the next generation of ocean explorers, scientists, and engineers. The 2017 *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition had a particular emphasis on engaging global community through telepresence, ship tours, live interactions, and partnerships. Some of these activities were conducted by the at-sea mission personnel and others were conducted by shore-based personnel. The team also engaged the general public in ocean exploration through live video and a variety of other web-based products, both during and after the cruise. Web content included topical essays written before the cruise, daily updates, mission logs, highlight videos, still imagery and mapping products—all of which are posted on the OER website (http://oceanexplorer.noaa.gov/okeanos/welcome.html). Upon completion of the expedition, the Ocean Exploration Celebration was held in partnership with the Schmidt Ocean Institute (SOI) and the University of Hawai‘i at Mānoa (UH); over 600 people attended the event. Additional details about the engagement activities conducted for this expedition can be found in Section 7.4.

5. Clearances and Permits

A permit—U.S. Fish and Wildlife Service (USFWS) Convention on International Trade in Endangered Species (CITES) permit #17US36207C/9—to collect CITES-listed species was received from the USFWS on August 6, 2017. This permit covered all sampling operations conducted outside of the U.S. EEZ. Permit requirements may trigger additional inspections of the vessel and samples collected upon return to Honolulu, HI. A copy of the permit can be found in Appendix B.

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-03012018.pdf) 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. A categorical exclusion (CE) evaluation memorandum has been completed for this survey, in accordance with Section 4 of the Companion Manual. This evaluation document memorandum describes EX-17-08 and explains how it is consistent with one or more of the CE categories

listed/described in Appendix E of the Companion Manual. The completed evaluation document also summarizes the review conducted to determine that no extraordinary circumstances exist that would preclude the use of a CE or require preparation of an environmental assessment or environmental impact statement. This document is on file with OER and a copy can be found in the EX-17-08 project instructions (Cantwell, 2017).

Informal consultation was initiated under Section 7 of the Endangered Species Act (ESA), requesting NOAA National Marine Fisheries Service's (NMFS's) Protected Resources Division concurrence with OER's biological evaluation determining that the *2016 Deepwater Exploration of the Marianas* expedition, and all other planned NOAA Ship *Okeanos Explorer* operations during the 2016-17 expeditions, may affect, but are not likely to adversely affect, ESA-listed marine species. The informal consultation was completed on February 3, 2016 when OER received a signed letter from the Regional Administrator of NMFS Pacific Islands Regional Office (PIRO), stating that NMFS concurred with OER's determination that conducting proposed NOAA Ship *Okeanos Explorer* cruises were not likely to adversely affect ESA-listed marine species. This documentation is on file with OER and a copy can be found in the EX-17-08 project instructions (Cantwell, 2017).

OER completed consultation with NOAA's Habitat Conservation Division on potential impacts of these operations to Essential Fish Habitat (EFH). They concurred that OER operations would not adversely affect EFH, provided adherence to OER's proposed procedures and their guidance stated in the letter. This documentation is on file with OER and a copy can be found in the EX-17-08 project instructions (Cantwell, 2017).

6. Operational Summary

The expedition was planned for a total of 25 days at sea, from September 6-30, 2017, departing from Ford Island, Honolulu and arriving at the UH Marine Center, Honolulu (Fig. 1). There were 22 ROV dives completed during EX-17-08 (Tables 3 and 4). Dive 06 at Debussy Seamount was aborted at 50 m due to a ground fault with the ROVs. Upon completion of the vehicle repair, the ROVs were deployed again for Dive 7 to complete the exploration of Debussy Seamount. Two dives were canceled during the course of EX-17-08 due to a mechanical problem with the ship's bow thruster, and another dive was canceled due to weather.

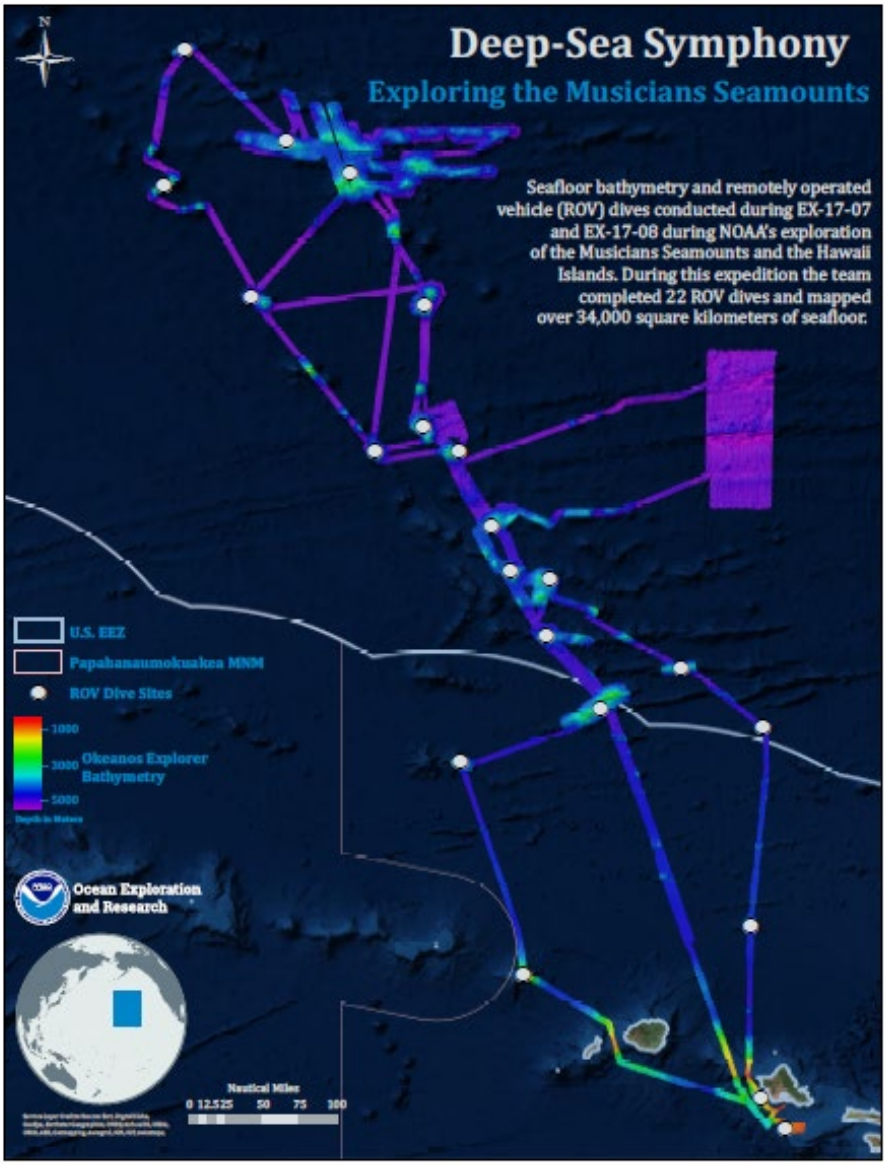

Figure 1. *Expedition map of the* Deep-Sea Symphony: Exploring the Musicians Seamounts *expedition. This expedition was composed of ROV and mapping operations that took place over two field components (EX-17-07 and EX-17-08). Shown here is the footprint of bathymetric coverage obtained during the two cruises and ROV dives conducted during EX-17-08. Mapping priorities during EX-17-07 targeted areas where previous data was sparse and needed to inform potential ROV dive sites. Mapping during EX-17-08 built upon coverage from EX-17-07 and mapped features in the proximity of ROV dive sites.*

Table 3: *EX-17-08 expedition calendar. Each day during EX-17-08 completed a diversity of objectives that included ROV dives, mapping, and outreach. Additional details about specific expedition objectives can be found in Section 2 of this report.*

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
9/3 Mission personnel arrive	**9/4** Mobilization	**9/5** Mobilization	**9/6** 0900: departure Transit Mapping Outreach: 0730: Testing with International MPA Congress (IMPAC4)	**9/7** Dive 01: "Tropic of Cancer" Seamount Overnight mapping Outreach: 0930: IMPAC4 live interaction	**9/8** Dive 02: "Beach" Ridge Overnight mapping Outreach: none scheduled	**9/9** Dive 03: "Beethoven" Ridge Overnight mapping Outreach: none scheduled
9/10 Dive 04: Sibelius Seamount + midwater transects Overnight mapping Outreach: none scheduled	**9/11** Dive 05: "Gounod" Seamount Overnight mapping Outreach: none scheduled	**9/12** Dive Canceled Overnight mapping Outreach: 0930-1030: Korean Hydrographic & Oceanographic Administration	**9/13** Dive 06: Dive Aborted Dive 07: Debussy Seamount + midwater transects Overnight mapping Outreach: 1400: Navy group at IRC ECC on science line 1700-1830: EK60 Workshop on science line	**9/14** Dive 08: Wagner Seamount Overnight mapping Outreach: 0600: Louisiana Kiwanis club science lunch	**9/15** Dive 09: Verdi Seamount Overnight mapping Outreach: none scheduled	9/**16** Dive 10: Shostakovich Seamount + midwater transects Overnight mapping Outreach: Start of Midwater Week
9/17 Dive 11: Full day midwater Water Column 1 Overnight mapping Outreach:	**9/18** Dive 12: Mussorgsky Seamount Overnight mapping Outreach:	**9/19** Dive 13: Paganini Seamount + midwater transects Overnight mapping Outreach:	**9/20** Dive 14: Liszt Seamount Overnight mapping Outreach: MTS Oceans @ 1245	**9/21** Dive 15: Mozart Seamount Overnight mapping Outreach: 1100: USFWS @	**9/22** Dive 16: Full day midwater Water Column 2 Overnight mapping Outreach:	**9/23** Dive 17: Rapano Ridge + midwater transects Overnight mapping Outreach:

0745: Midwater Facebook Live	1330: Pacific Islands Leadership @ UH ECC 1530: Test with Marine Technology Society (MTS) Oceans Conference	1400-1445: Science on the Bayou at Lafayette Science Museum		SS ECC Interaction	none scheduled	None Scheduled
9/24 Dive 18: Schumann Seamount Overnight mapping Outreach: none scheduled	**9/25** Dive 19: Mendelssohn Seamount Overnight mapping Outreach: 1030-1100: Rotary Group in IRC ECC on science line	**9/26** Dive 20: "Middle Bank" Overnight mapping Outreach: 1200: Answer Kai's questions over live feed	**9/27** Dive Canceled Overnight mapping Outreach: none scheduled	**9/28** Dive 21: "Caiman" Anomaly Overnight mapping	**9/29** **UCH DIVE** Dive 22: S-28 Target 0815-1630 Overnight mapping. Enter UCH Boundary ~0515 , exit @ ~1730 Outreach: 1330-1400: UH Librarian Students in IRC ECC on science line (Bruce Mundy to host)	**9/30** 0700: EX at the Pearl Harbor sea buoy. Mission operations complete. EX arrives into UH Marine Center 0900-1700: Prepare for ship tours. Staging for port event
10/1 **Ocean Exploration Celebration** 0900-1000: Media event 0900: Opening remarks followed by media tour	**10/2** EX departs UH Marine Center CAPSTONE Wrap up meeting @ IRC EX Fuels and then ties up at Ford Island					

1000: VIP Tours 1000-1600: Public tours. 1600-1730: Wrap up and close out event						

Table 4: *ROV dive schedule as executed during EX-17-08*

Date	Dive #	Site Name	Lat (on bottom)	Long (on bottom)	Lat (off bottom)	Long (off bottom)	Max Depth (m)	Dive Time	Bottom time
9/7	1	"Tropic of Cancer" Seamount	23°, 18.373' N	158°, 21.450' W	23°, 18.521' N	158°, 21.498' W	1,855.5	6:11:48	3:40:54
9/8	2	"Beach" Ridge	25°, 33.234' N	158°, 12.830' W	25°, 33.193' N	158°, 12.982' W	3,285.5	7:39:03	3:24:59
9/9	3	“Beethoven” Ridge	26°, 13.373' N	159°, 08.793' W	26°, 13.431' N	159°, 08.527' W	2,534.5	8:05:53	5:20:35
9/10	4	Sibelius Seamount + midwater	27°, 14.674' N	160°, 37.960' W	27°, 14.862' N	160°, 38.014' W	2,655.1	10:16:43	5:23:59
9/11	5	“Gounod” Seamount	27°, 50.251' N	161°, 17.646' W	27°, 50.467' N	161°, 17.517' W	2,934.3	8:09:18	4:51:53
9/13	6	Aborted dive on Debussy	-	-	-	-	-	-	-
9/13	7	Debussy Seamount	30°, 20.446' N	162°, 03.269' W	30°, 20.368' N	162°, 03.333' W	2,054.1	5:30:30	3:07:44
9/14	8	Wagner Seamount	31°, 51.118' N	162°, 53.688' W	31°, 51.067' N	162°, 53.947' W	2,432.4	8:07:20	5:26:52
9/15	9	Verdi Seamount	32°, 12.266' N	163°, 36.926' W	32°, 12.341' N	163°, 36.962' W	3,098.3	6:03:47	2:36:40
9/16	10	Shostakovich Seamount	33°, 14.847' N	164°, 46.206' W	33°, 15.094' N	164°, 46.065' W	2,869.7	9:48:12	4:44:19
9/17	11	Water Column 1	31°, 41.995' N	165°, 00.278' W	31°, 41.557' N	165°, 00.294' W	1,003.0	8:01:31	0:00
9/18	12	Mussorgsky Seamount	30°, 26.418' N	164°, 00.818' W	30°, 26.159' N	164°, 00.769' W	2,058.6	8:05:02	5:40:12
9/19	13	Paganini Seamount + midwater	28°, 40.709' N	162°, 36.585' W	28°, 40.920' N	162°, 36.529' W	1,812.2	9:35:47	5:41:16
9/20	14	Liszt Seamount	28°, 57.523' N	162°, 04.279' W	28°, 57.767' N	162°, 04.319' W	2,564.5	8:04:56	5:19:47
9/21	15	Mozart Seamount	28°, 41.677' N	161°, 39.830' W	28°, 41.624' N	161°, 40.171' W	3,854.1	10:11:53	5:58:13

9/22	16	Water Column 2	27°, 18.954' N	161°, 04.117' W	27°, 19.016' N	161°, 04.528' W	1,001.3	8:01:15	0:00
9/23	17	Rapano Ridge + midwater	26°, 35.817' N	160°, 40.126' W	26°, 35.703' N	160°, 40.388' W	2,050.3	9:58:49	5:45:11
9/24	18	Schumann Seamount	25°, 45.689' N	160°, 03.526' W	25°, 46.580' N	160°, 03.663' W	2,317.4	8:05:03	5:34:10
9/25	19	Mendelssohn Seamount	25°, 09.632' N	161°, 38.635' W	25°, 09.651' N	161°, 38.877' W	1,795.8	6:30:40	4:29:39
9/26	20	"Middle Bank"	22°, 45.249' N	160°, 55.692' W	22°, 45.281' N	160°, 55.957' W	477.7	7:57:39	7:03:10
9/27		Dive Canceled							
9/28	21	"Caiman" anomaly/I-203	21°, 12.940' N	158°, 08.032' W	21°, 12.964' N	158°, 07.341' W	843.6	7:59:15	6:52:39
9/29	22	USS *Baltimore*	**UCH info withheld**	**UCH info withheld**	**UCH info withheld**	**UCH info withheld**	**UCH info**	7:59:14	6:53:51

7. Results

Exploration of the high seas is of increasing importance, not only because these are the least studied areas on the planet, but because they are unequivocally connected to the EEZs of countries across the globe. The *Deep-Sea Symphony: Exploring the Musicians Seamounts* telepresence-enabled expedition on NOAA Ship *Okeanos Explorer* collected critical baseline information about unknown and poorly understood deepwater areas around the Musicians Seamounts (examples in Fig. 2), a chain of largely unexplored seamounts located northwest of the MHI. Previous research conducted along this 650-nautical-mile-long seamount chain generally consisted of only low-resolution singlebeam and multibeam sonar opportunistic transit mapping data and a handful of dredges to establish seamount ages (Clague and Dalrymple, 1975). Understanding the potential connectivity between the MHI and the PMNM will inform management decisions, such as fisheries and Monument management plans.

