Ocean Exploration and Research

doi: 10.25923/jdqm-qx44

Cruise Report: EX-16-03

2016 Hohonu Moana: Exploring the Deep Waters off Hawaiʻi (ROV/Mapping)

Remotely Operated Vehicle (ROV) and Mapping Exploration of the Papahānaumokuākea Marine National Monument (PMNM)

February 25 to March 18, 2016

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April 15, 2020

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Abstract

EX-16-03 was a combined mapping and ROV expedition to the Papahānaumokuākea Marine National Monument (PMNM) that took place between February 25 and March 18, 2016. During the cruise, eight ROV dives were conducted from 648 m and 4,292 m—between the northeast of Mokumanamana Island (also known as Necker Island) and the southwest of Castellano Seamount—for a total of over 40 hours of bottom time, and covered a linear survey distance of 4.85 km. This expedition yielded 14 geological samples and 20 biological samples, seven of which were commensal animals collected with the 13 primary specimens. The ROV video obtained during EX-16-03 recorded at least 249 different types of organisms, documented high-density biological communities at six of the eight surveyed dive sites—including within the oxygen minimum layer (800-1000 m) as well as the deepest known high-density community at a depth of nearly 4,000 m—and noted a new species (possibly new genus) of incirrate octopus, which was also the deepest record for this suborder. EX-16-03 mapping operations mapped over 31,000 km^2 of seafloor, with over 10,000 km^2 mapped within the PMNM. Five Northwest Hawaiian Islands (NWHI) seamounts were mapped in their entirety, one inside and four outside the PMNM boundaries. Among these newly mapped seamounts, only Castellano Seamount had previously been partially mapped using multibeam sonars.

This report can be cited as follows:
Wagner, D., Tree, J., Kennedy, B., Malik, M.(2019). Cruise EX-16-03—2016 Hohonu Moana: Exploring the Deep Waters off Hawaiʻi (ROV/Mapping). Office of Ocean Exploration and Research, National Oceanographic & Atmospheric Administration, Silver Spring, MD 20910. OER Expedition Cruise Report, 58p. doi: 10.25923/jdqm-qx44.

Acknowledgements:
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Amy Bowman, Consultant on contract with NOAA National Marine Sanctuary Foundation
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1. Introduction

By leading national efforts to explore the ocean and make ocean exploration more accessible, the NOAA Office of Ocean Exploration and Research (OER) is filling gaps in basic understanding of deep waters and the seafloor, providing deep-ocean data, information, and awareness. Exploration within the U.S. Exclusive Economic Zone (EEZ) and international waters as part of Seabed 2030 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 the *Okeanos Explorer*, mapping and characterizing areas of the ocean that have not yet been explored. Collected data about deep waters and the seafloor—and the resources they hold—establishes a foundation of information and fills gaps in the unknown.

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

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

2. Project Background

The **C**ampaign to **A**ddress **P**acific Monument **S**cience, **T**echnology, and **O**cean **Ne**eds (CAPSTONE), was a three-year effort designed to provide critical new information on the deepwater resources within the U.S. National Marine Monuments and Sanctuaries located throughout the Pacific. The primary goal of all *Okeanos Explorer* expeditions in this campaign was to obtain baseline data and information about the poorly known deepwater areas and resources in these extensive marine protected areas (MPAs).

2.1 *2016 Hohonu Moana* (EX-16-03) Expedition Overview

The third NOAA Ship *Okeanos Explorer* (*EX*) expedition of 2016, titled *2016 Hohonu Moana: Exploring Deep Waters off Hawai'i,* is also referred to as EX-16-03. This was the second CAPSTONE combined remotely operated vehicle (ROV) and mapping expedition to focus on the Papahānaumokuākea Marine National Monument (PMNM) as well as the sixth CAPSTONE expedition. The prior *cruise* combined ROV and mapping expedition to focus on this area was EX-15-04-L2; it was titled *2015 Hohonu Moana: Exploring Deep Waters off Hawai'i*. This report provides a summary of operations and findings from the EX-16-03 expedition.

2.2 Rationale for EX-16-03 Exploration of PMNM

The PMNM surrounding the Northwestern Hawaiian Islands (NWHI) is the largest contiguous MPA in the United States and one of the largest conservation areas in the world. At the time of EX-16-03 the Monument encompassed 362,073 km^2 and spanned roughly 2,000 km northwest from the SE of Nihoa Island to the NW of Kure Atoll, and is thereby larger than all of the United States' national parks combined. With a spectrum of elevations ranging from abyssal depths greater than 5,000 m to rugged volcanic islands reaching 275 m above sea level, the PMNM harbors diverse habitats—including pelagic basins, abyssal plains, seamounts, submarine escarpments, flat-topped banks, coral reefs, shallow lagoons, littoral shores, dunes, and dry coastal grasslands. Due to the PMNM's vast geographic isolation, its ecosystems have remained largely protected from many of the human stressors that impact more populated areas, and are considered among the most pristine in the world. The marine habitats of the PMNM are home to more than 7,000 species, at least 25% of which are endemic to the region, found nowhere else on the planet. Therefore, the PMNM truly represents one of the major reservoirs of biodiversity on the planet.

The geology of the PMNM is equally as fascinating. The Monument's seafloor is covered with volcanic platforms that provide a detailed record of the formation of the Hawaiian Archipelago and tracks the movement pattern of the Pacific Plate over the last 30 million years. Many of the 52 volcanoes in the Hawaiian Archipelago, which includes the Main Hawaiian Islands (MHI) and the NWHI, are terraced with drowned fossil reefs that have recorded sea level change and the subsidence history of the region. However, many aspects of the archipelago's geological history in the NWHI remain poorly documented. For instance, even the most widely accepted conclusion that the volcanoes increase in age to the northwest is not without controversy, as several submarine features inside the PMNM have been dated back 60-90 million years to the Cretaceous period.

These are just a few of the many unique biological and geological features of the Monument. However, most of these have only been studied in the PMNM's shallow waters. More than 98% of the PMNM's seafloor lies below 100 m, the vast majority of which is completely unexplored. Early efforts by the R/V *Albatross* in 1902 included limited collections of deep-sea specimens in the NWHI using dredges and trawls. More recently, manned submersibles and ROVs operated by the Hawaiʻi Undersea Research Laboratory (HURL) conducted a number of surveys of the deepwater geology and biology in the Monument. However, most of these have been much shallower than 1,500 m, and consequently, the Monument's deepwater resources are very poorly known.

Recognizing this large exploration gap, NOAA launched an expedition in 2015 (EX-15-04-L2) to survey the deep-sea biology and geology of the region. During that expedition, ROV surveys discovered numerous high-density communities of corals and sponges at depths between 1,500-2,200 m. These communities were all located within the manganese crust depth zone (1,000-2,500 m), where cobalt-rich ferromanganese (FeMn) crusts represent a vast mineral resource that will likely be targeted in the future by the deep-sea mining industry. The Hawaiian Archipelago lies along the eastern boundary of the Prime Crust Zone (PCZ), which harbors what are believed to be the richest and most commercially valuable crusts on Earth.

While the dense coral and sponge communities located inside the Monument are protected against future anthropogenic impacts, we need to acquire a greater understanding of these biological communities. Obtaining such baseline data and information will allow managers to develop management strategies to better maintain these deepwater resources. Specifically, we need to gain a better understanding of where these high-density communities are located, how they form, at what depths they are found, and what are their species compositions. Discovery of more of these communities serves two purposes: (1) it provides invaluable data on the deepwater resources within the PMNM, and (2) it provides a proxy for those communities that lie outside the Monument. The purpose of the *2016 Hohonu Moana* expedition to the PMNM aboard the NOAA Ship *Okeanos Explorer* was to follow up on the previous expedition, Leg 2 of *2015 Hohonu Moana* (EX-15-04-L2), in order to gain a better understanding of the deepwater biology and geology found on FeMn crusts in the region.

2.3 Objectives

Okeanos Explorer cruises in general have a large number of objectives that can be categorized as being either programmatic or scientific in nature. Typically, programmatic objectives (i.e., operations, telepresence, data management, and education and outreach) are common to all expeditions, whereas scientific objectives are specific to a particular cruise or set of cruises. Below are brief descriptions of the programmatic and science objectives for EX-16-03.