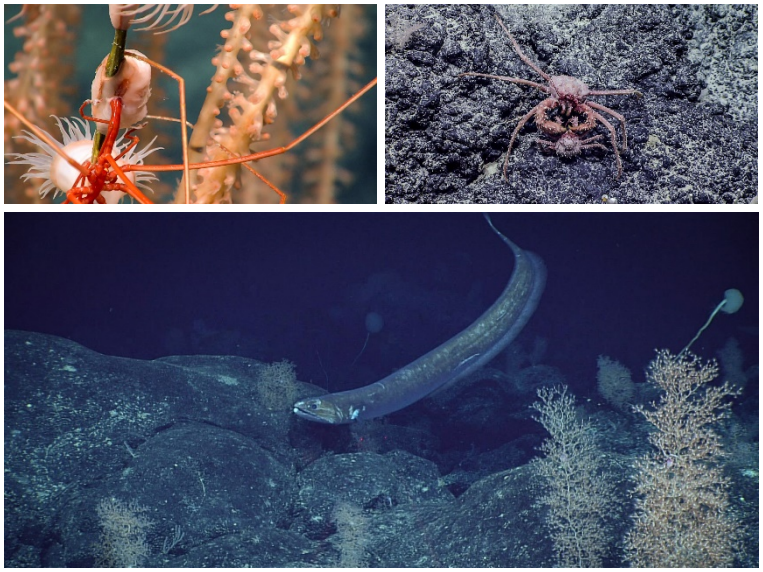

Figure 2. *Fauna associated with deep-sea coral and sponge communities were observed exhibiting natural behaviors. (Upper left) A giant sea spider, in the family Colossendeidae, was spotted predating on an anemone that had settled on a branch of bamboo coral. (Upper right) A pair of* Paralomis *sp. king crabs were locked in a mating embrace. (Lower middle) A cutthroat eel,* Synaphobranchus brevidorsalis*, cruising through the dense coral community at Paganini Seamount (Dive 13).*

Additionally, the Musicians Seamounts offered a unique opportunity to expand scientific geological knowledge about fracture zones, hotspot volcanism, and the interactions between mantle plumes and mid-ocean ridges. As the final expedition of NOAA's CAPSTONE efforts, the *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition aimed to support characterization of the biological diversity and the geological setting of this fascinating region that lies just outside of the U.S. EEZ.

7.1 ROV seafloor surveys

During EX-17-08, a total of 22 dives were conducted over the course of 25 days at sea. Survey depths ranged from 290 m to 3,854 m. Dive 01, 02, 19-22 were conducted in the US EEZ. ROV exploration during this expedition focused on the Musician Seamount chain and examined both benthic and midwater deep-sea communities as well as the unique geology of the hot spot seamount chain and its interaction with a mid-ocean fracture zone. Dives 11 and 16 were dedicated fully to midwater exploration and Dives 04, 10, 13, and 17 had midwater transects following the benthic portion of the dive. Note, Dive 06 (which was scheduled to conduct midwater work) was aborted early due to a ground fault with the vehicles and Dive 07 at the same location did not include midwater exploration. Dive 20 examined bottomfish and precious coral habitats within the MHI. Dives 21 and 22 explored potential Underwater Cultural Heritage (UCH) sites off the southern coast of O'ahu.

7.1.1 Geology

Geological Setting and Previous Work

The Musicians Seamounts are a province, or collection, of about 25 underwater mountains in the central Pacific Ocean—just north of the MHI and bordering the eastern boundary of the PMNM in the Northwestern Hawaiian Islands. The Musicians Seamounts group was given that name in 1959 by Dr. H. W. Menard, a renowned marine geologist at the Scripps Institution of Oceanography. The individual features are names for famous composers, such as Mendelssohn, Tchaikovsky, Gershwin, Beethoven, Verdi, etc. Many of the seamounts within that group were named by David Rea and Fred Naugler of the U.S. Coast and Geodetic Survey, a predecessor agency to NOAA's Office of Coast Survey and NOAA's National Geodetic Survey, following a dedicated series of expeditions to the Musicians Seamounts and other areas in the north central Pacific and U.S. West Coast. This focused effort, called the Scientific Exploration and Mapping Program (SEAMAP), took place from 1960-1973 with the goals of systematically mapping the seafloor and collecting oceanographic data from these regions.

The Musicians Seamounts are extrusive constructional volcanic features, meaning they were erupted as molten lava from the seafloor and built up over millions of years. Based on the new data, some appear to have broken the sea surface and become islands before eroding and subsiding far below sea level once again, while most never made it to the surface at all. As mentioned already, little research had been previously conducted in this region. As far as is known, the Musicians Seamount volcanoes have long been extinct. There have been several theories as to the exact origin of the Musicians Seamounts, although all agree they are volcanic seamounts and a hot spot plume was involved—mimicking the method of formation of the neighboring Hawaiian chain, which is the classic hot spot plume model most often studied and

referred to in this field of research. Complications to this model of formation, in the case of the Musicians Seamounts and associated ridge structures, include interaction of said hot spot with an ocean ridge spreading center or its remnant fracture zone ridges, or even from simple cracking and subsequent "leaking" of the oceanic, or tectonic, plate comprising the seafloor.

Overview of Results

Present-day thinking considers that the formation of the Musicians Seamounts chain resulted from eruptions fed by partial melting of an upwelling mantle plume (Kopp et al., 2003). The portions of the Musicians Seamounts chain explored during this expedition formed near a mid-ocean ridge, in contrast to other linear, plume-fed seamount chains, such as Hawai‘i. As a result of close proximity to the ridge, the underlying mantle plume fed not only a chain of seamounts, but also two sets of anomalous volcanic ridges that extend from the main seamounts eastward toward the former location of the ridge axis. These volcanic ridges are known as lineaments.

The new mapping data reveal that the Musicians lineaments were constructed of large volumes of volcanic material, much greater than erupted at similar times along the main Musicians Seamounts. For example, within the northern set of lineaments, several volcanoes sit atop an extensive plateau constructed approximately 100 kilometers east of the main seamount chain (Fig. 3). Along the lineaments, the new maps reveal many flat-topped seamounts (guyots), that likely were previously subaerial and subjected to wave and wind erosion.

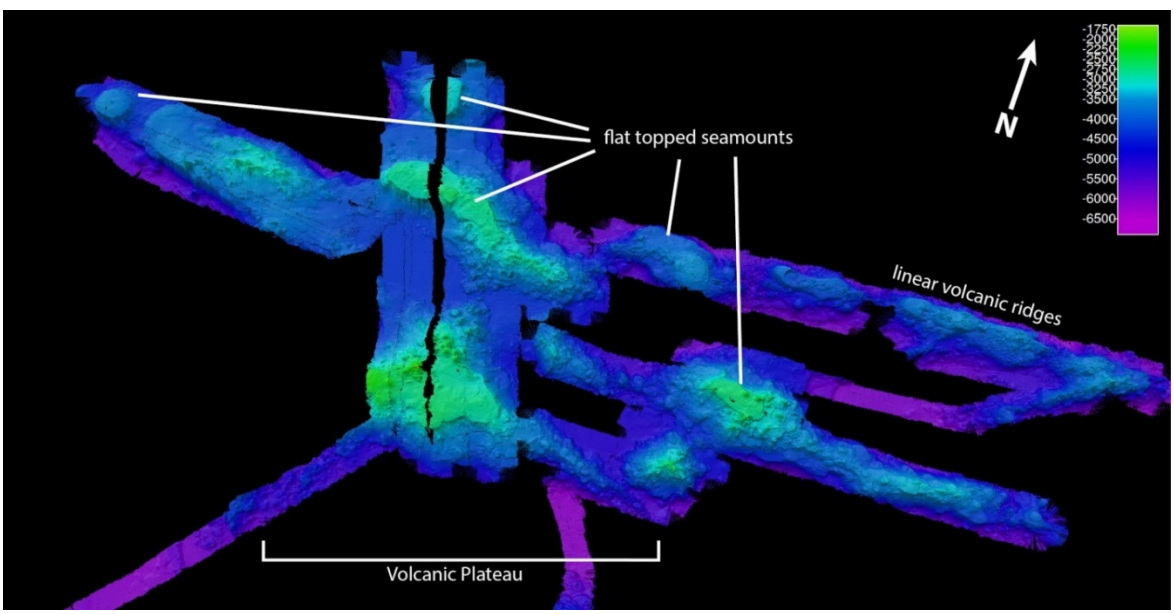

Figure 3. *New mapping data along the northern extent of the expedition operating area revealed an elevated volcanic plateau with several guyots and linear volcanic ridges. Courtesy of Eric Mittelstaedt.*

Remarkably, video observations of extensive sheet flows with little to no pillow basalt construction suggest that high effusion rate eruptions fed by voluminous magma supplies were the norm. Seamounts of the Musicians lineaments contrast dramatically with other hotspot lineaments of similar origin. For example, the volume of erupted material making up the young (<2 Ma) Galápagos lineaments is a fraction of that erupted to construct the main Galápagos Archipelago (Mittelstaedt et al., 2014). Furthermore, limited photographic imagery from the Galápagos lineaments reveals significant pillow basalt eruptions, suggesting lower effusion rates.

Such differences imply that the dynamics of plume-ridge interaction at the Musicians Seamounts may have differed greatly from other near-ridge mantle plumes.

Mapping and ROV dives provided new information on the interaction of mantle plumes and fracture zones at the intersection of the Musicians Seamounts and the Murray Fracture Zone. Although some geochemical and age-related questions await sample analysis, data collected have already addressed some geological questions. For example, a ridge feature extending to the east-northeast off of Liszt Seamount was mapped that is coincident with a fracture in the Murray Fracture Zone (Fig. 4). If this feature is volcanic in origin, then this observation supports the hypothesis that melts ascending at Liszt Seamount may have exploited structural weaknesses of the fracture zone to reach the surface.

ROV Dive Observations

Generally speaking, the ROV dives documented the full range of seafloor morphologies, structural elements, volcanological constructs, and substrates, such as basalt lavas, secondary volcanism including volcaniclastic products, lagoonal sediments, polymetallic crusts, and other geological oddities. ROV dives were sited on classic conical or stellate seamounts or solitary volcanic cones, guyots now capped by carbonate, and volcanic ridges or lineaments. One of the geological features most utilized by the biology in residence were large, isolated boulders that had presumably broken free from upslope outcrops and slid or tumbled into their current place. Deep-sea coral and sponge communities took full advantage of these tiny islands in the current stream, as such rocks were typically festooned with these organisms in a high-density fashion.

Into the Fracture Zone

Perhaps the most interesting dive series, in a geological sense, were the three dives conducted on features near or within the Murray Fracture Zone: Paganini, Liszt, and Mozart Seamounts (Dives 13, 14, and 15, respectively). Summaries of the dive observations follow, and please refer to Figure 4 with the bathymetric map image below.

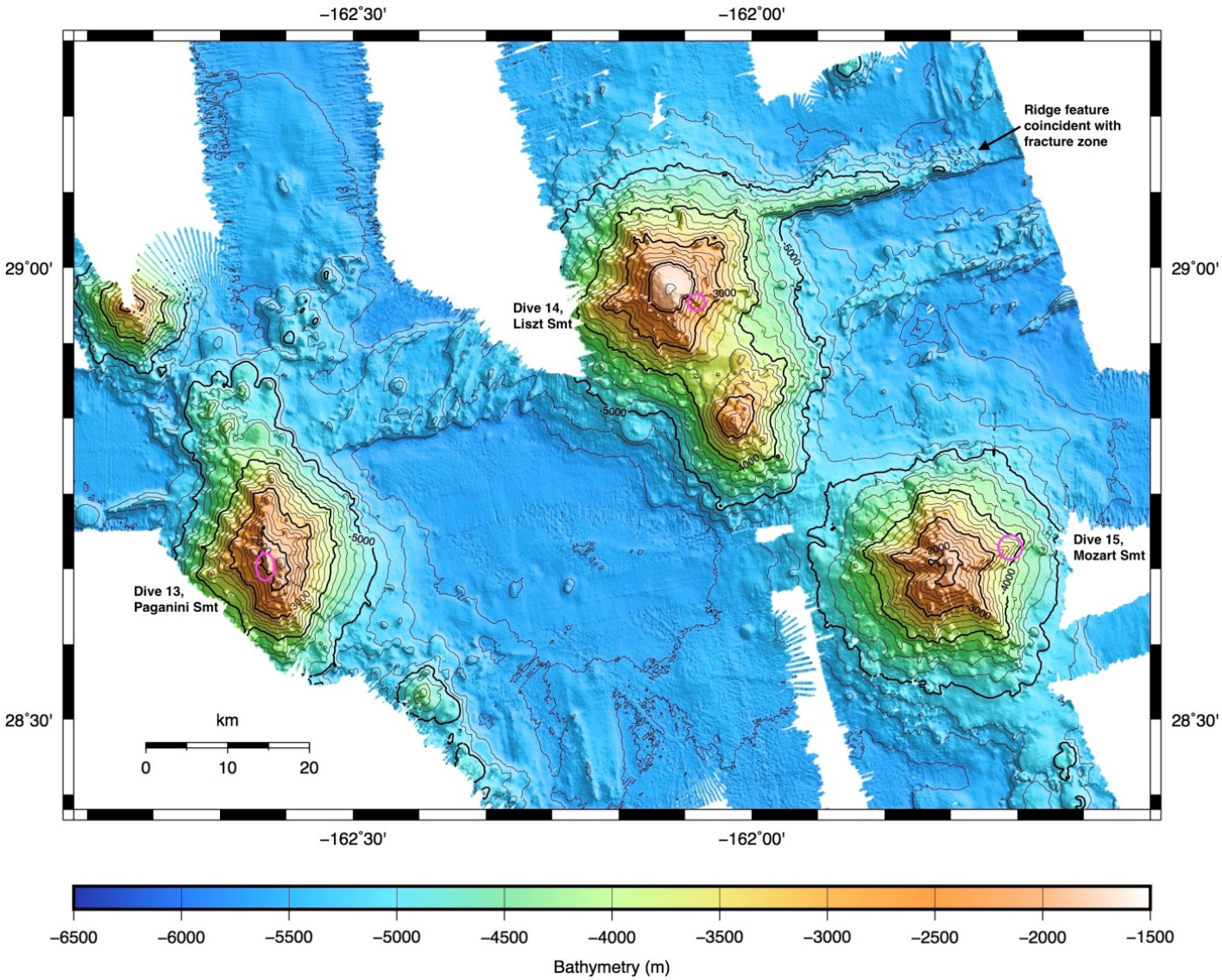

Figure 4. *Multibeam bathymetric synthesis for the three seamounts discussed within this section: Paganini, Liszt, and Mozart Seamounts (Dives 13-15, magenta circles). Grid cell interval at 60 m, 200 m contours, bold every 1,000 m.*

Paganini Seamount

Dive 13 was conducted primarily to characterize the distribution and abundance of benthic fauna on a rift zone ridge along the summit of Paganini Seamount**.** The dive ascended from the middle of the rift zone ridge to the seamount's summit peak (Fig. 4). The dive began at 1,812 m in field of jagged, angular talus surrounding a massive, almost columnar outcrop (Fig. 5), which was covered with many large coral colonies and glass sponges (Fig. 6). This outcrop originated either from an intrusive complex, such as a sill or large dike, or extrusion as the core of a thick lava flow, cooling slowly and developing cleavage planes. A small, blocky brick size rock was collected from the base of this outcrop.

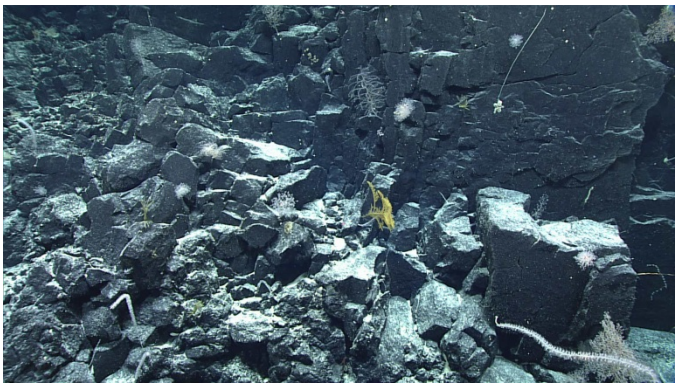

Figure 5. *Columnar jointed basalt (likely) outcrop sampled on Dive 13.*

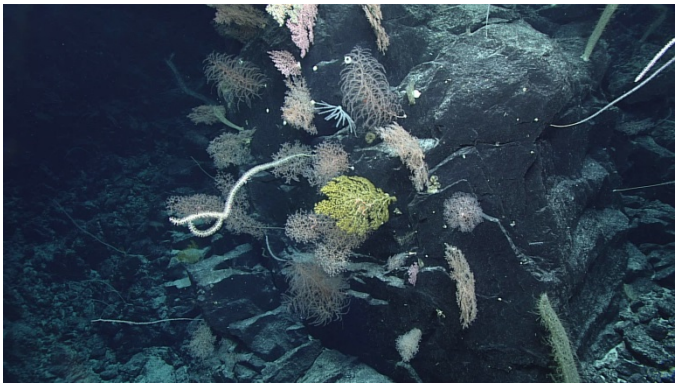

Figure 6. *Another view of outcrop in Figure 5 showing a high-density community of corals and sponges.*

A chute filled with angular talus (slope ~30°) was observed at 1,805 m with massive outcrop walls to either side, and a nearly vertical wall of massive outcrop was traversed at 1,797 m. There was a transition to talus and sediment covered slope with rounded pillows that occurred at 1,792 m, but a reversion to a massive wall and blocky talus was observed at 1,790 m. The ~flat ridge top, at 1,772 m, was mostly talus with some pillowed flow outcrops, but a transition to large outcrops, boulders, and talus took place at 1,766 m. Overall, this summit area was low and broadly sloping, rather lacking the spectacular geological exposures farther down the ridge. However, a rock sample was collected from a pillow outcrop that exhibited the textbook botryoidal ('bunch of grapes') texture common to polymetallic crust (Fig. 7).

Figure 7. *Rock sample from Dive 13 showing the botryoidal ("bunch of grapes") texture of polymetallic crust.*

Liszt Seamount

Dive 14 on Liszt Seamount investigated the interaction between hot spot volcanism and fracture zones, as the seamount is located directly over these closely spaced fracture zones (Fig. 4). This dive explored the geomorphology and targeted the rock collections to look for evidence of different magma types or rock composition at areas close to the Murray Fracture Zone. Additionally, the team was seeking evidence of post-emplacement deformation of the volcanic edifice due to continuing motion across the fracture zone.

The dive began at 2,564 m on a flat sediment plain with small ripples, covered in gravel-sized cobbles and a large boulder occupied by a crinoid, a sponge, and a sea star. At 2,554 m, meter-sized boulders and smaller talus were observed, which was followed by a transition to a sedimented angular talus field at 2,552 m, and then to intact pillow flows at 2,549 m on a 25-30° slope. The slope increased to ~60° at 2,536 m, with the substrate being composed of some sort of consolidated or cemented material, such as small talus resembling hardpan. Large, exposed, intact linear pillow lavas or tubes were seen at 2,368 m followed by a flow front of <1 m meter in thickness at 2,366 m; massive flows continued upslope. A combination of massive outcrops, walls, and thin surficial flows and pillows—along with boulders and sedimented talus—were present in one general location at 2,340 m, suggesting multiple stages of volcanism separated by relatively significant periods of time. Fractured massive outcrops poised for failure downslope were observed at 2,330 m (Fig. 8).

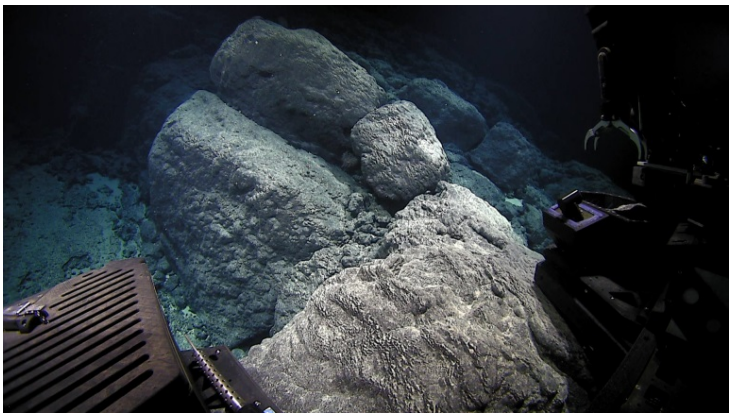

Figure 8. *Rock outcrop from Dive 14 with precariouslyy positioned pieces.*

At 2,309 m, the ROV ran along a narrow ridgeline covered by intact, smooth lava flows. A calved-off, sharp edge with attendant coral colonies was observed at 2,303 m (Fig. 9). The strike of the ridgeline was 320° and a 5 m vertical drop to the first of two possible steps was measured by the *D2* altimeter. More steps may have occurred farther down the flank, out of view. Thin, featureless, smooth lava sheet flows, only a few inches thick, were also present here (Fig. 10). The rift zone ridge continued up with a vertical wall to port and a 30-45° slope to starboard, although it was difficult to estimate the slope accurately looking downhill.

Figure 9. *Large block of rock with smooth lava flows on top from Dive 14.*

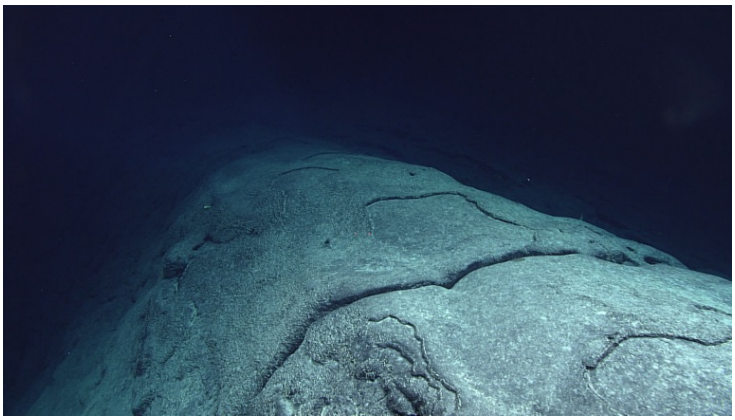

Figure 10. *Ridgeline covered by thin, fluid lava flows from Dive 14.*

Mozart Seamount

Dive 15 at Mozart Seamount was conducted to compare to Dive 14 at Liszt Seamount; specifically to contrast the geomorphology and geological environments of seamounts formed via hotspot volcanism with different proximities to the Murray Fracture Zone**.** Mozart Seamount is near the Murray Fracture Zone, although it does not directly intersect it (Fig. 4)**.**

The dive began at 3,854 m on a ~20° inclined talus slope; a single stalked sponge was in view. A pillow flow front consisting of two or three thin layers was observed at 3,850 m, where the slope steepened to ~50°, and thick polymetallic crusting was evident. At 3,843 m, the slope increased again to greater than 60°. The first rock sample was collected at 3,794 m; it was a piece of angular talus, with a nubbin on the side that was later determined to be a separate fragment welded on with polymetallic crust. Examination of the main piece revealed a break in the crust with consolidated brownish-tan material exposed, suggesting the rock was some sort of sediment conglomerate, or perhaps—less likely—of carbonate origin (Fig. 11). Once the sample dried out, it became extremely brittle and began breaking apart under its own weight.

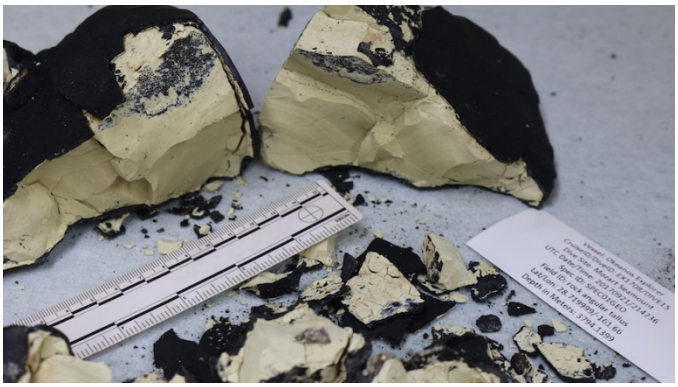

Figure 11. *Sedimentary rock sample from Dive 15, possibly a lagoonal mudstone, coated by a thin layer of polymetallic crust.*

Low-relief sheet flows and talus were observed at 3,786 m—along with sponges, sea stars, anemones, and corals—and there was a sharp, linear contact between a low-angle talus slope and a flat, gravelly, hardpan-like surface with long, wavelength ripples. Flow front edges <1 m thick were seen at 3,765 m, where there was an unusual observation of a field of nearly spherical "pillow balls" that seemingly rolled downslope intact (Fig. 12), but there was little evidence of slide activity on the >20° slope. The overhead *Serios* view showed a distinct contact between the "pillow balls" and a featureless slope at 3,761 m, and intact pillow talus was also observed farther upslope at 3,752 m, where the slope was a steeper >30°. Some in place, low-relief outcrops may have been poking through the talus, and the area was barren of obvious large biology except for isolated stalked sponges.

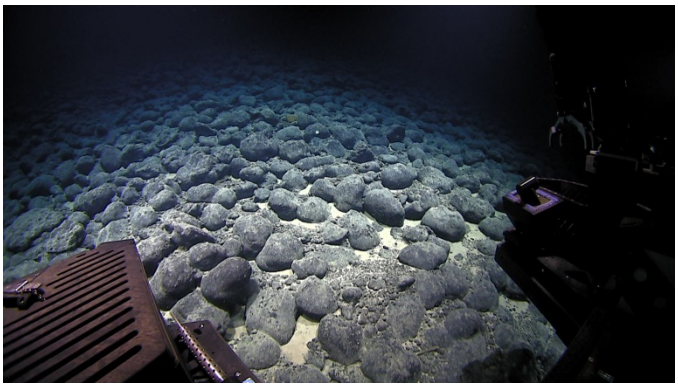

Figure 121. *"Pillow talus ball" field from Dive 15. One was sampled at a later site.*

At 3,730 m, the slope increased again to >50° where low-relief pillow flows presented. Broken pillows, truncated and/or collapsed, were observed at 3,723 m followed by a sudden slope break to a flat step at 3,714 m. Above this step, thin sheet flows overriding pillows were seen at ~3,705 m. An odd series of potential polymetallic crust rinds (Figs. 13 and 14) were observed at 3,700 m. It looked as if boulders had been lifted off and the basal rings cementing them to the seafloor remained, but it could also have been an old glass sponge skeleton—the material appeared too thin and friable to successfully collect and no consensus was reached.

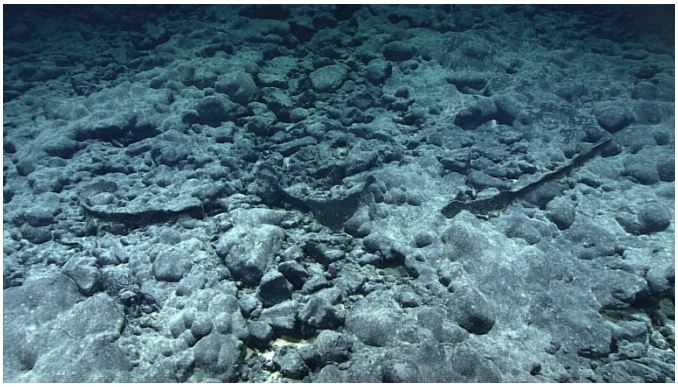

Figure 13. *A series of three polymetallic crust or sponge rinds (middle section of photo) from Dive 15.*

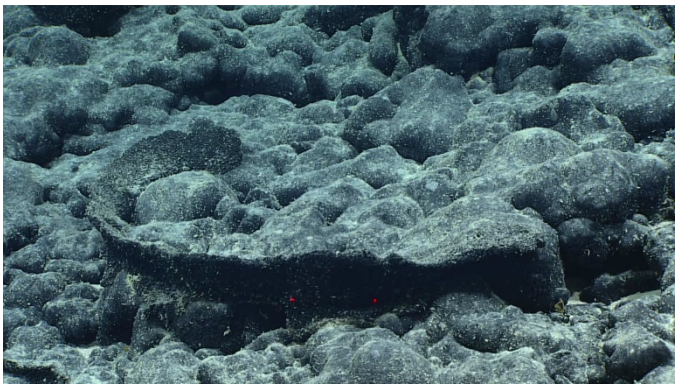

Figure 14. *Close-up of the crust or sponge rind on the left side of Fig. 11, from Dive 15.*

At 3,650 m, there was contact between a pillow talus flow field with lava flows on a ~10° slope to a flat, gravelly plain, similar to the one earlier in the dive. Some time was spent here lighting

up the area and viewing it from the overhead *Serios* camera. It appeared to be a north-south oriented saddle, or low point, of gravel surrounded by pillow talus fields. A 28.5 kg rock was collected at 3,645 m, one of the spherical intact "pillow talus balls" previously seen during this dive (Fig. 15). During laboratory examination, a portion of the polymetallic crust flaked off, revealing a brownish material beneath, suggesting these spherical oddities may be of a similar material origin to the first rock sample collected on this dive. breaking a piece off revealed a core of massive angular (possibly columnar) basalt with a thin polymetallic crust (<1 mm) surrounded by two layers of clay or other marine sediment, each separated by layers of polymetallic crust (Fig. 16). The outer layer of polymetallic crust thickness was 4 mm on bottom, 2 mm to ~1 cm on top. From 3,630 m, the pillow talus field continued up the ~30° slope. Contact with the broken edge of a flow front and the talus deposit it generated was observed at 3,618 m, along with a long, linear, intact pillow tube, fractured pillow faces, and thin flows on top of talus.

Figure 15. *Sampling one of the "pillow talus balls" on Dive 15 from a field similar to that seen farther downslope in Figure 10.*

Figure 16. *Laboratory photo of "pillow talus ball" (sampled on Dive 15) in Figure 15 showing interior layers of materials and polymetallic crust. Diameter of main sample is approximately 30 cm.*

Concluding Remarks

While it was a priority of this expedition to investigate the interaction of seamounts in a hot spot trace with fracture zone lineaments, a wire-length limitation resulted in the ROV being unable to dive deep enough to examine where this intersection may occur. It can be stated that there were no obvious morphologies or rock types unique to this tectonic setting observed when compared

with the other seamounts, ridges, and cones studied during this expedition. However, with only one dive per feature and limited ground covered during dives (relative to the size of the feature), one cannot make major statements to this effect. Additional exploration of these features is needed to build on this foundation of exploration.

Polymetallic crust was observed everywhere, even on the northern seamounts, which are outside of the PCZ, as demarcated by Hein et al, 2000. The other surprise was the deep depths where carbonate or lagoonal mudstones were found. Additionally, the proportionally high number of guyots and platforms mapped was not expected here, although the collaborative mapping effort between the SOI's R/V *Falkor* and NOAA Ship *Okeanos Explorer* has been revealing many such features around the Pacific over the past four years (*Falkor* began operations in the area in 2014, and NOAA began in 2015).