2.3.1 Programmatic Objectives

a) Mapping and ROV Operations

Mapping objectives were to collect high-resolution acoustic data from all four types of sonars that were installed on the Okeanos Explorer at the time: EM 302 multibeam, EK60 echo sounder, 3.5 kHz subbottom profiler, and Acoustic Doppler Current Profiler (ADCP). Mapping data were acquired during transits, as well as on specific targets identified by the science team. Data from these systems were processed onboard 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 procedures for the multibeam sonar were to obtain sound velocity profiles at regular intervals no longer than 3-4 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, on ascent and descent, 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.

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. The EX-16-03 Data Management Plan is located in **Appendix A** of this report.

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, daily updates, web logs, highlight videos, still imagery, and mapping products—all of which were posted on the EX-16-03 expedition website (https://oceanexplorer.noaa.gov/okeanos/explorations/ex1603/welcome.html). Other education and outreach objectives included educational webinars, press interviews, and social media posts during the expedition.

2.3.2 Science Objectives

The objectives of the expedition were to survey deepwater areas in and around the PMNM that had never been surveyed before, in order to provide baseline data and information to support the management and science needs of the Monument. Specifically, this expedition sought to:

(1) survey FeMn-crusted habitats within and near the PCZ;
(2) identify and characterize vulnerable deepwater marine habitats, particularly high-density communities of deep-sea corals and sponges living on FeMn crusts;
(3) collect information on the geologic history of central Pacific seamounts, including differentiating seamounts that formed in Hawaiʻi from those that are Cretaceous in origin;
(4) collect geological specimens near Mokumanamana Island, also known as Necker Island, to support the Extended Continental Shelf (ECS) project; and
(5) provide a foundation of publicly accessible data and information products to spur further exploration, research, and management activities in the future;
(6) collect high resolution mapping data from all sonars in priority areas as dictated by operational needs as well as science and management community needs.

3. Methodology

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

(1) dual-body ROV system to conduct daytime seafloor surveys, as well as to collect a limited number of specimens to help further characterize the deepwater fauna and geology of the region;
(2) mapping systems 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.

3.1 ROV surveys

The first dive of the expedition was conducted to support the ECS project, whereas all other ROV surveys targeted areas that were thought to contain high-density communities of deep-sea corals and sponges. The ECS project dive targeted the northeast side of Mokumanamana, also known as Necker Island, and its purpose was to obtain information on whether there is a connection between Mokumanamana Island and Necker Ridge, a narrow feature that extends for over 640 km and protrudes past the exclusive economic zone (EEZ) of the United States. For this purpose, the dive sought to collect geological samples in order to determine whether these have the same composition as samples that were previously collected near Mokumanamana Island. The location for the dive was chosen by the ECS project.

All other ROV dives targeted rift zone ridges and other types of abrupt topography (**Fig. 1**) due to their higher likelihood of hosting high-density communities of deep-water corals and sponges. Dive sites were chosen using high-resolution bathymetry data, as well as known locations of dense coral and sponge communities inside PMNM. With the exception of one site (Pioneer Bank Ridge), all chosen dive locations were completely unexplored. At Pioneer Bank Ridge, previous surveys conducted by both HURL in 2003 and the Okeanos Explorer in 2015 documented a high-density biological community extending for over 8 km at depths between 1800-2100 m. At the site, the ROV explored locations directly below the known community in order to determine its geographic extent and depth range. All other ROV dive sites were in areas that had not been previously explored. Pioneer Bank is also known in the literature as Pioneer Tablemount, in this report the geographic feature will be referred to as Pioneer Bank.

During each dive survey, the ROV descended onto the seafloor and then slowly moved up the slope documenting the geology and biology of the area. Onboard and shore-based scientists identified each encountered organism to the lowest possible taxon. For this purpose, scientists used the online animal guide of HURL (University of Hawai'i, 2019). Additionally, onboard and shore-based scientists provided geological interpretations of the observed substrate throughout each ROV survey. The NOAA Ship *Okeanos Explorer* is equipped with NOAA's custom-built, dual-body, 6,000-meter-rated ROV that is comprised of two interconnected vehicles: *Deep Discoverer* (*D2*) and *Seirios*. *Seirios* is directly cabled to the ship and is, therefore, subjected to the vertical movements of the ship from surface swell. *D2* is laterally tethered to *Seirios* and is, therefore, largely isolated from surface conditions.

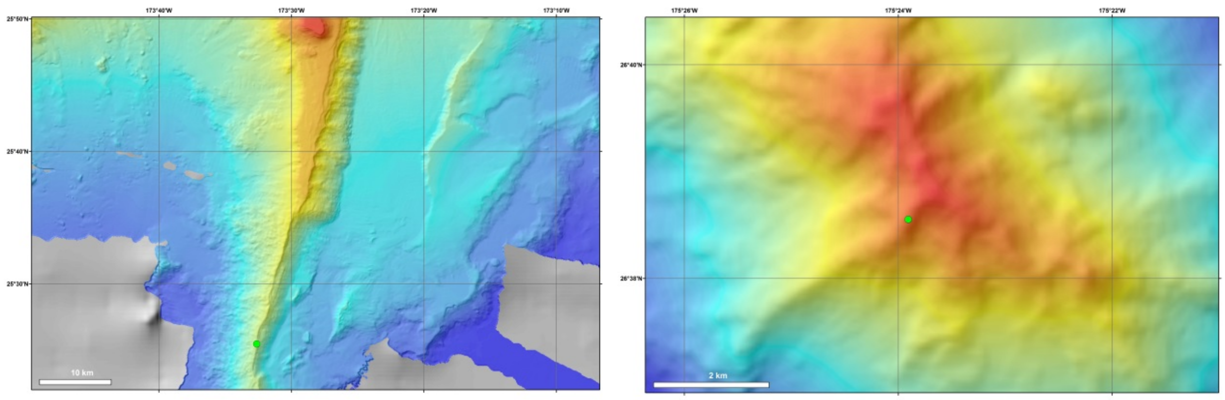

Figure 1. *Examples of abrupt topographical features targeted during ROV surveys. Green circle shows ROV dive start positions on (left) Pioneer Bank Ridge (dive 3), and (right) an unnamed seamount east of "Bank 9" (dive 5).*

D2 has five high-definition (HD) cameras, five standard-definition cameras, and 24 light-emitting diode (LED) lights that bring 144,000 lumens to the seafloor—resulting in some of the highest-quality deep-sea footage in the industry. Four custom-built lighting swing arms allow for the position and angle of the light to be adjusted for optimal imaging. *D2* also has two manipulator arms, a Schillings Orion arm and a Kraft Predator arm. The Kraft arm is more dexterous and is outfitted with custom-built jaws that allow for delicate work like sample collection, detaching small sample fragments, and equipment deployment or recovery. The Orion arm is used as a backup; this arm is also outfitted with a color calibration card. At the beginning of each dive, the HD video cameras on *D2* are color-corrected and white-balanced with the use of this card.

Seirios has one HD camera, five standard-definition cameras, and 18 LED lights that add 108,000 lumens to *D2*'s lighting. The vehicles work in tandem, with *D2* surveying the seafloor, and *Seirios* providing additional lighting and situational awareness, as well as dampening the movement of the ship. Both vehicles have a Sea Bird 9/11+ CTD with dissolved oxygen (DO) sensors. Additional information about the general process of site selection, collaborative dive planning, scientific equipment on the ROVs, and the approach to benthic exploration can be found in Kennedy et al. (2019).

3.2 Sample 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 *D2.* For each collected specimen, the date, time, latitude, longitude, depth, salinity, temperature, and DO content were recorded at the time of collection. 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. Any commensal organisms found were separated from the sample and processed separately.

Geological samples were weighed, air dried, and placed into rock bags. These samples will be shipped to Oregon State University (OSU) after the 2016 expeditions are completed, where they will be analyzed in the laboratory for their chemical composition and geological 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 not more than 1 cm^2 of tissue, was removed the original sample and processed using the OGL DNA extraction kit. For most collected specimens, the remainder of the biological sample was preserved in 95% ethanol.

Additionally, one subsample was taken from a biological specimen from Dive 6 of the expedition (D2_DIVE06_SPEC02BIO) and preserved in 10% buffered formalin for future histological examinations. This subsample was transferred to 70% ethanol after three days. At the conclusion of the 2016 expeditions, all DNA samples will be sent to OGL for DNA sequencing, archival, and storage, whereas the biological specimens preserved in ethanol and formalin will be sent to the Smithsonian Institution's National Museum of Natural History (USNM) for taxonomic identification, archival, and permanent storage in their invertebrate collections.

3.3 Seafloor Mapping

Seafloor mapping was carried out during all transits between ROV dive sites. Additionally, targeted mapping operations were conducted during days when weather did not allow for ROV dive operations. Targeted mapping operations were conducted in the vicinity of: (1) Lisianski Island, (2) Salmon Bank, (3) Castellano Seamount, and (4) an unnamed seamount southwest of Castellano. Mapping operations consisted of collecting bathymetry and backscatter data with the ship's EM 302 sonar system, water column data with the EK60 split-beam, sounding beneath the ocean floor with the Knudsen subbottom profiler, and current speed and direction with the Acoustic Doppler Current Profiler (ADCP). All mapping data collected during the expedition was submitted to NOAA's National Centers for Environmental Information (NCEI) at the end of the 2016 expeditions for archive. A comprehensive list of all hardware and software components, configuration, calibrations and system evaluations in use during the 2016 field season can be found in the 2016 Mapping Systems Readiness Report (Lobecker et al., 2016).

3.3.1 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).

3.3.2 Subbottom 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 subbottom profiler was operated simultaneously with the multibeam sonar during mapping operations in order to provide supplemental information about the sedimentary features underlying the seafloor.

3.3.3 Split-beam Sonars (Kongsberg EK60)

The 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.

3.3.4 ADCPs (Teledyne ADCPs)

The NOAA Ship *Okeanos Explorer* is equipped with two ADCPs: a Teledyne Workhorse Mariner (300 kHz) and a Teledyne Ocean Surveyor (38 kHz). 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.

3.3.5 XBTs

XBTs were deployed to obtain sound velocity profiles to help calibrate the multibeam system and ensure accurate bathymetric mapping. The XBT type is the Deep Blue probe produced by Lockheed Martin Sippican. 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 SVP-70 sound velocity probe, and salinity measurements near the transducers were taken using the ship's flow-through thermosalinograph (TSG).

3.4 Operations

During all CAPSTONE expeditions, *Okeanos Explorer* operations were conducted continuously around-the-clock and involved either 24-hour-per-day sonar mapping (i.e., mapping-only cruises) or both sonar mapping and ROV dives. Operations were conducted in the Hawaii-Aleutian time zone (GMT-10). For dive planning purposes, existing gridded bathymetry data were viewed in collaboration with the onshore science team as the ROV was being recovered each day. Dive tracks for the next day were then planned, plotted in 3D, and shared with the onboard and shoreside teams prior to the next dive. Tables of the at-sea mission personnel and the shore-based science team are located in **Appendix B** of this report.

3.4.1 Onboard Operations

On this ROV and mapping cruise, mapping operations were initiated as soon as the ship left port and continued each day as soon as the ROVs were secure on deck around 1700 (GMT -10). Mapping continued throughout the night until the ship arrived on the next dive site, generally around 0600 (GMT -10). Transit surveys were conducted to fill as many data gaps as possible while still ensuring the ship arrived at the dive site on time. Site surveys were conducted at a number of locations when permitted by a shorter transit between dive sites. The mapping and science leads worked together to develop the ROV trackline plans for these sites, since these surveys in particular were carried out in support of science objectives.

During combined mapping and ROV expeditions, HD video data are recorded and archived in several different formats and resolutions. The dives were recorded in their entirety at 720p. In addition to the full dive recording, a subset of the video collected was preserved in ProRes 4.2.2. 1080i, 145 Mbps. These ProRes highlight clips were selected by the onboard videographers to capture the seafloor habitats and features imaged any time the ROV slowed, stopped, or zoomed in to take a closer look at a feature of interest; features and habitats of interest to the participating science team; and other “best of” imagery. The video clips were time coded to Universal Time Coordinated (UTC) time to coordinate with all data products collected on the ship. In addition to the video itself, at least one frame grab was taken from each ProRes clip that was representative of that video segment for the purpose of discoverability. ProRes clips were then compressed for archiving.

All four sonars were operated simultaneously during mapping operations, with the acquisition of multibeam data generally being the priority for ROV trackline planning. Sound velocity profiles were obtained with XBTs every few hours as standard protocol to ensure the quality of the multibeam data.

ROV operations were conducted during daylight hours, generally starting with the ship arriving on site at 0600, the ROV entering the water around 0830, and the ROV exiting the water around 1630. This schedule generally yielded approximately eight hours of video per dive. CTD data were collected during each dive via the CTD sensors onboard both the *Seirios* sled and *D2*. Both geological and biological samples were collected during the seafloor portion of each dive using *D2*'s manipulator arms. These samples were placed into the sample boxes and retrieved by the onboard science team after the ROV had been secured on deck. Samples were processed immediately in the ship's lab, the protocol for which was described in **Section 3.2**.

3.4.2 Shoreside Operations

The current operating model for *Okeanos Explorer* cruises are based on telepresence-enabled participation whereby the small onboard science team is augmented by a much larger shoreside science team located around the world. When this model was first implemented from 2010 to 2012, all of the shore-based scientists were co-located at only a few ECCs around the U.S., where they actively helped in the planning and execution of dives. This first effort was called the core participation model because it only accommodated a limited core group of shoreside participants. Subsequently, this model was replaced by a distributed participation model when the ship's video and audio communication became accessible from any location with an Internet connection (Elliott et al., 2014). This enabled many geographically dispersed scientists to actively participate in the dives from their home institutions or even their own homes. In this paradigm, digital communications such as email and instant messaging replaced the person-to-person discussions and idea exchanges that naturally occur when a group is stationed together. The benefit of this distributed model was that the size of the science team was much larger.

For this expedition, a hybrid of the core and distributed models occurred. Shoreside participation involved small core teams stationed across the country in ECCs in addition to a larger geographically distributed team. This hybrid participation model still benefited from the information exchange and collaboration networks that developed during the use of the distributed model. However, it also benefited from the advantages of having ECCs that included higher Internet2 speeds, the means to simultaneously display all of the video feeds being sent off the ship, and direct interaction between the scientists participating at ECCs. This model is particularly effective for *EX*'s exploration.

3.5 Education and Outreach Activities

A number of education and outreach and education activities were conducted both before and during the expedition. Activities preceding the expedition included education webinars and live media interviews. Activities conducted during the expedition included live interactions with school groups and others, social media activity, a live conversation with the captain of the Polynesian Voyaging Society's double-hulled voyaging canoe, *Hōkūleʻa*, and a media interview.

4. Expedition Schedule

The expedition was originally planned for a total of 25 days at sea, from February 23 to March 18, 2016, starting from Pearl Harbor and ending in Kwajalein. However, mechanical problems delayed the departure from Pearl Harbor by two days; therefore, the expedition included a total of 23 days at sea between February 25 and March 18, 2016 (**Table 1**). The original schedule included 18 ROV dives; however, the delayed departure from Pearl Harbor, as well as bad weather throughout the expedition, resulted in multiple ROV dives having to be cancelled. A total of eight ROV dives were conducted throughout the expedition (**Table 1**).

Table 1. *Schedule of the EX-16-03 expedition to the Northwestern Hawaiian Islands. Note that the expedition crossed the international dateline on 3/11/2016.*

Date	Location	Operations
2/25/2016	Pearl Harbor	Departed Pearl Harbor
2/26/2016	Transit	Mapping in transit
2/27/2016	Mokumanamana	ROV Dive 1
2/28/2016	French Frigate Shoals (FFS)	ROV Dive 2
2/29/2016	Transit	Mapping in transit
3/1/2016	Pioneer Bank Ridge	ROV Dive 3
3/2/2016	"Bank 9"	Mapping
3/3/2016	Pioneer Bank	Mapping
3/4/2016	North Pioneer Bank	ROV Dive 4
3/5/2016	Unnamed Seamount E of "Bank 9"	ROV Dive 5

Date	Location	Operations
3/6/2016	Transit	Mapping in transit
3/7/2016	Seamounts W of Salmon Bank	Mapping
3/8/2016	Seamounts W of Salmon Bank	Mapping
3/9/2016	Unnamed Seamount W of Salmon Bank	ROV Dive 6
3/10/2016	Castellano Seamount	ROV Dive 7
3/11/2016	Unnamed Seamount SW of Castellano	ROV Dive 8
3/13/2016	**Transit across dateline**	Mapping in transit
3/14/2016	Transit	Mapping in transit
3/15/2016	Transit	Mapping in transit
3/16/2016	Transit	Mapping in transit
3/17/2016	Transit	Mapping in transit
3/18/2016	Kwajalein	Arrived at Kwajalein

5. Expedition Map

The expedition started in Pearl Harbor, Hawaiʻi and ended in Kwajalein, Marshall Islands (**Fig. 2**). After departing from Pearl Harbor, the *Okeanos Explorer* transited northwest towards the PMNM. ROV and mapping operations were conducted in and around the PMNM, starting around Nihoa Island, and extended to the areas west of Salmon Bank, just outside the PMNM boundary (**Fig. 2**). After completing ROV dive operations on March 11, the *Okeanos Explorer* transited to Kwajalein and conducted mapping operations throughout the transit.