7.1.2 Biology

Musicians Seamounts High-Density Coral Communities

Of the regions explored during CAPSTONE (Kennedy et al, 2019), the greatest number of high-density coral and sponge communities were discovered in the Musicians Seamounts (example in Figs. 17 and 18). A high-density deep-sea community is generally defined as an aggregation of individuals in which at least one coral or sponge is observed per square meter over a distance of one kilometer. The densities observed in each community classified as high-density during this expedition were far higher than this minimum definition, with at least two or more colonies per square meter or with colonies larger than one square meter side by side. In addition, many of these communities exhibited high diversity. The structure and location of these seamounts are likely drivers for the organism density and biodiversity observed. Seamounts are known to accelerate currents and create eddies that can scour sediment from the seafloor, concentrate larvae and other plankton, and enhance food supply to the benthic environment. Yet, in other locations in the Pacific, high-density communities were not as frequently discovered. There is potential that the high frequency of high density deep-sea coral and sponge communities discovered during EX-17-08 was due to improved ability and skill in site selection that evolved during the course of CAPSTONE. As gaining additional data about these communities was a key CAPSTONE objective, many dives during the campaign targeted areas that would be likely to host high density deep-sea coral and sponge communities. Each expedition, OER and the participating expedition science teams learned more about what types of sites and features would be likely to host such a community. As the final CAPSTONE expedition, EX-17-08 benefited from the culmination of this knowledge. However, taking into consideration the area covered by EX-17-08 and the natural variability between the dive sites, at the very least, the summit and high-relief areas facing the prevailing current of each of the seamounts in the chain likely act as an essential habitat for deep-sea coral and sponge communities, and the uncovering

Figure 17. *Dense bamboo coral community at the summit of Mendelssohn Seamount (Dive 19).*

of this many communities cannot be due to luck alone. Additional exploration and research is needed to further understand the unique characteristics of Musicians Seamounts that support so many high-density communities.

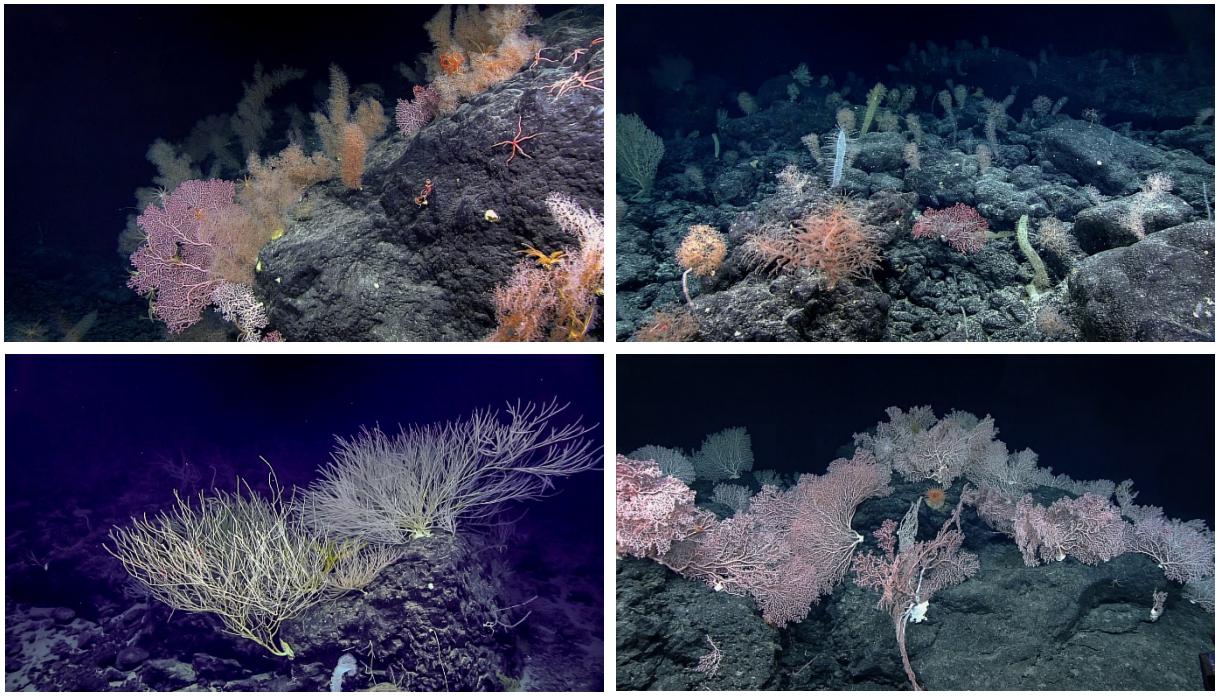

Figure 18. *Dense coral communities were observed on the ridges, summits, and high relief areas of a majority of the seamounts surveyed during the EX-17-08* Deep-Sea Symphony: Exploring the Musicians Seamounts *expedition. (upper left) Gounod Seamount—Dive 5, (upper right) Lizst Seamount—Dive 14, (lower left) "Tropic of Cancer" seamount—Dive 01, (lower right) Mendelssohn Seamount—Dive 19.*

High-density deep-sea coral and sponge communities provide habitat for other organisms, foster biodiversity throughout the ocean, contribute to important commercial fisheries, and are a potential source of biomedical compounds (Hourigan et al., 2017). Of the 18 high-density communities discovered, each site had a unique community composition. Some communities consisted of one major taxa such as at Shostakovich Seamount (Dive 10), where huge bamboo corals 3 m tall and 2 m wide predominated. "Beethoven Ridge" (Dive 03) was a "coral fantasy" of countless mushroom corals, *Anthomastus* sp., amid a diversity of primnoid corals, precious corals, and glass sponges. Paganini Seamount (Dive 13) supported a diversity of chrysogorgiid corals carpeting the bottom with low concentrations of other coral and sponge taxa. Mendelssohn Seamount (Dive 19) hosted two high-density patches of precious corals. Upon ROV touchdown, there was a pink coral garden (*Hemicorallium* sp.) composed of large colonies (>1m wide). Upslope, a forest of massive bamboo colonies 2-3 m tall was discovered, which was one of the densest communities surveyed during CAPSTONE. Other locations exhibited mixed groups of high densities of precious coral (bamboo coral, pink coral, and black coral), chrysogorgiid coral, and large sponges. It is also important to note that at least one occurrence of a precious coral was recorded on each dive.

Furthermore, because there are no true boundaries in the ocean, the Musicians Seamounts chain potentially acts as a source of genetic diversity through larval dispersal and refugia for transient

fish populations. Many of the organisms observed also have been observed in other locations in the Hawaiian Islands and in other areas in the Pacific. In some cases, these observations extended the known range for a species or group. Additionally, at Schumann Seamount (Dive 18) a massive species of sponge, affectionately known as the "minivan" sponge (Wagner and Kelley, 2016), was observed and collected. This species, which is currently being described but is known to be in the subfamily Lanuginellinae, was discovered in 2015 and, until now, has only been observed a couple times within the PMNM boundaries (Wagner and Kelley, 2017). Given the rarity of this sponge species and the proximity to the PMNM, its presence in the Musicians Seamounts may be an indication of connectivity between the two regions.

Even dives within the U.S. EEZ, including the "Tropic of Cancer Seamount" (Dive 01), Mendelssohn Seamount (Dive 19), and "Middle Bank" (Dive 20), showed similar patterns of diversity and density as the dives within the main chain of the Musicians Seamounts. These dives were unique in that they were proposed by NOAA groups researching the potential of these locations as important habitat. The survey at "Tropic of Cancer Seamount" was carried out to ground-truth a coral habitat suitability model developed by the National Centers for Coastal Ocean Science (NCCOS). During the dive, the discovery of a high-diversity deep-sea coral and sponge community led credence to their predictive model. The dive at "Middle Bank", a feature bisected by the PMNM boundary, was carried out at the request of the Monument staff and NOAA National Ocean Service (NOS) NCCOS to explore fish and invertebrate boundary communities and ground-truth coral habitat suitability and taxonomic richness models based on multibeam sonar bathymetry and slope data. Again, the survey revealed a high-density community that included several large precious corals including, gold coral (*Kulamanamana haumeaae*) and an extensive aggregation of black corals.

Musicians Seamounts Deep Communities (>3000 m)

In the Musicians Seamounts, the few dives that did not feature high-density deep-sea coral and sponge communities were distinctly those that surveyed areas on the flanks of seamounts at depths greater than 3,000 m. This was not a new observation. It is well known that with an increase in depth, there is a decrease in the availability of food and, therefore, fewer organisms. Yet, surprisingly high densities of organisms are routinely found at depths between 1,000-3,000 m; but at depths greater than this, organism density drops significantly. This pattern has been observed over the course of the CAPSTONE project.

Despite the lower density of organisms, these seamounts hosted a diversity of corals, sponges, and other associated organisms with very few areas where no animals were in sight. Dive 02, given the moniker "Beach Seamount" after the famous female composer Amy Beach, started at a depth of 3,280 m and transited to a final depth around 3,180 m. Numerous species of glass sponges, black corals, and fishes were observed, including the potbelly sponge, *Hyalonema* sp.; feather-like black corals, *Heteropathes* sp. and *Bathypathes* sp.; red coffinfish, *Chaunacops coloratus*; and arrowtooth eel, *Illyophis* sp. At Verdi Seamount, Dive 9, the sparse landscape supported a number of unique organisms, including stalked glass sponges, *Caulophacus* sp.; *Hyalostylus* sp.; a swimming polychaete worm, *Teuthidodrillus* sp.; and fishes, *Ilyophis* sp. eel, *Bathysaurus mollis* lizardfish, Ophidiidae cusk eel, and *Coryphaenoides* sp. rattail fish. Even at Mozart Seamount, Dive 15, stalked glass sponges were observed consistently along the dive track with primnoid and bamboo corals nearby.

7.1.3 Underwater Cultural Heritage

The last two dives of the *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition explored UCH sites off the southern coast of O‘ahu. The first, Dive 21, examined a series of previously identified sonar anomalies south of O‘ahu, possibly associated with the wreck of the Japanese fast-attack submarine I-203, thought to be in this general area. The Japanese constructed eight of these high-speed submarines, which were specifically designed to stay at depth longer and dive deeper than any other submarine at the time. However, the submarines were captured by American troops, brought to Pearl Harbor for study, and disposed of offshore prior to seeing operational status during WWII. Five targets selected from multibeam sonar data were examined and found to be rock formations. However, by happenstance, *D2* discovered the remains of a WWII-period “rhino barge” (Fig. 19). This type of barge was used to transport supplies, equipment, and vehicles for many amphibious operations in the Pacific. This barge had likely been towed offshore and purposefully sunk. During the transit between two of the anomaly sites, *D2* collected spectacular footage of a sixgill stingray, *Hexatryon bickelli*, a poorly documented species.

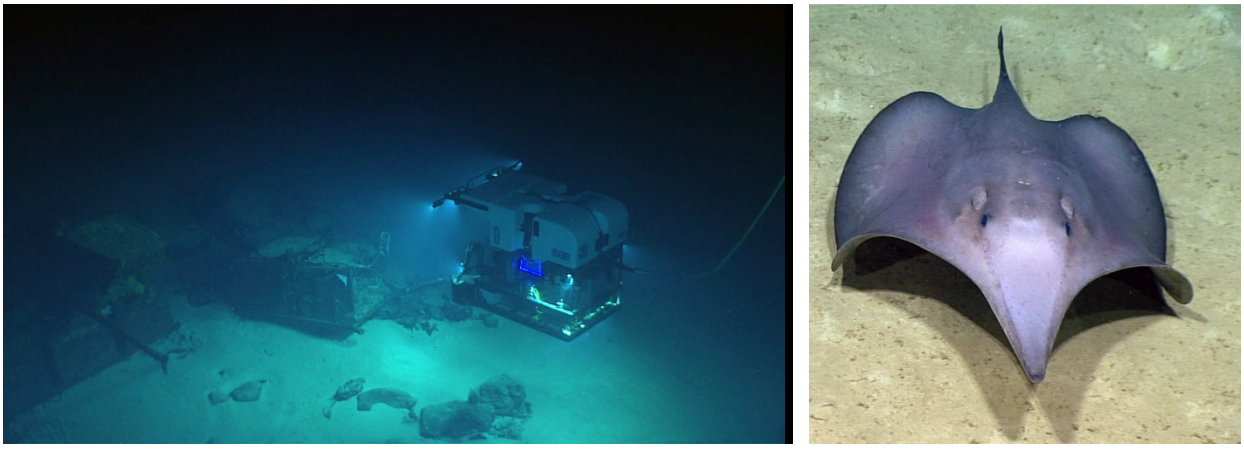

Figure 19. *Left: At 785 m, ROV* Deep Discoverer *encountered a WWII-period “rhino barge,” a floating pontoon section that allowed easy access to beaches for offloading of vehicles and supplies following initial amphibious assault landings in the Pacific. Right: A rarely observed sixgill stingray, Hexatrygon bickelli, at 835 m at the “Caiman” anomaly dive site.*

Dive 22 characterized the USS *Baltimore*, a late nineteenth-century cruiser that served the Navy from the Spanish American War of 1898 through World War I, when its crew was responsible for laying mines in European waters to block German U-boats. The USS *Baltimore* was commissioned in 1890 and was best known for her role in the Battle of Manila Bay during the Spanish American War. It was decommissioned at Pearl Harbor during the 1920s and scuttled at sea in 1944, south of O‘ahu. The dive conducted a non-invasive video survey of USS *Baltimore*’s remains, assessed the general state of preservation and scuttling damage caused by explosives in the engine room, and inventoried the organisms residing on the shipwreck (Fig. 20). The first half of the dive was dedicated to collecting video data that could be used to generate a new type of 3D photogrammetry model of the USS *Baltimore*. Though, due to the size of the USS *Baltimore,* modeling efforts were only partially successful. The second half of the

dive investigated the unique aspects of the ship, including her ram bow, steam engines, blast damage in the iron hull, and the local biological community.

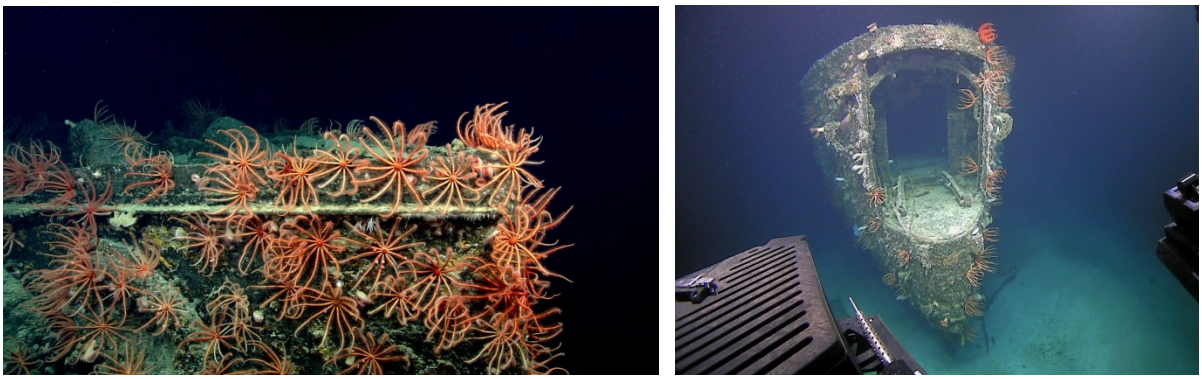

Figure 20. *Left: At the bow of the USS* Baltimore*, there was a large aggregation of brisingid sea stars. Right: The stern of the USS* Baltimore*, as seen from ROV* Deep Discoverer*, was modified to accommodate mine laying operations.*

7.2 Mapping Summary

Prior to the Musician Seamounts cruises (EX-17-07 and EX-17-08), there was little—if any—targeted survey data on the seafloor features in the area. Publically-available data at the National Centers for Environmental Information (NCEI) was mostly ship transect data, as ships have their sonars acquiring data on their way to or from the Hawaiian Islands. During EX-17-08, mapping was conducted during non-ROV operations, including overnight as well as during transit operations (Fig. 21 and Table 5; White et al, 2020). Overnight focused mapping operations were balanced with the need to transit between ROV dive sites.

Mapping operations included EM 302 multibeam, EK60 split-beam, Knudsen subbottom profiles, and ADCP data collection. XBTs were collected every six hours and applied in real time through Velocipy software into the SIS software. Sound speed at the sonar head was determined using a Reson SVP-70 probe and the ship's flow-through TSG. At the completion of the ROV dives, the sound speed profile generated by the ROV CTD was applied to SIS instead of performing an XBT cast.