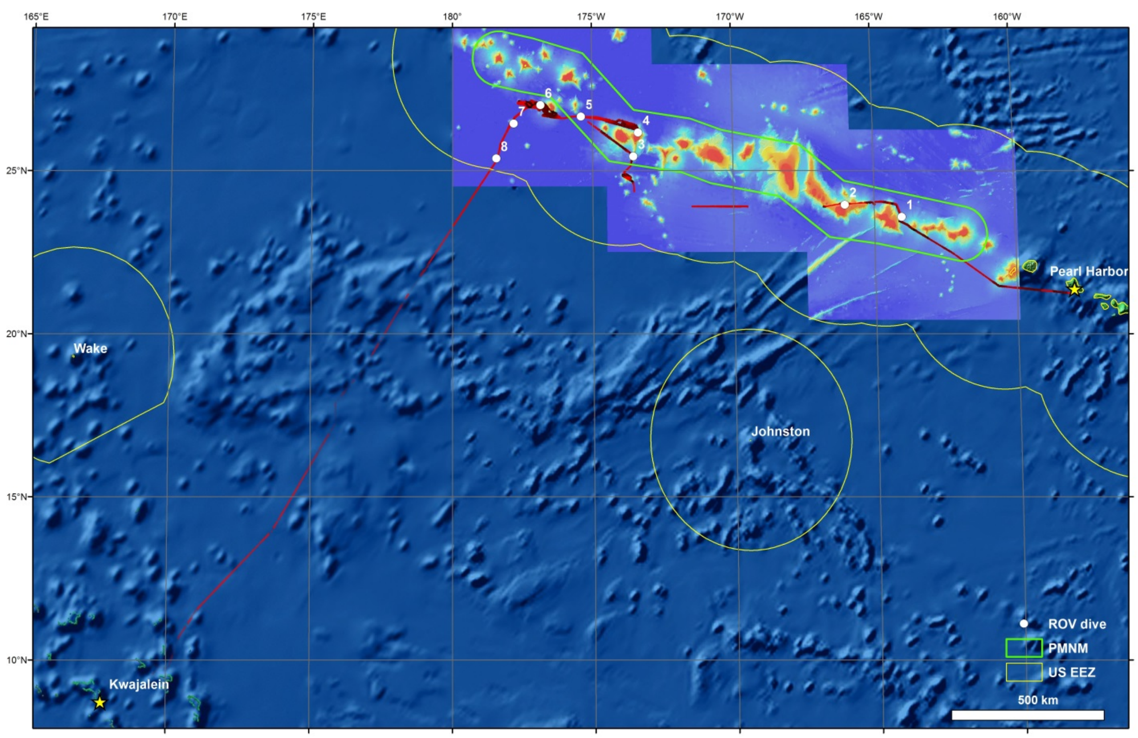

Figure 2. *Map showing the locations of the ROV dives (white circles) and mapping operations (red lines) conducted during EX-16-03, as well as the expedition's starting and ending ports.*

6. Results

6.1 ROV Seafloor Surveys

Depth ranges explored during ROV surveys ranged between 648 m and 4,292 m; bottom times ranged between 2:18 and 8:52 hours. Linear distances covered during ROV surveys ranged between 190 m and 1,470 m. During the eight dives, the ROV spent a total of 40:55 h on the bottom and covered a total linear distance of 4.85 km, yielding an average of 119 m surveyed per hour of bottom time (**Table 2**).

Table 2. *Summary information for the eight ROV dives conducted during EX-16-03.*

ROV Dive No.	Date	Location	Start Latitude	Start Longitude	Start depth (m)	End Depth (m)	Bottom Time (h)	Distance covered (m)	High-density biological community	Geo. samples collected	Biol. samples collected	Com-mensal samples Collected
1	2/27/2016	Ridge NE of Necker Island	23.57326	-164.02763	4292	4228	2:18	365	No	2	0	0
2	2/28/2016	Canyon N of FFS	23.94473	-166.03708	1405	1088	5:18	555	No	1	2	1
3	3/2/2016	S Pioneer Bank Ridge	25.42439	-173.54362	2357	2345	4:57	670	Yes	2	2	1
4	3/4/2016	Pinnacle N of Pioneer Bank	26.15336	-173.36317	1513	1156	5:12	330	Yes	2	2	2
5	3/5/2016	Seamount E of "Bank 9"	26.64254	-175.39842	1757	1587	5:19	625	Yes	2	2	0
6	3/9/2016	Seamount W of Salmon Bank	26.99260	-176.84571	1293	648	8:52	1470	Yes	1	2	0
7	3/10/2016	Castellano Seamount	26.43077	-177.80110	2019	1839	5:40	645	Yes	2	1	3
8	3/11/2016	Seamount SW of Castellano Seamount	25.35972	-178.43078	3987	3922	3:19	190	Yes	2	2	0
							40:55	**4,850**	**6**	**14**	**13**	**7**

Two geological specimens were collected during the ECS dive around Mokumanamana (or Necker) Island (Dive 1), thereby achieving the main objective of that dive. On the remaining seven dives, high-density communities of deep-sea corals and sponges were recorded at six sites (**Table 2**; **Fig. 3**). Besides the ECS dive, the only other surveyed site that did not contain a high-density coral and sponge community, was on a submarine canyon north of the French Frigate Shoals (FFS).

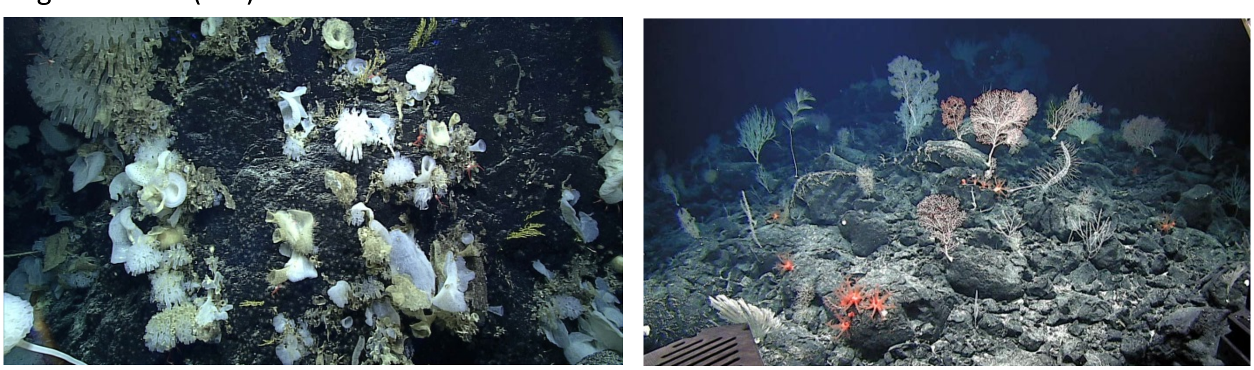

Figure 3. *High-density communities of deep-sea corals and sponges encountered at (left) 1,160 m on the top of a pinnacle north of Pioneer Bank, and (right) on a ridge of Castellano Seamount at 2,020 m.*

The first dive of the expedition was conducted to support the ECS project, whereas all other ROV surveys targeted areas that were thought to contain high-density communities of deep-sea corals and sponges. The ECS project dive, Dive 1, targeted the northeast side of Mokumanamana, also known as Necker Island, and its purpose was to obtain information on whether there is a connection between Mokumanamana Island and Necker Ridge, a narrow feature that extends for over 640 km and protrudes past the U.S. EEZ. For this purpose, the dive sought to collect geological samples in order to determine whether these have the same composition as samples that were previously collected near Mokumanamana Island. The location for the dive was chosen by the ECS project.

All other ROV dives targeted rift zone ridges and other types of abrupt topography (**Fig. 4**) due to their higher likelihood of hosting high-density communities of deep-water corals and sponges. Dive sites were chosen using high-resolution bathymetric data, as well as known locations of dense coral and sponge communities inside the PMNM. With the exception of one site (Pioneer Bank Ridge), all chosen dive locations were completely unexplored. At Pioneer Bank Ridge, previous surveys—conducted by both HURL in 2003 and the *Okeanos Explorer* in 2015—documented a high-density biological community extending for over eight kilometers at depths between 1800-2100 m. At the site, the ROV explored locations directly below the known community in order to determine its geographic extent and depth range. All other ROV dive sites were in areas that had not been previously explored.