Table 5: *Summary of mapping statistics.*

EM302 Linear Kilometers Mapped	**5,069**
EM 302 Square Kilometers Mapped	**30,317**
Number of XBT Casts	**36**
Number of CTD Casts	**1**

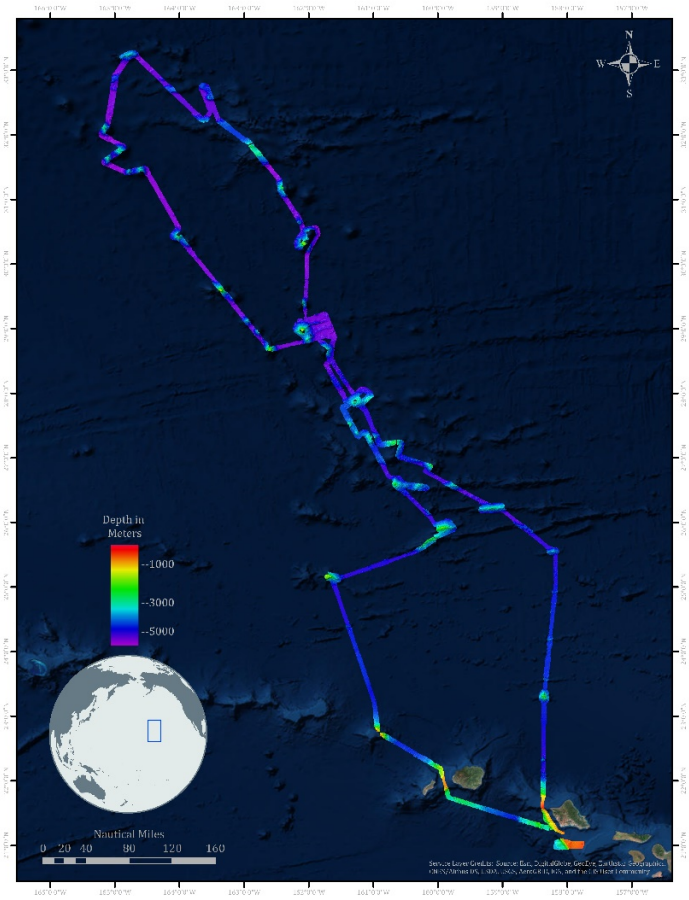

Figure 21. *Map showing cruise track and multibeam bathymetry collected during EX-17-08. This cruise began and ended in Honolulu, Hawai'i.*

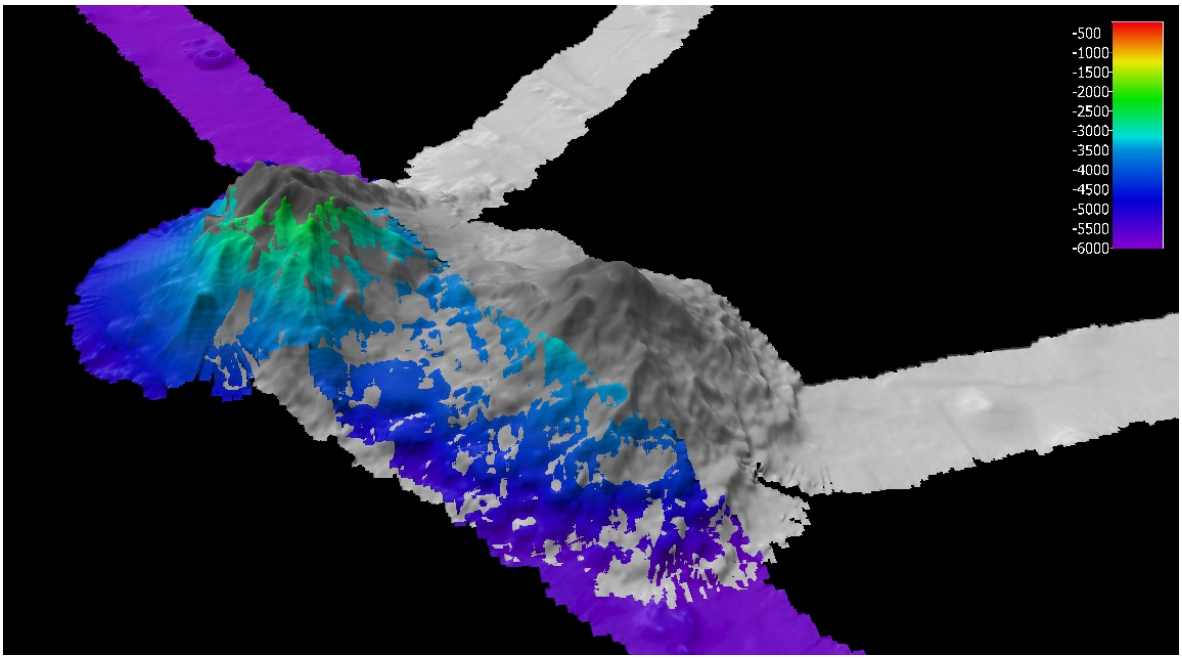

Figure 22. *Rainbow bathymetry from EX-17-08 and bathymetry from EX-17-07 in grey over Mussorgsky Seamount. When possible, mapping operations on EX-17-08 leveraged existing coverage from EX-17-07.*

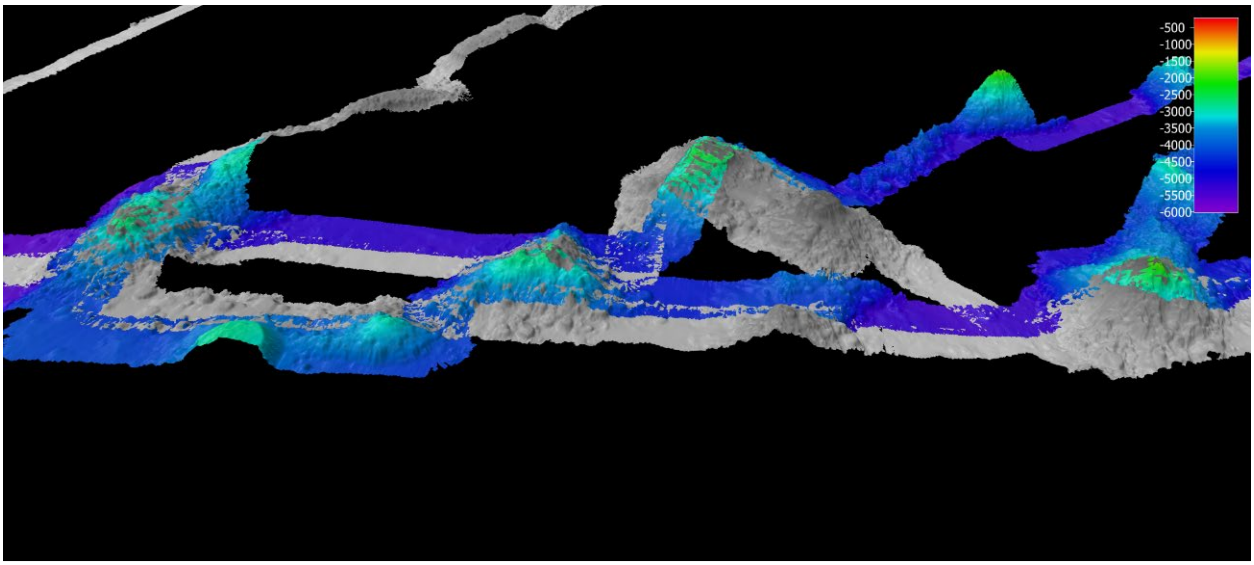

Figure 23. *Rainbow bathymetry from EX-17-08 and bathymetry from EX-17-07 in grey over Gluck, Sibelius, Gounod and several unnamed seamounts.*

Throughout EX-17-07 and EX-17-08, mapping operations targeted areas that contained no modern bathymetry, areas with poor quality data, and—when possible—edge matched existing data. When possible, transits were planned to optimize new data collection and the building of a continuous bathymetric surface (Figs. 22 and 23). Background data used to guide exploration mapping primarily included data collected by EX-17-07. Additionally, EX-17-07 data were heavily used to plan ROV dives. Data collected on previous NOAA Ship *Okeanos Explorer* cruises, EX-16-09 and EX-09-09, were also used to plan operations in the vicinity of the MHI. Sandwell et al (2014) satellite altimetry data were also used in operational planning. During the course of the cruise, mapping data were collected over the following features: "Beethoven Ridge" (Fig. 24), Gluck Seamount, Sibelius Seamount, Gounod Seamount, Mozart Seamount, Liszt Seamount, Tchaikovsky Seamount, Debussy Seamount, Wagner Seamount, Verdi Seamount, Parker Seamount, Bellini Seamount, Shostakovich Seamount, Hammerstein Seamount, Mahler Seamount, Stravinsky Seamount (Fig. 25), Mussorgsky Seamount, Rachmaninoff Seamount, Paganini Seamount, Rapano Ridge, Schumann Seamount, and Mendelssohn Seamount. For many of these features, this was the first time focused survey data were acquired. Transit data were also added to the Hawaiian Ridge, east of Kaua‘i and east of O‘ahu. A focused mapping survey was completed east of Penguin Bank in search of UCH sites.

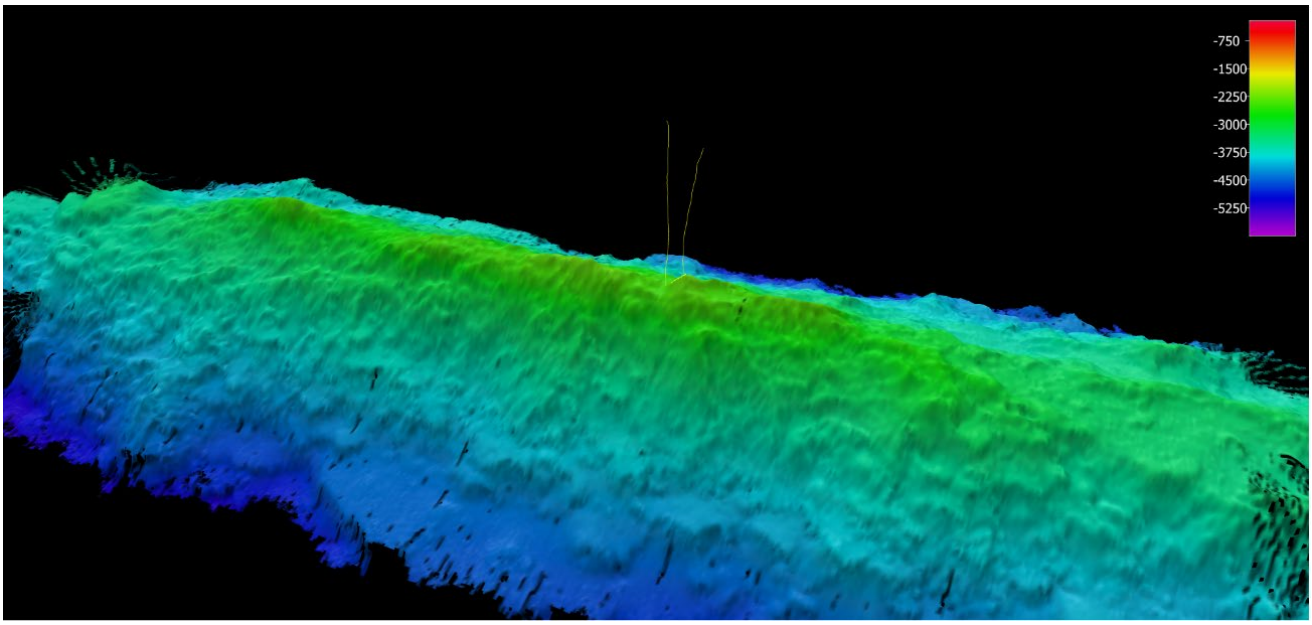

Figure 24. *Multibeam bathymetry collected over "Beethoven Ridge" during overnight mapping operations. These data were used the following morning plan an ROV dive; the ROV dive track is in yellow.*

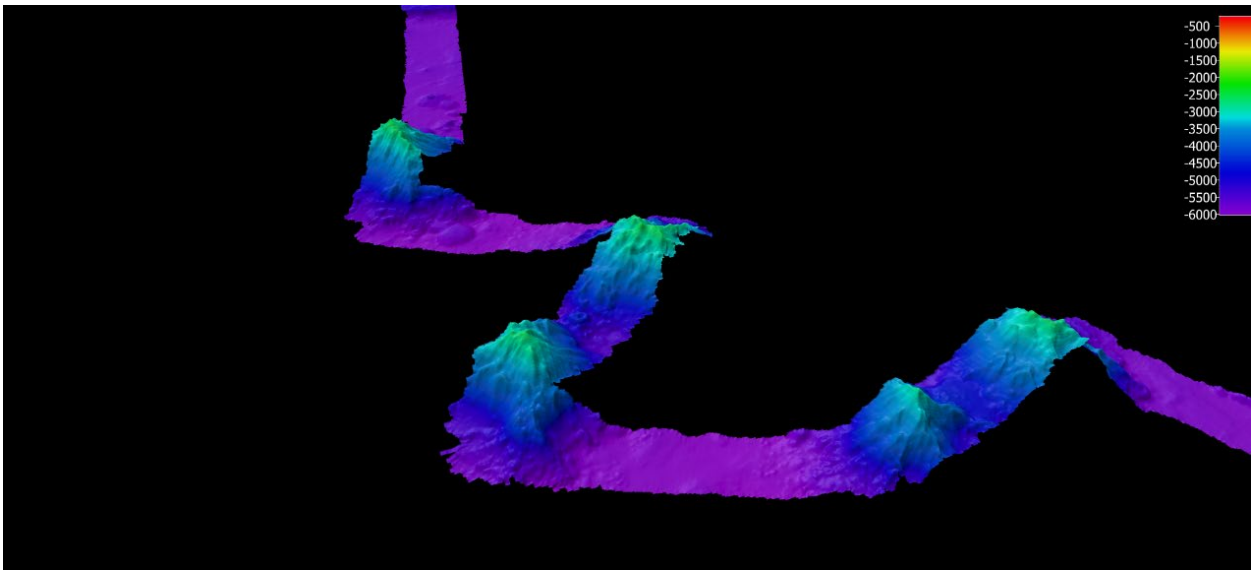

Figure 25. *Transit mapping data collected over the summits of Hammerstein, Mahler and Stravinsky Seamounts. Prior to EX-17-08, there was no publicly available, high-resolution multibeam bathymetry available over these seafloor features prior to this survey.*

Throughout EX-17-08, multibeam data quality was monitored in real time by acquisition watchstanders. When not in transit to ROV dive sites, the ship's speed was adjusted to maintain data quality. Mapping was conducted during ship transits and when time allowed; focused mapping was completed over areas lacking multibeam data. Line spacing was planned at 30% overlap to avoid holidays in the data. Cutoff angles in SIS were adjusted on the port and starboard sides to ensure balance between data quality and coverage. Normal mapping operations data were collected with the EM 302, EK60s (except the 38kHz), and subbottom profiler. During ROV operations, the EM 302 and subbottom profiler were secured, and the ADCP and EK60s

(including the 38 kHz) were active. The Ocean Surveyor 38 kHz ADCP was not operational during EX-17-08. Several times the Workhorse 300 kHz ADCP was run with the EM 302 multibeam. The at-sea team recorded inference in the starboard sectors of the EM 302 swath that became particularly pronounced over areas of deep, featureless—and likely muddy—seafloor. The EK60s were run during ROV dives. Screenshots of the EK60 acquisition screen were sent to shore to plan ROV midwater transects. All sonar data and sound velocity data files collected—and products created during the cruise—can be found in the NOAA archives; additional information can be found in Appendix A.