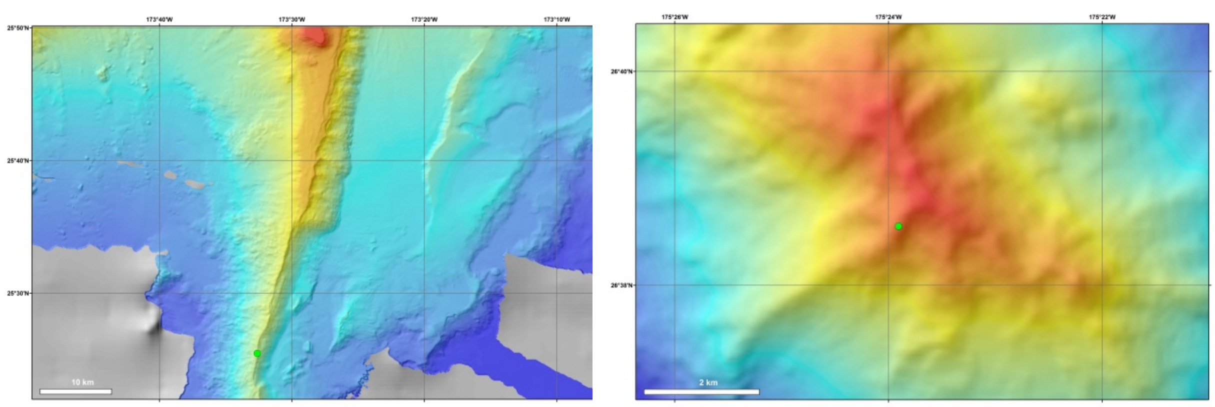

Figure 4. *Examples of abrupt topographical features targeted during ROV surveys. Green circle shows ROV dive start positions on (left) Pioneer Bank Ridge (Dive 3), and (right) an unnamed seamount east of "Bank 9" (Dive 5).*

During each dive survey, the ROV descended onto the seafloor and then slowly moved up the slope documenting the geology and biology of the area. Onboard and shore-based scientists identified each encountered organism to the lowest possible taxon. For this purpose, scientists used the HURL online animal guide (University of Hawai'i, 2019), as well as a test version of an animal identification guide that is currently being developed by OER. Additionally, onboard and shore-based scientists provided geological interpretations of the observed substrate throughout each ROV survey. Depth ranges explored during ROV surveys ranged between 648 m and 4,292 m, and bottom times ranged between 2:18 h and 8:52 h. Linear distances covered during ROV surveys ranged between 190 m and 1,470 m. During the eight dives the ROV spend a total of 40:55 h on the bottom and covered a total linear distance of 4.85 km, yielding an average of 119 m surveyed per hour of bottom time (**Table 3**).

Table 3. *Summary information for the eight ROV dives conducted during EX-16-03.*

ROV Dive No.	Date	Location	Start Latitude	Start Longitude	Start depth (m)	End Depth (m)	Bottom Time (h)	Dist-ance covered (m)	High-density biological community	Geo. samples	Biol. samples	Comm-ensal samples
1	2/27/2016	Ridge NE of Necker	23.57326	-164.02763	4292	4228	2:18	365	No	2	0	0
2	2/28/2016	Canyon N of FFS	23.94473	-166.03708	1405	1088	5:18	555	No	1	2	1
3	3/2/2016	S Pioneer Bank Ridge	25.42439	-173.54362	2357	2345	4:57	670	Yes	2	2	1
4	3/4/2016	Pinnacle N of Pioneer Bank	26.15336	-173.36317	1513	1156	5:12	330	Yes	2	2	2
5	3/5/2016	Seamount E of “Bank 9”	26.64254	-175.39842	1757	1587	5:19	625	Yes	2	2	0
6	3/9/2016	Seamount W of Salmon	26.99260	-176.84571	1293	648	8:52	1470	Yes	1	2	0
7	3/10/2016	Castellano Seamount	26.43077	-177.80110	2019	1839	5:40	645	Yes	2	1	3
8	3/11/2016	Seamount SW of Castellano	25.35972	-178.43078	3987	3922	3:19	190	Yes	2	2	0
							40:55	**4,850**	**6**	**14**	**13**	**7**

Two geological specimens were collected during the ECS dive around Mokumanamana Island (Dive 1), thereby achieving the main objective of that dive. On the remaining seven dives, high-density communities of deep-sea corals and sponges were recorded at six sites (**Table 3**; **Fig. 4A**). Besides the ECS dive, the only other surveyed site that did not contain a high-density coral and sponge community, was on a submarine canyon north of French Frigate Shoals (FFS).

The six high-density communities that were surveyed were all found on ridges (Dives 3, 5-8) or a pinnacle (Dive 4). Among the high-density communities that were surveyed, five were previously unknown, and one represents a substantial expansion of the previously known community at Pioneer Bank Ridge. Prior to the dive, the high-density community at Pioneer Bank Ridge was known to cover an area of close to 8 km at depths between 1,800-2,100 m. The dive on Pioneer Bank Ridge (Dive 3) extended the known extent of the community by an additional eight kilometers to the south, as well as ~150 m deeper.

Additionally, a moderate- to high-density community was discovered throughout the oxygen minimum layer (800-1000 m) on an unnamed seamount west of Salmon Bank (Dive 6). This observation challenges previous assumptions that high-density communities do not form in environments with low oxygen concentrations (<1mg/l). Finally, a moderate- to high-density community was discovered at depths approaching 4,000 m on an unnamed seamount southwest of Castellano Seamount (Dive 8). This represents by far the deepest high-density community ever documented in the region, as it is nearly twice as deep as the deepest high-density communities that were previously known from Hawaiʻi (2,200 m).

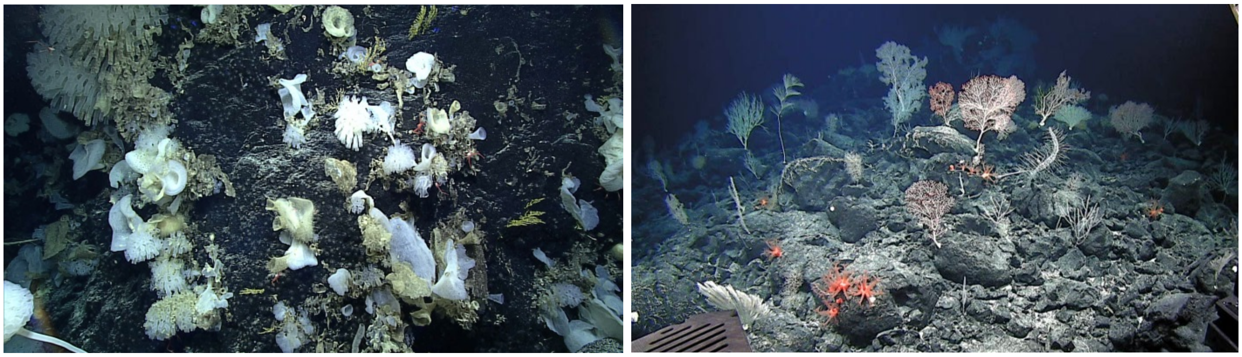

Figure 4A. *High-density communities of deep-sea corals and sponges encountered at (left) 1,160 m on the top of a pinnacle north of Pioneer Bank, and (right) on a ridge of Castellano Seamount at 2,020 m.*

A total of 249 different types of animals were identified from video ROV surveys and included cnidarians, sponges, echinoderms, arthropods, mollusks, tunicates, bryozoans, ctenophores, and fishes. Of these, the majority represents undescribed species that were, therefore, only identified to genus or higher taxonomic groups. This observation highlights the need for further work in the region. A noteworthy animal imaged during the expedition included an incirrate octopus recorded on Dive 1, which represents a new species and possibly a new genus, and is also the deepest record for this suborder of octopuses. It is important to point out that all field identifications made from video surveys should be considered provisional until they are confirmed by a taxonomic authority. Dive summaries for each dive can be found in **Appendix B**, and animals observed on this expedition can be found in **Appendix C** of this report.

6.2 Sample Collections

A total of 34 specimens were collected during the expedition, including 14 geological samples, 13 biological specimens, and seven commensal organisms. The geological specimens all consisted of basalt rocks with manganese encrustations of varying thicknesses (**Fig. 5 A & B**). The weight of individual geological specimens ranged between 1.6-19.6 kg, and the 14 samples weighed a total of 133.4 kg (**Table 4**). Geological specimen collections targeted samples that were volcanic in origin and angular in shape, due to their higher likelihood of providing information on the geological age and chemical composition of the feature from where they were collected.

Table 4. *Inventory of geological samples collected during EX-16-03.*

Specimen ID	Description	Preser-vation	Weight (kg)	Date (UTC)	Time (UTC)	Latitude	Longitude	Depth (m)	Salinity	Temp. (°C)	Oxygen (mg/l)
D2_DIVE01_SPEC 01GEO	Mn-encrusted volcanic	Dry	8.7	20160227	23:30:15	23.57450	-164.03011	4245	34.69	1.47	4.55
D2_DIVE01_SPEC 02GEO	Mn-encrusted volcanic, subangular	Dry	13.6	20160228	0:13:45	23.57462	-164.03062	4223	34.69	1.47	4.55
D2_DIVE02_SPEC 01GEO	Mn-encrusted volcanic	Dry	2.4	20160228	22:12:38	23.94569	-166.04026	1235	34.54	3.15	1.92
D2_DIVE03_SPEC 01GEO	Mn-encrusted volcanic	Dry	9.2	20160302	21:54:20	25.42638	-173.54341	2320	34.65	1.67	3.56
D2_DIVE03_SPEC 02GEO	Mn-encrusted volcanic	Dry	9.9	20160302	23:15:55	25.42759	-173.54317	2311	34.65	1.69	3.60
D2_DIVE04_SPEC 02GEO	Mn-encrusted volcanic	Dry	6.1	20160305	0:27:54	26.15435	-173.36487	1220	34.46	3.20	1.36
D2_DIVE04_SPEC 04GEO	Mn-encrusted volcanic	Dry	11.7	20160305	1:52:49	26.15457	-173.36466	1155	34.47	3.12	1.44
D2_DIVE05_SPEC 01GEO	Mn-encrusted volcanic	Dry	15.5	20160305	19:36:13	26.64255	-175.39847	1757	34.59	2.30	2.48
D2_DIVE05_SPEC 03GEO	Mn-encrusted volcanic	Dry	1.6	20160305	23:09:41	26.64536	-175.39638	1635	34.59	2.41	2.42
D2_DIVE06_SPEC 01GEO	Mn-encrusted volcanic	Dry	6.2	20160309	19:39:13	26.99258	-176.84570	1292	34.48	2.93	1.54
D2_DIVE07_SPEC 01GEO	Mn-encrusted volcanic	Dry	16.6	20160310	20:05:48	26.43078	-177.80114	2018	34.62	1.94	2.93
D2_DIVE07_SPEC 03GEO	Mn-encrusted volcanic	Dry	8.9	20160311	0:14:24	26.43183	-177.80412	1912	34.61	2.04	2.74
D2_DIVE08_SPEC 01GEO	Mn-encrusted volcanic	Dry	19.6	20160311	21:27:14	25.35999	-178.43043	3982	34.70	1.43	4.71
D2_DIVE08_SPEC 03GEO	Mn-encrusted pillow lava fragment	Dry	3.4	20160311	23:22:17	25.35992	-178.42944	3920	34.69	1.43	4.57

Figure 5A. *Laboratory photographs of the 14 geological specimens collected during EX-16-03.*

Figure 5B. *Laboratory photographs of the 14 geological specimens collected during EX-16-03.*

The 20 biological specimens included 13 specimens that were purposely collected, as well as seven specimens that were incidentally collected as commensal organisms on other samples. Biological specimens collected included 11 corals, three sponges, one pair of brittle stars, one hydroid, one crinoid, one urchin, one zoanthid and one polychaete (**Table 5**; **Fig. 6 A-D**).

Biological specimen collections targeted samples that represented potential new species, or were not previously known to occur in the region.

Table 5. *Inventory of biological samples collected during EX-16-03.*

Specimen ID	Description	Group	Preser-vation	DNA sub-sample	Date (UTC)	Time (UTC)	Latitude	Longitude	Depth (m)	Salinity	Temp. (°C)	Oxygen (mg/l)
D2_DIVE02_SPEC02BIO	*Hyalonema* sp.	Sponge	95% ethanol	Yes	20160228	22:34:36	23.94570	-166.04043	1226	34.53	3.17	1.92
D2_DIVE02_SPEC02BIO_C01	Zoanthid on sponge	Zoanthid	95% ethanol	Yes	20160228	22:34:36	23.94570	-166.04043	1226	34.53	3.17	1.92
D2_DIVE02_SPEC03BIO	Gorgonian	Coral	95% ethanol	Yes	20160228	22:56:38	23.94571	-166.04045	1221	34.52	3.29	1.80
D2_DIVE03_SPEC01GEO_C01	Hydroidolina on rock	Hydroid	95% ethanol	Yes	20160302	21:54:20	25.42638	-173.54341	2320	34.65	1.67	3.56
D2_DIVE03_SPEC03BIO	*Chrysogorgia* sp.	Coral	95% ethanol	Yes	20160302	23:55:04	25.42823	-173.54297	2328	34.65	1.68	3.52
D2_DIVE03_SPEC04BIO	*Pleurocorallium* sp.	Coral	95% ethanol	Yes	20160303	0:03:07	25.42829	-173.54300	2327	34.65	1.69	3.55
D2_DIVE04_SPEC01BIO	Hexactinellida	Sponge	95% ethanol	Yes	20160304	21:24:28	26.15337	-173.36330	1502	34.56	2.40	2.20
D2_DIVE04_SPEC01BIO_C01	Comatulida on sponge	Crinoid	95% ethanol	No	20160304	21:24:28	26.15337	-173.36330	1502	34.56	2.40	2.20
D2_DIVE04_SPEC01BIO_C02	Polychaete on sponge	Polychaete	95% ethanol	No	20160304	21:24:28	26.15337	-173.36330	1502	34.56	2.40	2.20
D2_DIVE04_SPEC03BIO	*Iridogorgia* sp.	Coral	95% ethanol	Yes	20160305	1:44:15	26.15447	-173.36460	1155	34.45	3.21	1.32
D2_DIVE05_SPEC02BIO	*Stichopathes* sp.	Coral	95% ethanol	Yes	20160305	20:58:49	26.64383	-175.39786	1701	34.59	2.31	2.49
D2_DIVE05_SPEC04BIO	*Bathypathes* sp.	Coral	95% ethanol	Yes	20160306	1:09:37	26.64669	-175.39516	1604	34.59	2.37	2.45
D2_DIVE06_SPEC02BIO	Isididae	Coral	95% ethanol	Yes	20160310	1:21:53	26.99798	-176.84322	842	34.20	4.49	1.56
D2_DIVE06_SPEC02BIO_S01	Isididae (subsample)	Coral	10% formalin	No	20160310	1:21:53	26.99798	-176.84322	842	34.20	4.49	1.56
D2_DIVE06_SPEC03BIO	Echinothuriidae	Urchin	95% ethanol	No	20160310	3:21:40	27.00154	-176.84043	685	34.11	5.00	2.37
D2_DIVE07_SPEC02BIO	*Paracalyptrophora* sp.	Coral	95% ethanol	Yes	20160310	22:26:43	26.43096	-177.80216	1985	34.59	2.08	2.75
D2_DIVE07_SPEC02BIO_C01	Ophiocanthidae (N=2) on coral	Brittle star	95% ethanol	No	20160310	22:26:43	26.43096	-177.80216	1985	34.59	2.08	2.75
D2_DIVE07_SPEC03GEO_C01	*Anthomastus* sp. on rock	Coral	95% ethanol	Yes	20160311	0:14:24	26.43183	-177.80412	1912	34.61	2.04	2.74
D2_DIVE07_SPEC03GEO_C02	Hexactinellida on rock	Sponge	95% ethanol	No	20160311	0:14:24	26.43183	-177.80412	1912	34.61	2.04	2.74
D2_DIVE08_SPEC02BIO	*Chrysogorgia* sp.	Coral	95% ethanol	Yes	20160311	22:18:08	25.35990	-178.43022	3957	34.68	1.47	4.66
D2_DIVE08_SPEC04BIO	Branched Isididae	Coral	95% ethanol	Yes	20160311	23:44:14	25.36000	-178.42912	3915	34.68	1.46	4.53