7.3 Specimen collections

A total of 178 samples were collected during the expedition, including 31 primary geological samples, 5 associate geological samples, 55 primary biological samples, and 87 associate biological samples (Tables 6, 7, 8, and 9). Biological specimen collections represented potential new species, range extensions of animals not previously known to occur in the region, or dominant species in the area (Figs. 25, 26, and 27). Some of the specimens have been confirmed by experts to be previously undiscovered species. In addition, a sample of the massive glass sponge in subfamily Lanuginellinae was collected as the paratype collection of this rare species. Most of the substrate was heavily manganese crusted. Therefore, geological collections specifically targeted rock samples that likely had a basalt rock center, which is essential to elucidating the age and origin of the seamount. Information regarding sample archival locations is shown in Table 10. Sample access information is located in Appendix A.

Table 6: *Geological specimens collected as the primary collection during the EX-17-08 expedition sampling events.*

Dive	Specimen ID	Description
DIVE01	EX1708_20170907T224700_D2_DIVE01_SPEC03GEO	rock
DIVE01	EX1708_20170907T232500_D2_DIVE01_SPEC04GEO	rock
DIVE02	EX1708_20170908T234600_D2_DIVE02_SPEC02GEO	rock
DIVE02	EX1708_20170909T001016_D2_DIVE02_SPEC03GEO	rock
DIVE03	EX1708_20170909T200313_D2_DIVE03_SPEC01GEO	rock
DIVE03	EX1708_20170910T011052_D2_DIVE03_SPEC06GEO	rock
DIVE04	EX1708_20170910T203037_D2_DIVE04_SPEC01GEO	rock
DIVE05	EX1708_20170911T202152_D2_DIVE05_SPEC01GEO	rock
DIVE05	EX1708_20170911T234833_D2_DIVE05_SPEC03GEO	rock
DIVE07	EX1708_20170914T011728_D2_DIVE07_SPEC01GEO	rock
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO	rock
DIVE08	EX1708_20170914T202914_D2_DIVE08_SPEC01GEO	rock in place sheet flow
DIVE08	EX1708_20170915T000441_D2_DIVE08_SPEC04GEO	rock with 2 corals
DIVE09	EX1708_20170915T235123_D2_DIVE09_SPEC01GEO	rock angular talus outcrop base near summit
DIVE09	EX1708_20170916T002343_D2_DIVE09_SPEC02GEO	rock angular talus summit depression
DIVE10	EX1708_20170916T215631_D2_DIVE10_SPEC01GEO	rock small slab from sheet flow area

DIVE10	EX1708_20170917T000425_D2_DIVE10_SPEC05GEO	rock angular talus from summit ridge
DIVE12	EX1708_20170918T205210_D2_DIVE12_SPEC01GEO	rock slope base pillow toe talus
DIVE12	EX1708_20170918T225532_D2_DIVE12_SPEC02GEO	rock in place slab rectangular
DIVE13	EX1708_20170919T203059_D2_DIVE13_SPEC01GEO	rock from base of massive outcrop
DIVE13	EX1708_20170920T000914_D2_DIVE13_SPEC04GEO	rock from base of pillow outcrop - rounded larger
DIVE14	EX1708_20170920T213103_D2_DIVE14_SPEC01GEO	rock talus from ledge of pillow outcrop
DIVE14	EX1708_20170920T234328_D2_DIVE14_SPEC04GEO	rock small brick of talus on flow slope
DIVE15	EX1708_20170921T214236_D2_DIVE15_SPEC01GEO	rock angular talus
DIVE15	EX1708_20170922T013813_D2_DIVE15_SPEC06GEO	rock intact pillow talus ball
DIVE17	EX1708_20170923T202723_D2_DIVE17_SPEC01GEO	rock
DIVE17	EX1708_20170924T002839_D2_DIVE17_SPEC04GEO	rock angular talus outcrop base near summit
DIVE18	EX1708_20170924T215003_D2_DIVE18_SPEC01GEO	rock wedge shaped massive talus from outcrop base
DIVE18	EX1708_20170925T010510_D2_DIVE18_SPEC05GEO	rock rounded talus from summit ridge
DIVE19	EX1708_20170925T215933_D2_DIVE19_SPEC02GEO	rock Mn-crusted talus from slope
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO	rock angular talus from open slope

Table 7: *Geological specimens collected as associates with the primary collection during the EX-17-08 expedition sampling events.*

Dive	Specimen ID	Description
DIVE01	EX1708_20170907T214500_D2_DIVE01_SPEC01BIO_A01	rock
DIVE03	EX1708_20170909T224219_D2_DIVE03_SPEC03BIO_A01	rock
DIVE08	EX1708_20170914T223327_D2_DIVE08_SPEC02BIO_A01	rock
DIVE15	EX1708_20170921T221847_D2_DIVE15_SPEC02BIO_A01	rock piece
DIVE15	EX1708_20170922T001025_D2_DIVE15_SPEC03BIO_A01	rock

Table 8: *Biological specimens collected as the primary collection during the EX-17-08 expedition sampling events.*

Dive	Specimen ID	Field Identification
DIVE01	EX1708_20170907T214500_D2_DIVE01_SPEC01BIO	*Stichopathes* sp.
DIVE01	EX1708_20170907T222300_D2_DIVE01_SPEC02BIO	*Acanthogorgia* sp.
DIVE02	EX1708_20170908T215023_D2_DIVE02_SPEC01BIO	?Primnoidae
DIVE02	EX1708_20170909T003400_D2_DIVE02_SPEC04BIO	*Bathypathes* sp.
DIVE03	EX1708_20170909T211928_D2_DIVE03_SPEC02BIO	Ceriantharia
DIVE03	EX1708_20170909T224219_D2_DIVE03_SPEC03BIO	*Anthomastus* sp. (2, on rock)
DIVE03	EX1708_20170910T001113_D2_DIVE03_SPEC04BIO	?Chrysogorgia sp.
DIVE03	EX1708_20170910T010121_D2_DIVE03_SPEC05BIO	Hexactinellida (vase?)
DIVE04	EX1708_20170910T214239_D2_DIVE04_SPEC02BIO	Paragorgiidae

DIVE04	EX1708_20170910T231532_D2_DIVE04_SPEC03BIO	Stolonifera (on stalk)
DIVE04	EX1708_20170910T234940_D2_DIVE04_SPEC04BIO	*Hemicorallium* sp.
DIVE04	EX1708_20170911T004747_D2_DIVE04_SPEC05BIO	Goniasteridae
DIVE04	EX1708_20170911T010427_D2_DIVE04_SPEC06BIO	*Circeaster* sp.
DIVE05	EX1708_20170912T005605_D2_DIVE05_SPEC04BIO	*Metallogorgia* sp.
DIVE05	EX1708_20170911T221903_D2_DIVE05_SPEC02BIO	?Corbitellinae
DIVE07	EX1708_20170914T024149_D2_DIVE07_SPEC03BIO	Keratoisidinae (nodal)
DIVE07	EX1708_20170914T031055_D2_DIVE07_SPEC04BIO	Keratoisidinae (intermodal)
DIVE08	EX1708_20170914T223327_D2_DIVE08_SPEC02BIO	*Umbellapathes* sp.
DIVE08	EX1708_20170915T010738_D2_DIVE08_SPEC05BIO	Stolonifera (on bamboo)
DIVE08	EX1708_20170914T232126_D2_DIVE08_SPEC03BIO	Euplectellidae
DIVE09	EX1708_20170916T002648_D2_DIVE09_SPEC03BIO	*Bathypathes* cf. *patula*
DIVE09	EX1708_20170916T004243_D2_DIVE09_SPEC04BIO	Keratoisidinae (unbranched)
DIVE10	EX1708_20170916T222719_D2_DIVE10_SPEC02BIO	*Eknomisis* sp.
DIVE10	EX1708_20170916T232444_D2_DIVE10_SPEC04BIO	*Chrysogorgia* sp.
DIVE10	EX1708_20170916T231615_D2_DIVE10_SPEC03BIO	Corbitellinae
DIVE12	EX1708_20170918T230646_D2_DIVE12_SPEC03BIO	*Hemicorallium* sp.
DIVE12	EX1708_20170918T235841_D2_DIVE12_SPEC04BIO	?*Acanthogorgia* sp.
DIVE12	EX1708_20170919T000515_D2_DIVE12_SPEC05BIO	*Narella* sp.
DIVE12	EX1708_20170919T000600_D2_DIVE12_SPEC06BIO	Isididae (nodal)
DIVE13	EX1708_20170919T225351_D2_DIVE13_SPEC02BIO	*Antipathes* sp.
DIVE13	EX1708_20170919T230846_D2_DIVE13_SPEC03BIO	?*Acanthogorgia* sp.
DIVE13	EX1708_20170920T014315_D2_DIVE13_SPEC05BIO	*Aeginona* sp.
DIVE14	EX1708_20170920T221023_D2_DIVE14_SPEC02BIO	Hyocrinidae
DIVE14	EX1708_20170921T001134_D2_DIVE14_SPEC05BIO	?*Proisocrinus* sp.
DIVE14	EX1708_20170920T223436_D2_DIVE14_SPEC03BIO	Euplectellidae (vase)
DIVE15	EX1708_20170921T221847_D2_DIVE15_SPEC02BIO	?Keratoisidinae D clade
DIVE15	EX1708_20170922T001025_D2_DIVE15_SPEC03BIO	*Anthomastus* sp.
DIVE15	EX1708_20170922T002341_D2_DIVE15_SPEC04BIO	*Bathypathes* sp.
DIVE15	EX1708_20170922T010130_D2_DIVE15_SPEC05BIO	Primnoidae
DIVE17	EX1708_20170924T001959_D2_DIVE17_SPEC03BIO	*Acanthogorgia* sp.
DIVE17	EX1708_20170924T011710_D2_DIVE17_SPEC05BIO	Primnoidae
DIVE17	EX1708_20170924T043000_D2_DIVE17_SPEC06BIO	*Hemicorallium* sp.
DIVE17	EX1708_20170923T231340_D2_DIVE17_SPEC02BIO	Euplectellidae (frilly vase)
DIVE18	EX1708_20170924T222647_D2_DIVE18_SPEC02BIO	?*Parantipathes* sp.
DIVE18	EX1708_20170924T231730_D2_DIVE18_SPEC03BIO	Euretidae
DIVE18	EX1708_20170925T000857_D2_DIVE18_SPEC04BIO	Lanuginellinae (ruffles)
DIVE19	EX1708_20170926T013000_D2_DIVE19_SPEC05BIO	*Abudefduf saxatilis*
DIVE19	EX1708_20170925T211641_D2_DIVE19_SPEC01BIO	Keratoisidinae (internodal)
DIVE19	EX1708_20170926T000438_D2_DIVE19_SPEC03BIO	Keratoisidinae I4 clade
DIVE19	EX1708_20170926T010000_D2_DIVE19_SPEC04BIO	*Hemicorallium* sp.
DIVE20	EX1708_20170927T023000_D2_DIVE20_SPEC06BIO	*Abudefduf* sp.
DIVE20	EX1708_20170926T222635_D2_DIVE20_SPEC02BIO	*Myriopathes* sp.
DIVE20	EX1708_20170926T223246_D2_DIVE20_SPEC03BIO	?*Myriopathes ulex*
DIVE20	EX1708_20170926T233314_D2_DIVE20_SPEC04BIO	Plexauridae

DIVE20	EX1708_20170927T012409_D2_DIVE20_SPEC05BIO	?*Antipathella* sp.

Table 9: *Biological specimens collected as associates with the primary collection during the EX-17-08 expedition sampling events.*

Dive	Specimen ID	Field Identification
DIVE01	EX1708_20170907T232500_D2_DIVE01_SPEC04GEO_A02	Bryozoa/Hydrozoa
DIVE01	EX1708_20170907T232500_D2_DIVE01_SPEC04GEO_A01	Stichopathes/Umbellapathes
DIVE01	EX1708_20170907T224700_D2_DIVE01_SPEC03GEO_A01	unknown
DIVE02	EX1708_20170908T234600_D2_DIVE02_SPEC02GEO_A01	Bryozoa
DIVE02	EX1708_20170909T001016_D2_DIVE02_SPEC03GEO_A01	Bryozoa
DIVE02	EX1708_20170908T234600_D2_DIVE02_SPEC02GEO_A02	Primnoidae
DIVE02	EX1708_20170908T234600_D2_DIVE02_SPEC02GEO_A04	?Actiniaria
DIVE02	EX1708_20170908T234600_D2_DIVE02_SPEC02GEO_A05	?*Stichopathes* sp.
DIVE02	EX1708_20170908T234600_D2_DIVE02_SPEC02GEO_A03	Cladorhizidae
DIVE03	EX1708_20170909T211928_D2_DIVE03_SPEC02BIO_A02	Polychaeta
DIVE03	EX1708_20170910T011052_D2_DIVE03_SPEC06GEO_A02	*Anthomastus* sp.
DIVE03	EX1708_20170910T011052_D2_DIVE03_SPEC06GEO_A03	Ophiuroidea
DIVE03	EX1708_20170909T211928_D2_DIVE03_SPEC02BIO_A01	Hexactinellida (stalk)
DIVE03	EX1708_20170910T011052_D2_DIVE03_SPEC06GEO_A01	Hexactinellida
DIVE03	EX1708_20170910T011052_D2_DIVE03_SPEC06GEO_A04	Hexactinellida
DIVE04	EX1708_20170910T214239_D2_DIVE04_SPEC02BIO_A01	Hormathiidae
DIVE05	EX1708_20170911T221903_D2_DIVE05_SPEC02BIO_A01	Polychaeta
DIVE05	EX1708_20170912T005605_D2_DIVE05_SPEC04BIO_A01	*Uroptychus* sp.
DIVE05	EX1708_20170912T005605_D2_DIVE05_SPEC04BIO_A02	Gastropoda
DIVE07	EX1708_20170914T011728_D2_DIVE07_SPEC01GEO_A01	Tunicata (ascidian)
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO_A03	Tunicata (ascidian)
DIVE07	EX1708_20170914T011728_D2_DIVE07_SPEC01GEO_A02	Stolonifera (purple)
DIVE07	EX1708_20170914T011728_D2_DIVE07_SPEC01GEO_A03	Primnoidae
DIVE07	EX1708_20170914T011728_D2_DIVE07_SPEC01GEO_A04	Octocorallia
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO_A04	Primnoidae
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO_A05	Isididae
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO_A06	Octocorallia
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO_A01	Hexactinellida
DIVE07	EX1708_20170914T021121_D2_DIVE07_SPEC02GEO_A02	Hexactinellida
DIVE08	EX1708_20170914T232126_D2_DIVE08_SPEC03BIO_A03	Polychaeta
DIVE08	EX1708_20170915T010738_D2_DIVE08_SPEC05BIO_A03	?Polychaeta
DIVE08	EX1708_20170914T232126_D2_DIVE08_SPEC03BIO_A04	Amphipoda
DIVE08	EX1708_20170914T223327_D2_DIVE08_SPEC02BIO_A02	Hydrozoa
DIVE08	EX1708_20170914T232126_D2_DIVE08_SPEC03BIO_A02	Stolonifera
DIVE08	EX1708_20170915T010738_D2_DIVE08_SPEC05BIO_A01	Hydrozoa
DIVE08	EX1708_20170915T010738_D2_DIVE08_SPEC05BIO_A02	Isididae (skeleton)