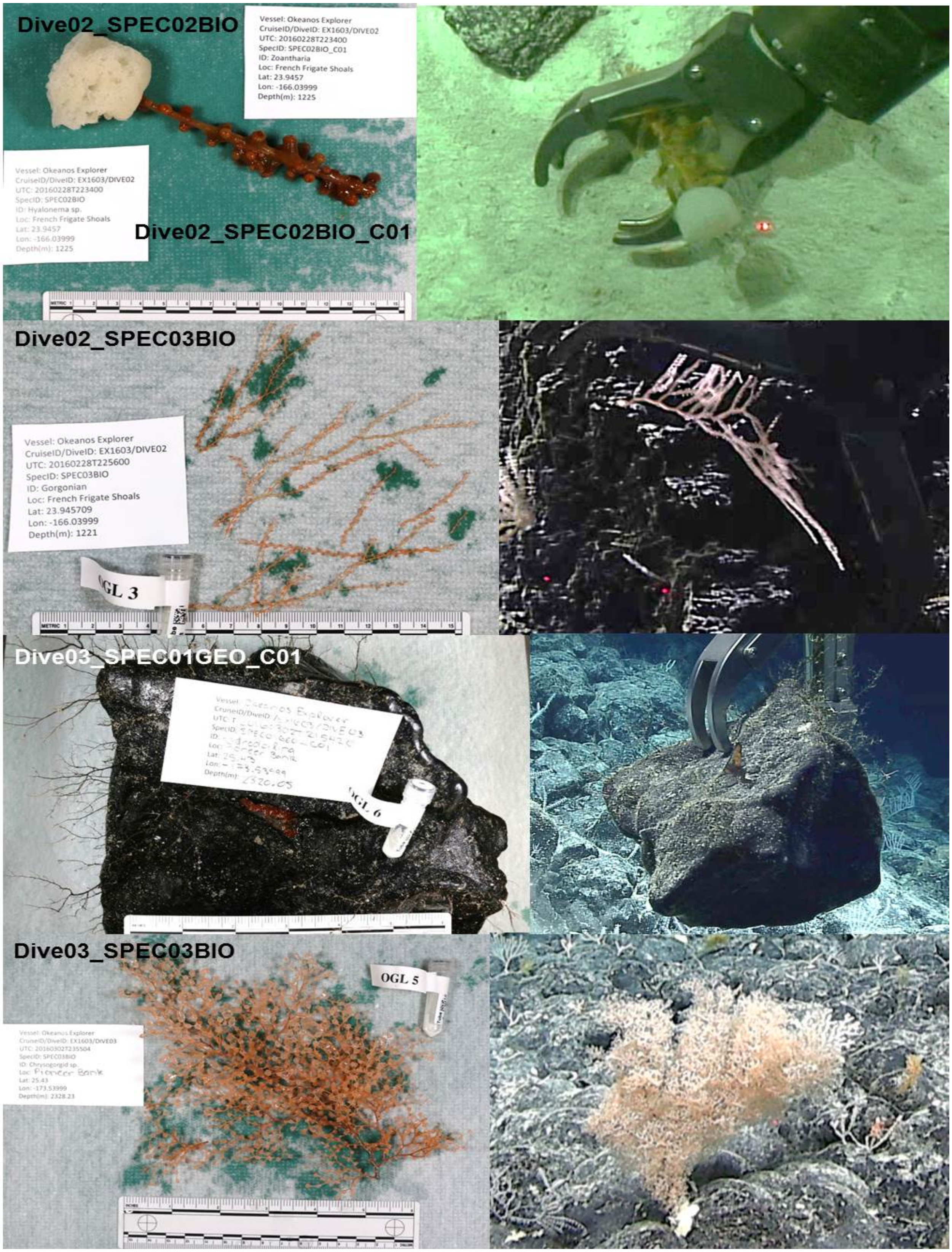

Figure 6A. *Laboratory (left) and in situ (right) photographs of the 13 biological and seven commensal specimens collected during EX-16-03.*

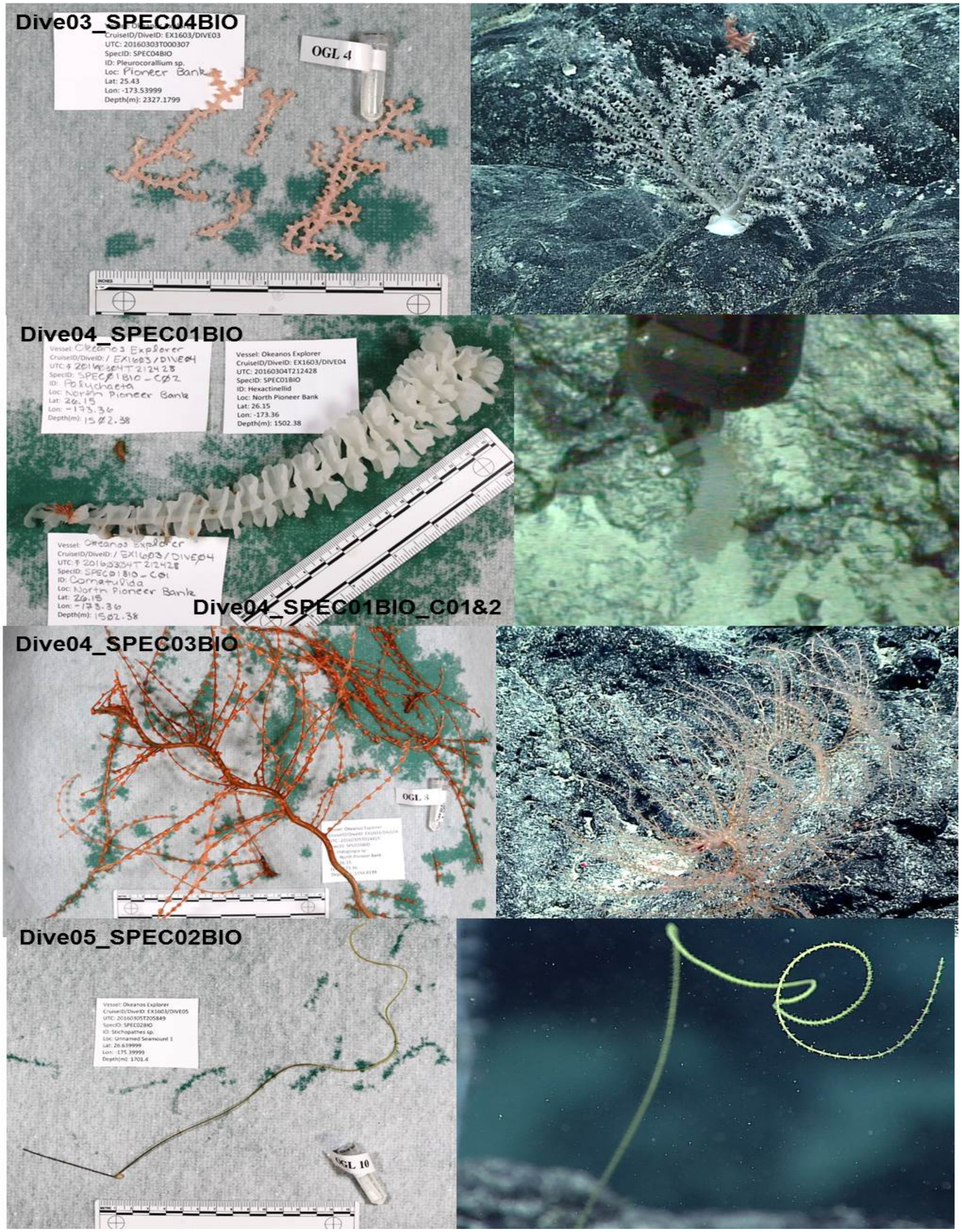

Figure 6B. *Laboratory (left) and in situ (right) photographs of the 13 biological and seven commensal specimens collected during EX-16-03.*