DIVE08	EX1708_20170914T223327_D2_DIVE08_SPEC02BIO_A03	Goniasteridae
DIVE08	EX1708_20170914T232126_D2_DIVE08_SPEC03BIO_A01	Gastropoda
DIVE09	EX1708_20170916T004243_D2_DIVE09_SPEC04BIO_A01	Actiniaria (red)
DIVE09	EX1708_20170916T004243_D2_DIVE09_SPEC04BIO_A02	Crinoidea (yellow)
DIVE10	EX1708_20170916T231615_D2_DIVE10_SPEC03BIO_A01	Ophiuroidea
DIVE10	EX1708_20170916T232444_D2_DIVE10_SPEC04BIO_A01	Ophiuroidea
DIVE10	EX1708_20170916T231615_D2_DIVE10_SPEC03BIO_A02	?Aplacophora
DIVE12	EX1708_20170918T230646_D2_DIVE12_SPEC03BIO_A02	Zoantharia
DIVE12	EX1708_20170918T230646_D2_DIVE12_SPEC03BIO_A01	*Asteroschema* sp.
DIVE12	EX1708_20170919T000515_D2_DIVE12_SPEC05BIO_A01	Crinoidea (yellow)
DIVE13	EX1708_20170919T230846_D2_DIVE13_SPEC03BIO_A02	Polychaeta
DIVE13	EX1708_20170919T230846_D2_DIVE13_SPEC03BIO_A03	Polychaeta
DIVE13	EX1708_20170919T230846_D2_DIVE13_SPEC03BIO_A04	Amphipoda
DIVE13	EX1708_20170920T014315_D2_DIVE13_SPEC05BIO_A01	*Iridogorgia magnispiralis*
DIVE13	EX1708_20170919T230846_D2_DIVE13_SPEC03BIO_A01	Crinoidea
DIVE13	EX1708_20170919T230846_D2_DIVE13_SPEC03BIO_A05	Aplacophora
DIVE13	EX1708_20170919T225351_D2_DIVE13_SPEC02BIO_A01	Hexactinellida
DIVE13	EX1708_20170919T203059_D2_DIVE13_SPEC01GEO_A01	Unknown
DIVE14	EX1708_20170920T223436_D2_DIVE14_SPEC03BIO_A01	Amphipoda
DIVE14	EX1708_20170920T223436_D2_DIVE14_SPEC03BIO_A02	Ctenophora (benthic)
DIVE14	EX1708_20170921T001134_D2_DIVE14_SPEC05BIO_A01	Crinoidea (unstalked)
DIVE14	EX1708_20170920T221023_D2_DIVE14_SPEC02BIO_A01	?Platyhelminthes
DIVE15	EX1708_20170922T013813_D2_DIVE15_SPEC06GEO_A01	Bryozoa
DIVE15	EX1708_20170921T221847_D2_DIVE15_SPEC02BIO_A02	Isididae (base)
DIVE15	EX1708_20170922T010130_D2_DIVE15_SPEC05BIO_A01	Actiniaria
DIVE15	EX1708_20170921T221847_D2_DIVE15_SPEC02BIO_A04	?Aplacophora
DIVE15	EX1708_20170921T214236_D2_DIVE15_SPEC01GEO_A01	?Porifera
DIVE15	EX1708_20170921T221847_D2_DIVE15_SPEC02BIO_A03	?Porifera
DIVE15	EX1708_20170922T013813_D2_DIVE15_SPEC06GEO_A02	Cladorhizidae
DIVE15	EX1708_20170922T013813_D2_DIVE15_SPEC06GEO_A03	Cladorhizidae
DIVE15	EX1708_20170922T013813_D2_DIVE15_SPEC06GEO_A04	Cladorhizidae
DIVE15	EX1708_20170922T013813_D2_DIVE15_SPEC06GEO_A05	?Porifera
DIVE17	EX1708_20170924T001959_D2_DIVE17_SPEC03BIO_A03	Amphipoda
DIVE17	EX1708_20170924T001959_D2_DIVE17_SPEC03BIO_A01	Hydrozoa
DIVE17	EX1708_20170924T002839_D2_DIVE17_SPEC04GEO_A01	*Hemicorallium* sp.
DIVE17	EX1708_20170923T231340_D2_DIVE17_SPEC02BIO_A01	Gastropoda
DIVE17	EX1708_20170924T001959_D2_DIVE17_SPEC03BIO_A02	Aplacophora
DIVE18	EX1708_20170924T231730_D2_DIVE18_SPEC03BIO_A01	Amphipoda
DIVE18	EX1708_20170925T000857_D2_DIVE18_SPEC04BIO_A01	Aplacophora
DIVE19	EX1708_20170926T010000_D2_DIVE19_SPEC04BIO_A01	Scalpellidae
DIVE20	EX1708_20170926T222635_D2_DIVE20_SPEC02BIO_A01	Scalpellidae
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A08	Bryozoa
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A03	*Hemicorallium* sp.

DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A04	Scleractinia (single polyp)
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A05	Scleractinia (colonial polyps)
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A06	Scleractinia (colonial polyps)
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A07	Hydrozoa
DIVE20	EX1708_20170926T233314_D2_DIVE20_SPEC04BIO_A01	Actiniaria
DIVE20	EX1708_20170927T012409_D2_DIVE20_SPEC05BIO_A01	Actiniaria
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A01	Demospongiae (encrusting)
DIVE20	EX1708_20170926T204454_D2_DIVE20_SPEC01GEO_A02	Porifera

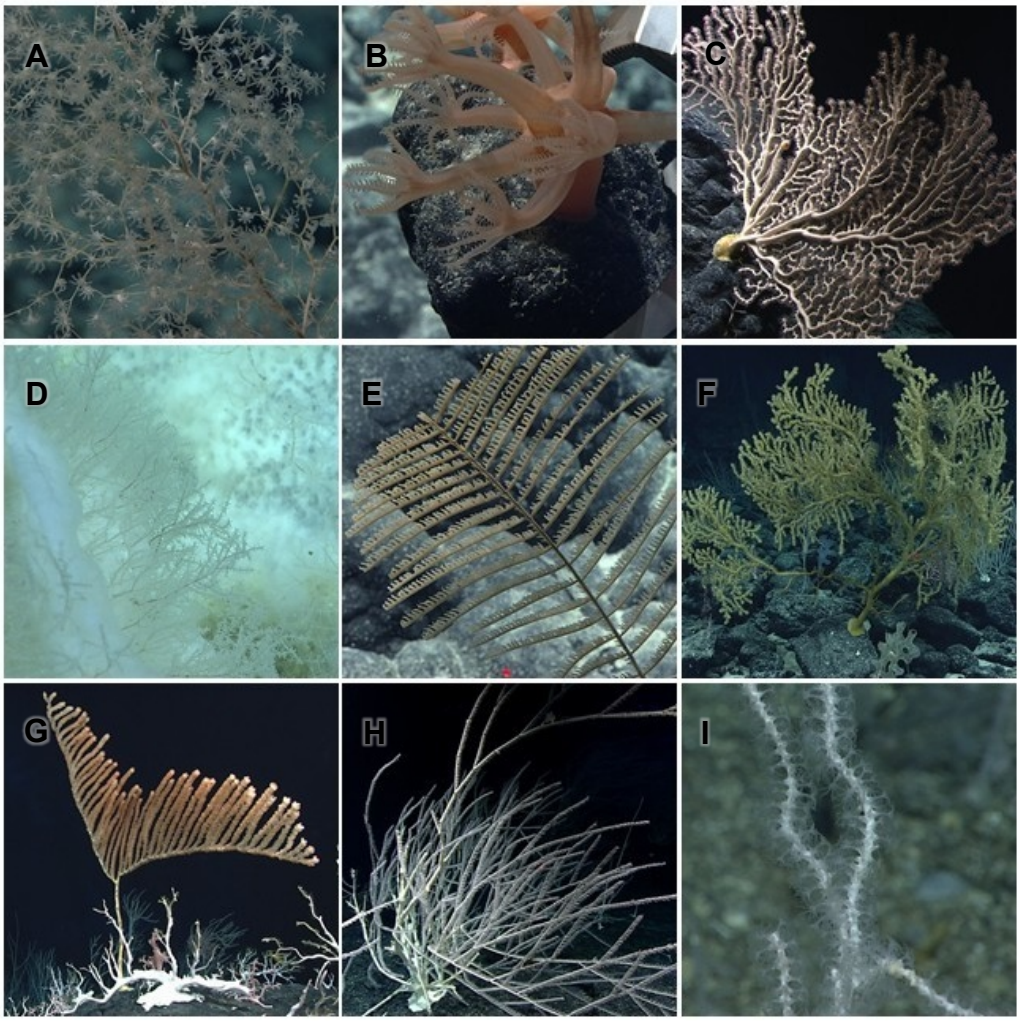

Figure 26. *Coral specimens collected during the EX-17-08 expedition were all potential new species or the representative taxa of the community. A)* Chrysogorgia *sp. EX1708-03_SPEC04; B)* Anthomastus *sp. EX1708-03_SPEC03; C)* Paragorgia *sp. EX1708-04_SPEC02; D)* Antipathes *sp. EX1708-13_SPEC02; E)* Bathypathes *sp. EX1708-02_SPEC04; F)* Acanthogorgia *sp. EX1708-17_SPEC03; G) Keratoisidinae I4 clade EX1708-19_SPEC03; H) Keratoisidinae "internodal" EX1708-19_SPEC01; I) Plexauridae EX1708-20_SPEC04.*

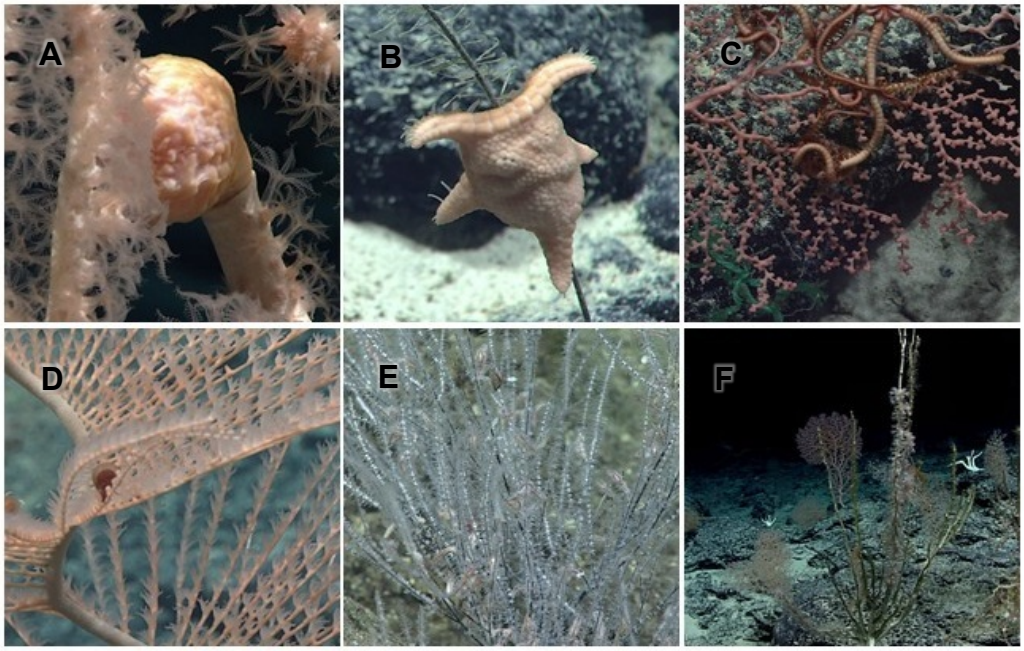

Figure 27. *Associate specimens collected from corals during the EX-17-08 expedition. A) Hormathiidae EX1708-04_SPEC02; B) Goniasteridae and Hydroidolina EX1708-08_SPEC02; C) Asteroschematidae and Parazoanthidae EX1708-12_SPEC03; D)* Aegonona *sp. EX1708-13_SPEC05; E) Poecilasmatinae EX1708-20_SPEC02; F) Solonifera and Hydroidolina EX1708-08_SPEC05.*

Figure 28. *Glass sponge specimens collected during the EX-17-08 expedition were all unique and possible new species. A) Hexactinellida "vase" EX1708-03_SPEC05; B) Corbitellinae EX1708-05_SPEC02; C) Euplectellidae EX1708-08_SPEC03; D) Corbitellinae EX1708-10_SPEC01; E) Corbitellinae "vase" EX1708-14_SPEC03; F) Euplectellidae "frilly vase" EX1708-18_SPEC02; G) Euretidae EX1708-18_SPEC03; H) Lanuginellinae "ruffles" EX1708-18_SPEC04; I) Hexactinellidae EX1708-03_SPEC06.*

Table 10. *Count of primary and associate subsample sent to each repository: Bernice Pauahi Bishop Museum (BM, Ocean Genome Legacy (OGL), Oregon State University (OSU), and Smithsonian Institution National Museum of Natural History (USNM). Information related to accessing data and samples can be found in Appendix A.*

Repository	Taxonomic Group	Total
BM	Arthropoda	1
	Cnidaria	34
	Porifera	10
BM Total		45
OGL	Arthropoda	3
	Bryozoa	3

	Chordata—fish	2
	Chordata—tunicate	2
	Cnidaria	56
	Ctenophora	1
	Echinodermata	12
	Platyhelminthes	1
	Porifera	14
OGL Total		94
OSU	Characteristic Rocks	36
OSU Total		36
USNM	Annelida	6
	Arthropoda	8
	Bryozoa	5
	Chordata—fish	2
	Chordata—tunicate	2
	Cnidaria	86
	Ctenophora	2
	Echinodermata	13
	Mollusca	8
	Platyhelminthes	1
	Porifera	25
	Unknown	2
USNM Total		160
Grand Total		335

7.4 Engagement Summary

From September 6 to 30, 2017, NOAA and partners conducted a telepresence-enabled ocean exploration expedition on NOAA Ship *Okeanos Explorer* to collect critical baseline information about unknown and poorly understood deepwater areas around the Musicians Seamounts and Hawaiian Islands. A total of 18 engagement events were hosted during EX-17-08, three of which were live telepresence interactions, which allows the science team to speak on video with groups with whom they interact on a dedicated audio line, and 11 were hosted science line interactions, which allows the science team to interact with groups via a dedicated audio line. Notable live telepresence interactions were hosted with the Big Ocean Network at the International MPA Congress (Thursday, September 7), the Interagency Working Group on Facilities and Infrastructure (IWG-FI) at the Marine Technology Society (MTS) Oceans Conference (Wednesday, September 20), and the USFWS at the Silver Spring ECC (Thursday, September 21). Informal live interactions on the science line welcomed the Korean Hydrographic Society (Tuesday, September 12), EK60 Acoustics Workshop at the University of New Hampshire (Wednesday, September 13), high-level U.S. Navy representatives from Washington, DC (Wednesday, September 13), Louisiana Kiwanis Club Science Lunch (Thursday, September 14), Pacific Islands Leaders Program at the UH ECC (Monday, September 18), Science on the Bayou (Tuesday, September 19), Rotary Group at the IRC ECC (Monday, September 25), the Special

Operations in the Pacific (SOTPAC) defense course at the IRC ECC on (Tuesday, September 12), and the Department of Defense Strategic Leaders International Course on (Monday, September 18), and UH Librarian Students (Friday, September 29). A Facebook Live Midwater Event was hosted (Sunday, September 17) from the Silver Springs ECC. Social media expanded on Facebook by +0.5% (~600 new likes), Twitter by +5.6% (~9,700 new followers), Instagram by +13.5% (1,100 new likes), and YouTube by +2.8% (~1,800 new subscribers). The live video stream of the dives was viewed over 387,000 times.

On Sunday, October 1, 2017, NOAA, SOI, and UH cohosted the Ocean Exploration Celebration at the UH Marine Center—Pier 35, in Honolulu, Hawai‘i. The daylong celebration consisted of a one-hour media event, VIP and public ship tours of both NOAA Ship *Okeanos Explorer* and R/V *Falkor*, and a dockside education pavilion with deep-sea science and education booths. The event began with opening remarks from Wendy Schmidt, Founder of SOI; Craig McLean, Assistant Administrator for NOAA Research and Acting Chief Scientist; and Brian Taylor, Dean of the UH School of Ocean and Earth Science and Technology. A media crew from KITV Island News was on site for the remarks and to conduct dockside interviews with representatives from each host organization. More than 600 people from the community participated in the ocean exploration celebration and toured the ships, including Senator Brian Schatz (D-HI) as well as his deputy chief of staff and congressional staffers for Senator Mazie Hirono and Representative Colleen Hanabusa. Members of the public disembarked from the ships with smiles and thanked the team for sharing the ocean exploration activities and discoveries. The dockside education pavilion included exhibits from NOAA, the Polynesian Voyaging Society, the Waikīkī Aquarium, the Hawai‘i Institute of Marine Biology, and UH. The public enjoyed the exhibits and had excellent questions about the various displays.

8. Conclusion

NOAA Ship *Okeanos Explorer* arrived at port in Honolulu, HI, on September 30, 2017, bringing the two-cruise (EX-17-07 and EX-17-08), 49-day *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition to a close. This expedition was an exciting finale to the three-year CAPSTONE effort that collected critical information about the deepwater habitats in some of the most remote places on earth. The *Deep-Sea Symphony: Exploring the Musicians Seamounts* expedition was the first to survey and to conduct ROV exploration in this region of the Pacific Ocean. The surprising frequency of high-density communities has shaped many new questions about the ecology of our oceans. Data from this expedition will be used to better understand regional biodiversity, interpret novel observations, inform habitat suitability models for deep-sea corals and sponges, as well as unravel the complex geologic story of this region. We anticipate future studies to evaluate the numerous high-density, deep-sea coral and sponge communities discovered and to conduct further research into regional biogeographical patterning. Future research is essential to furthering our understanding of the biogeographical connectivity between the Pacific Marine National Monuments, near shore areas, and other remote areas in the high seas. Noteworthy highlights include:

- Mapped 30,317km^2 during EX-17-08. When paired with data from EX-17-07, the expedition team mapped over 85,203 km^2 of previously unmapped seafloor. During the course of the expedition, over 50 seamounts and ridges were mapped, many for the first time. Other highlights included mapping of the Murray Fracture Zone, defining a ridge feature adjacent to Liszt Seamount as part of the fracture zone, and using high-resolution multibeam bathymetry to reveal flat-top guyots in areas where satellite altimetry predicted conical seamounts. Multibeam data also revealed the likelihood of secondary volcanism on several features.
- Conducted 22 ROV dives that explored seamounts, ridges, bottomfish and precious coral habitats, and the USS *Baltimore*.
    - Largest observation ever made of a species of cutthroat eel (*Synaphobranchus brevidorsalis*)
    - Documentation of exceptionally large gold coral, pink coral, and bamboo colonies at a number of sites
    - First live observation and in situ documentation of a six gill rays (Hexatryon bickelli). This species is previously only known from preserved specimen
    - Observation of a highly unusual fish at middle bank—likely a new genus and family in the order Beryciformes. The OER team of experts was unable to identify this during the dive, and after circulating the images to other colleagues, the identification of this fish is even more of a puzzle
    - Documentation of large aggregations of brisingid sea stars on the USS *Baltimore*
- 95 scientists participated from the U.S., Japan, Russia, New Zealand, and Canada.
- Documented 18 high-density, deep-sea coral and sponge communities. This was the highest number of these communities observed in any region explored during CAPSTONE. The observations made in the Musicians Seamounts raise interesting questions for future studies, such as the connectivity between the Northwest Hawaiian Islands and what oceanographic conditions contribute to such a high number of dense and diverse coral communities.
- Collection of potential new species, including a species of gonasterid sea star, glass sponges, and deep-sea corals.
- Collection of a paratype of the massive glass sponge that is currently being described in the subfamily Lanuginellinae. This sponge had only been previously observed in the PMNM, suggesting a potential connection between the two regions.
- Engaged over 575 people through 18 live interactions (a new record) and OER's first-ever Facebook Live event hosted from an ECC on shore, which garnered over 4,000 views. Live interaction audiences ranged from science and technical conferences, to visitors at a science museum in Louisiana, to partner agency senior leadership, to groups of students at ECCs.
- Conducted a successful "Midwater Week" with unprecedented exploration of the water column by NOAA Ship *Okeanos Explorer*. This week included a Facebook Live event focused on answering questions about this largely unknown biome as well as NOAA Ship *Okeanos Explorer*'s first-ever full-day midwater exploration ROV dives. The team also conducted four dives with midwater transects to help characterize sites from the seafloor to the surface. Beyond testing operational methodology, water column exploration documented a high biomass and a diversity of organisms throughout the water column. Specific highlights include:

- Rare observation of a fangtooth fish (*Anoplogaster* sp.)
- Several potential new species and novel observations of water column fauna
- A new species of ctenophore of a currently undescribed family

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10. Appendices

Appendix A: Data Access

Below is a list of access points and archival location for data collected during EX-17-08.

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/). To access these data, click on the Search Bathymetric Surveys button, select "NOAA Ship Okeanos Explorer" from the Platform Name dropdown menu, and "EX1708" from the Survey ID dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download data.

Subbottom Profiler (Knudsen Chirp 3260)
The subbottom profiler was not run during any of EX-17-08's ROV dive operations, but generally was operated during multibeam mapping operations. These data are archived at NCEI and accessible through their Trackline Geophysical Data Viewer (https://maps.ngdc.noaa.gov/viewers/geophysics/). To access these data, select "Subbottom Profile" under Marine Surveys and click on Search Marine Surveys. In the pop-up window, select "EX1708" in the Filter by Survey IDs dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download data.

Split-beam Sonars (Simrad EK60 and EK80)
EK60 and EK80 water column data for EX-17-08 are archived at NCEI and available through their Water Column Sonar Data Viewer (https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html). To access these data, click on the Additional Filters button, deselect "All" next to Survey ID, and select "EX1708" from the Survey ID list. Click OK, and the ship track for the cruise will appear on the map. Click on the ship track for options to download data.

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

ADCP data collected at each ROV dive location are archived at NCEI and available through their Global Ocean Currents Database (https://www.nodc.noaa.gov/gocd/sadcp_oer_inv.html). Access these data by searching the table for the Expedition identifier "EX1708."

Conductivity, Temperature, and Depth Measurements

CTD profile data from EX-17-08 are archived at NCEI and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). To access these data, click on the Search tab, enter "EX1708" in the Enter Search Text field, and click Search. Click on the point that represents EX-17-08 to access data options. In the pop-up window, select the Data Access tab for a link to download the CTD profile data. ROV CTD data can be found with the dive summaries on the Okeanos Explorer website (https://service.ncddc.noaa.gov/rdn/oer-rov-cruises/ex1708).

OER Digital Atlas

ROV data from EX-17-08 are archived at NCEI and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). To access these data, click on the Search tab, enter "EX1708" in the Enter Search Text field, and click Search. Click on the point that represents EX-17-08 to access data options. In the pop-up window, select the ROV Data Access tab for links to the ROV dive data, which is organized by dive.

ROV Dive Summaries

Individual ROV dive summaries and associated ROV dive data are archived at NCEI and available here: https://service.ncddc.noaa.gov/rdn/oer-rov-cruises/ex1708

ROV Dive Video

To search, preview, and download dive video for NOAA Ship *Okeanos Explorer* dives, go to the OER Video Portal (https://www.nodc.noaa.gov/oer/video/). Under Cruises, select the "Okeanos Explorer" radio button, then select 'Musicians Seamounts (EX1708)" from the list, then click the "Search" button to pull up video data from this cruise.

Sample Repositories

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

- Invertebrate Zoology Collections, National Museum of Natural History, Smithsonian Institution, Museum Support Center, MRC 534, 4210 Silver Hill Road, Suitland, MD 20746
  Contact: Abigail Reft, ReftAJ@si.edu
  Website: https://invertebrates.si.edu/LoanPolicy.html
- Biorepository, National Museum of Natural History, Smithsonian Institution, Museum Support Center, 4210 Silver Hill Road, Suitland, MD 20746
  Contact: Chris Huddleston, HuddlestonC@si.edu
  Website: https://naturalhistory.si.edu/research/biorepository
- Marine and Geology Repository, Oregon State University, Burt 346, Corvallis, OR 97331-5503

Contact: Kevin Konrad, konradke@geo.oregonstate.edu
Website: http://osu-mgr.org/noaa-ex/

- Ocean Genome Legacy Center, Northeastern University, 430 Nahant Road, Nahant, MA 01908
  Contact: Hannah Appiah-Madson, h.appiah-madson@northeastern.edu
  Website: https://www.northeastern.edu/ogl/
- Bishop Museum
  Request access: https://www.bishopmuseum.org/collections-access/

Sun Photometer Measurements

Sun photometer measurements are available through NASA's MAN (https://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html). Access these data by searching the table for "2017", "Okeanos Explorer", and "North Pacific Ocean". Click on the links to download the data. (Note: There may be more than one entry for NOAA Ship *Okeanos Explorer* in a region in a given year.)

Appendix B: CITES Permits

Antipatharian and Scleractinian samples from the high seas were collected under USFWS CITES permit #17US36207C/9. A copy of this permit is shown below.

FORM 3-201A (1/97)

CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA

IMPORT PERMIT

Page 1 of 1

1. Original Permit/Certificate No. 17US36207C/9

2. Valid 08/02/2018

3. Permittee (name and address, country)
NOAA OFFICE OF OCEAN EXPLORATION & RESEARCH
1315 EAST-WEST HWY, SSMC3 ROOM 10262
SILVER SPRING, MD 20910
U.S.A.

4. Consignor (name and address, country)
INTRODUCTION FROM THE SEA

5. Special Conditions
MUST COMPLY WITH ENCLOSED GENERAL PERMIT CONDITIONS.

PERMIT MAY BE COPIED FOR MULTIPLE SHIPMENTS. PERMITTEE TO RETAIN ORIGINAL.

PERMITTEE MUST COMPLETE BLOCKS 11 (QUANTITY) AND SUBMIT TO USFWS INSP. UPON IMPORT.

5a. Purpose of Transaction
S

6. U.S. Management Authority
Department of the Interior
U.S. FISH AND WILDLIFE SERVICE
DIVISION OF MANAGEMENT AUTHORITY
BRANCH OF PERMITS, MS: IA
5275 LEESBURG PIKE
FALLS CHURCH VA 22041-3803

U.S. CITES Management Authority

-May not be used for commercial purposes. For live animals, only valid if the transport conditions comply with the CITES Guidelines for Transport of Live Animals or, in the case of air transport, with IATA Live Animals Regulations.

08/03/2017
Issuing Date — United States Management Authority

AUTHORITY: Endangered Species Act of 1973 (16 USC 1531 et. seq.)

7/8. Common Name and Scientific name (genus and species) of Animal or Plant	9. Description of Part or Derivative, including identifying marks or numbers (age/sex if live)	10. Appendix No. and Source / 11. Quantity (including units) / 12. Country of Origin
A. Common Name: BLACK CORAL Scientific Name: ANTIPATHARIA	9. INTRODUCTION FROM THE SEA: BLACK CORAL SPECIMENS.	10. 2 X 11. Quantity (including units): NO 12. Country of Origin:
B. Common Name: STONY CORAL Scientific Name: SCLERACTINIA	9. INTRODUCTION FROM THE SEA: STONY CORAL SPECIMENS.	10. 2 X 11. Quantity (including units): NO 12. Country of Origin:
C. Common Name: CHAMBERED NAUTILUS Scientific Name: NAUTILIDAE	9. INTRODUCTION FROM THE SEA: CHAMBERED NAUTILUS SPECIMENS.	10. 2 X 11. Quantity (including units): NO 12. Country of Origin:
D. Common Name: [redacted] Scientific Name: [redacted]	9. [redacted]	10. [redacted] 11. Quantity (including units): [redacted] 12. Country of Origin: [redacted]
E. Common Name: [redacted] Scientific Name: [redacted]	9. [redacted]	10. [redacted] 11. Quantity (including units): [redacted] 12. Country of Origin: [redacted]

Appendix C: NASA Aerosol 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

Supporting Team Members Aboard (if required)

Activities Description(s) (Include goals, objectives and tasks)
The Maritime Aerosol Network (MAN) component of the Aerosol Robotic Network (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 ocean.

During the cruise the marine aerosol layer observations will be collected for the NASA MAN research effort. Observations were made by mission personnel (as time and weather allowed) with a sun photometer instrument provided by the NASA MAN program. Resulting data were delivered to the NASA MAN principle investigator, Alexander Smirnov, by the expedition coordinator. All collected data were archived and are publicly available at: http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html

Equipment resides on the ship and is stewarded by the Expedition Coordinator.

Appendix D: Acronyms

ADCP—Acoustic Doppler Current Profilers
AERONET—Aerosol Robotic Network
BM —Bernice Pauahi Bishop Museum
BOEM—Bureau of Ocean Energy Management
CAPSTONE—Campaign to Address Pacific monument Science, Technology, and Ocean NEeds
CCOG—NOAA Center for Coasts, Oceans, and Geophysics
CE—Categorical Exclusion
CIL—Central Identification Laboratories
CIOERT—NOAA Cooperative Institute for Ocean Exploration, Research & Technology
CITES—Convention on International Trade in Endangered Species
D2—ROV *Deep Discoverer*
DNA—Deoxyribonucleic acid
DO—Dissolved oxygen
DPAA—Defense POW/MIA Accounting Agency
DSCRTP—NOAA Deep Sea Coral Research and Technology Program
ECC—Exploration command center
EEZ—Exclusive Economic Zone
EFH—Essential Fish Habitat
ESA—Endangered Species Act
FAU—Florida Atlantic University
GFOE—Global Foundation for Ocean Exploration
GSO—Graduate School of Oceanography
HBOI—Harbor Branch Oceanographic Institute
HURL—Hawai‘i Undersea Research Lab
IHMC—Institute for Human & Machine Cognition
IMPAC4—International Marine Protected Area Congress
IRC—NOAA Inouye Regional Center
ISC—Inner Space Center
IWG-FI—Interagency Working Group on Facilities and Infrastructure
JAMSTEC—Japan Agency for Marine-Earth Science and Technology
MAN—Maritime Aerosol Network
MBARI—Monterey Bay Aquarium Research Institute
MHI—Main Hawaiian Islands
MHP—NOAA Marine Heritage Program
Mn—Manganese
MPA—Marine protected area
MTS—Marine Technology Society
NAO—NOAA Administrative Order
NASA—National Aeronautics and Space Administration
NCCOS—NOAA National Centers for Coastal Ocean Science
NCEI—NOAA National Centers for Environmental Information
NCSU—North Carolina State University
NEPA—National Environmental Policy Act
NHHC—Naval History and Heritage Command

NIOF—National Institute of Oceanography and Fisheries
NIWA—National Institute of Water and Atmospheric Research
NMFS—NOAA National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Adminstration
NOS—NOAA National Ocean Service
NPS—National Park Service
OAP—NOAA Ocean Acidification Program
OER—NOAA Office of Ocean Exploration and Research
OET—Ocean Exploration Trust
OMAO—NOAA Office of Marine and Aviation Operations
ONC—Ocean Networks Canada
ONMS—NOAA Office of National Marine Sanctuaries
OSU—Oregon State University
PCZ—Prime Crust Zone
PIFSC—NOAA Pacific Islands Fisheries Science Center
PIRO—NOAA Pacific Islands Regional Office
PMNM—Papahānaumokuākea Marine National Monument
RAS—Russian Academy of Sciences
ROV—Remotely Operated Vehicle
SBP—Subbottom profiler
SEAMAP—Scientific Exploration and Mapping Program
SI—Smithsonian Institution
SIS—Seafloor Information Software
SOI—Schmidt Ocean Institute
SVP—Sound velocity probe
TSG—Thermosalinograph
UCAR—University Corporation for Atmospheric Research
UCH—Underwater Cultural Heritage
UCSB—University of California, Santa Barbara
UH—University of Hawai‘i at Mānoa
ULL—University of Louisiana Lafayette
URI—University of Rhode Island
USGS—U.S. Geological Survey
USFSP—University of South Florida St. Petersburg
USFWS—U.S. Fish and Wildlife Service
USNM—National Museum of Natural History
USP—University of the South Pacific
UTRGV—University of Texas Rio Grande Valley
WHOI—Woods Hole Oceanographic Institution
WWII—World War II
XBT—Expendable bathythermograph