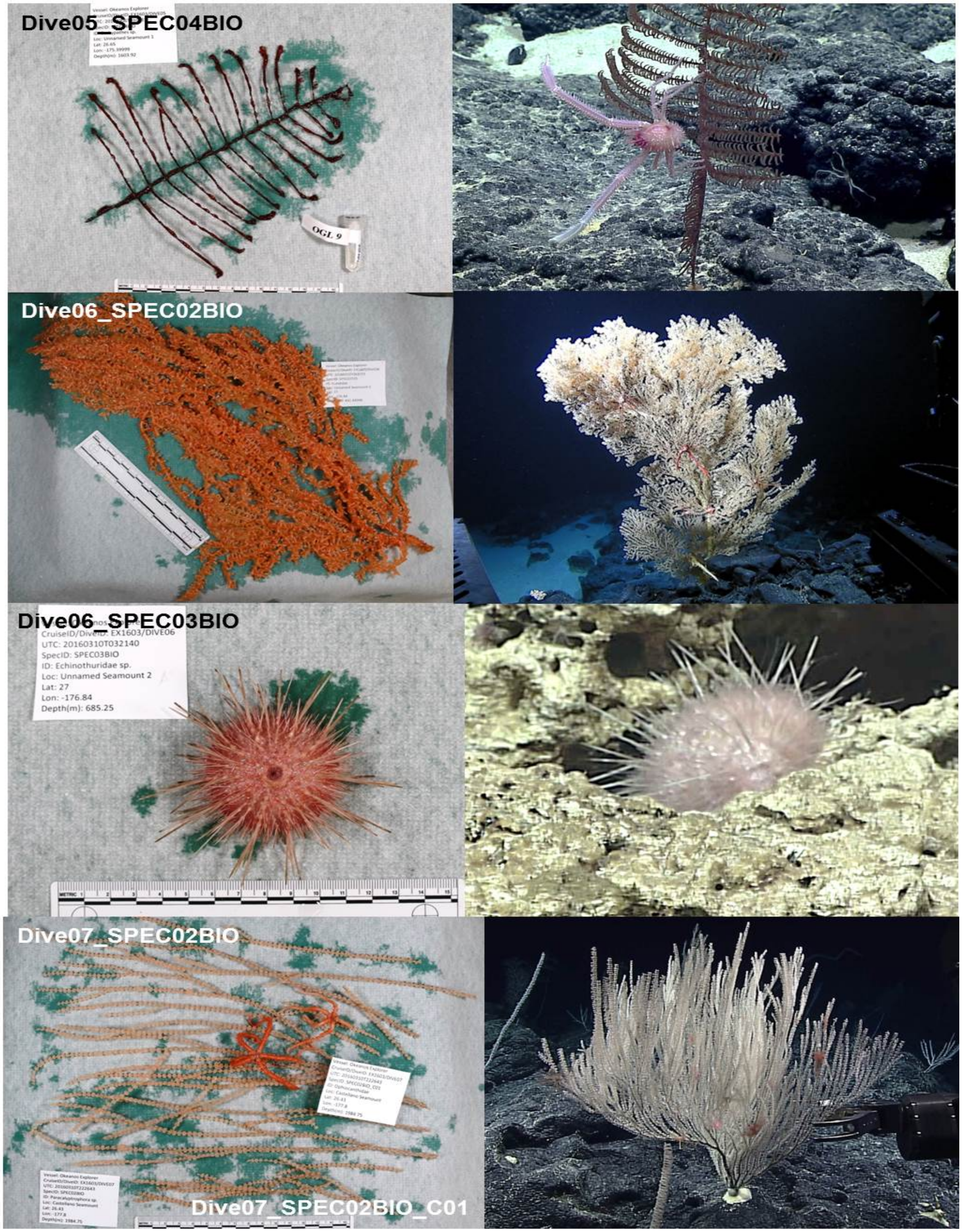

Figure 6C. *Laboratory (left) and in situ (right) photographs of the 13 biological and seven commensal specimens collected during EX-16-03.*

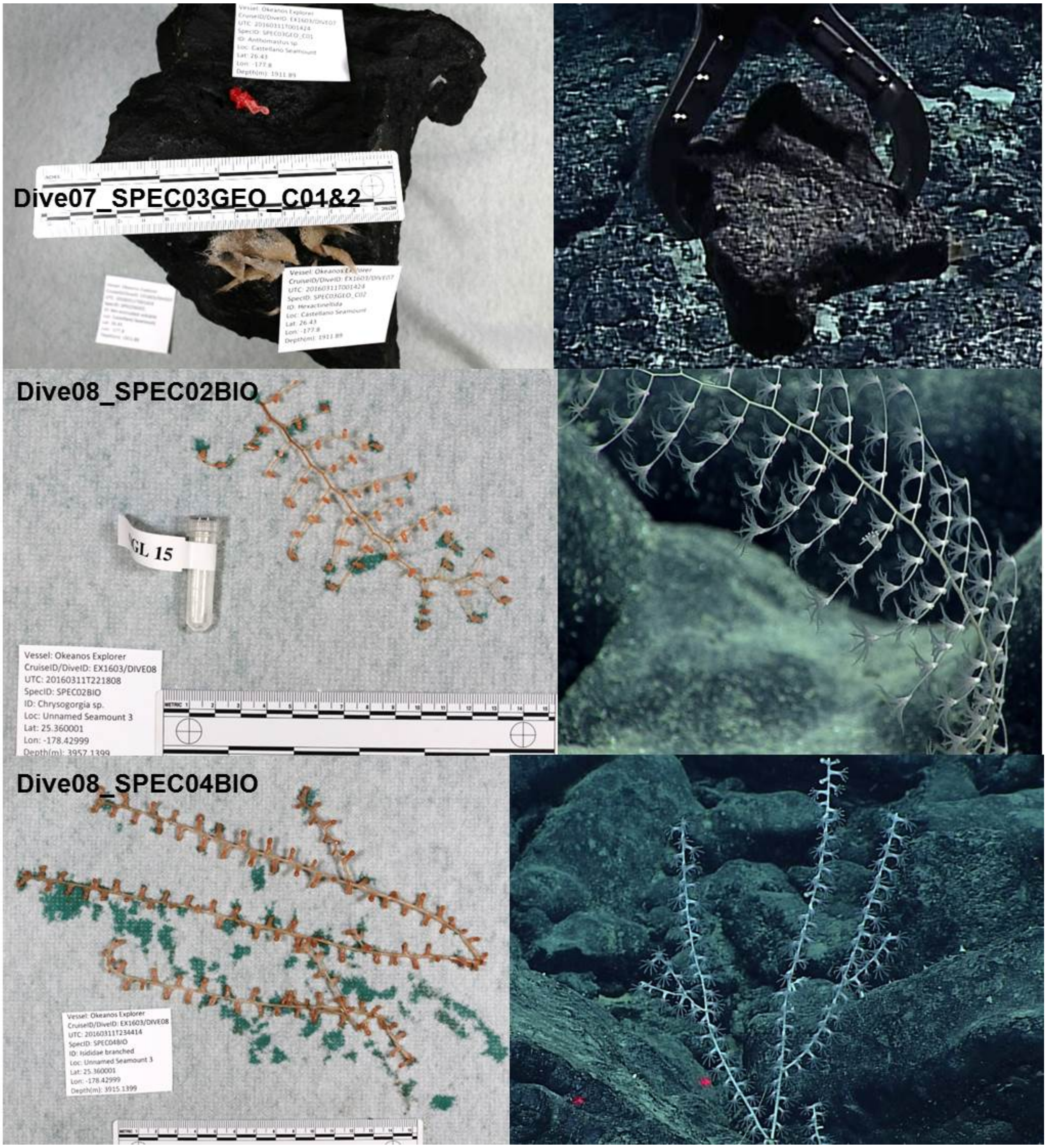

Figure 6D. *Laboratory (left) and in situ (right) photographs of the 13 biological and seven commensal specimens collected during EX-16-03.*

6.3 Seafloor Mapping

The total area mapped by NOAA Ship *Okeanos Explorer*'s EM 302 sonar during the expedition was more than 31,000 km^2, over 10,000 km^2 of which occurred within the waters of the PMNM.

This included mapping data acquired both in transits between sites, as well as targeted multibeam surveys in the vicinity of: (1) Lisianski Island, (2) Salmon Bank, (3) Castellano Seamount, and (4) an unnamed seamount southwest of Castellano Seamount (**Fig.2**). Through these targeted mapping operations, a total of five seamounts were mapped in their entirety, including one seamount inside the PMNM and four outside the Monument (**Fig. 7**). These newly mapped seamounts include (1) an unnamed seamount inside the PMNM west of Pioneer Bank Ridge (**Fig. 7b**), (2) two unnamed seamounts west of Salmon Bank (**Fig. 7c & 7d**), (3) Castellano Seamount (**Fig. 7e**), and (4) an unnamed seamount southwest of Castellano Seamount (**Fig. 7f**). Among these newly mapped seamounts, only Castellano Seamount had previously been partially mapped using multibeam sonars.

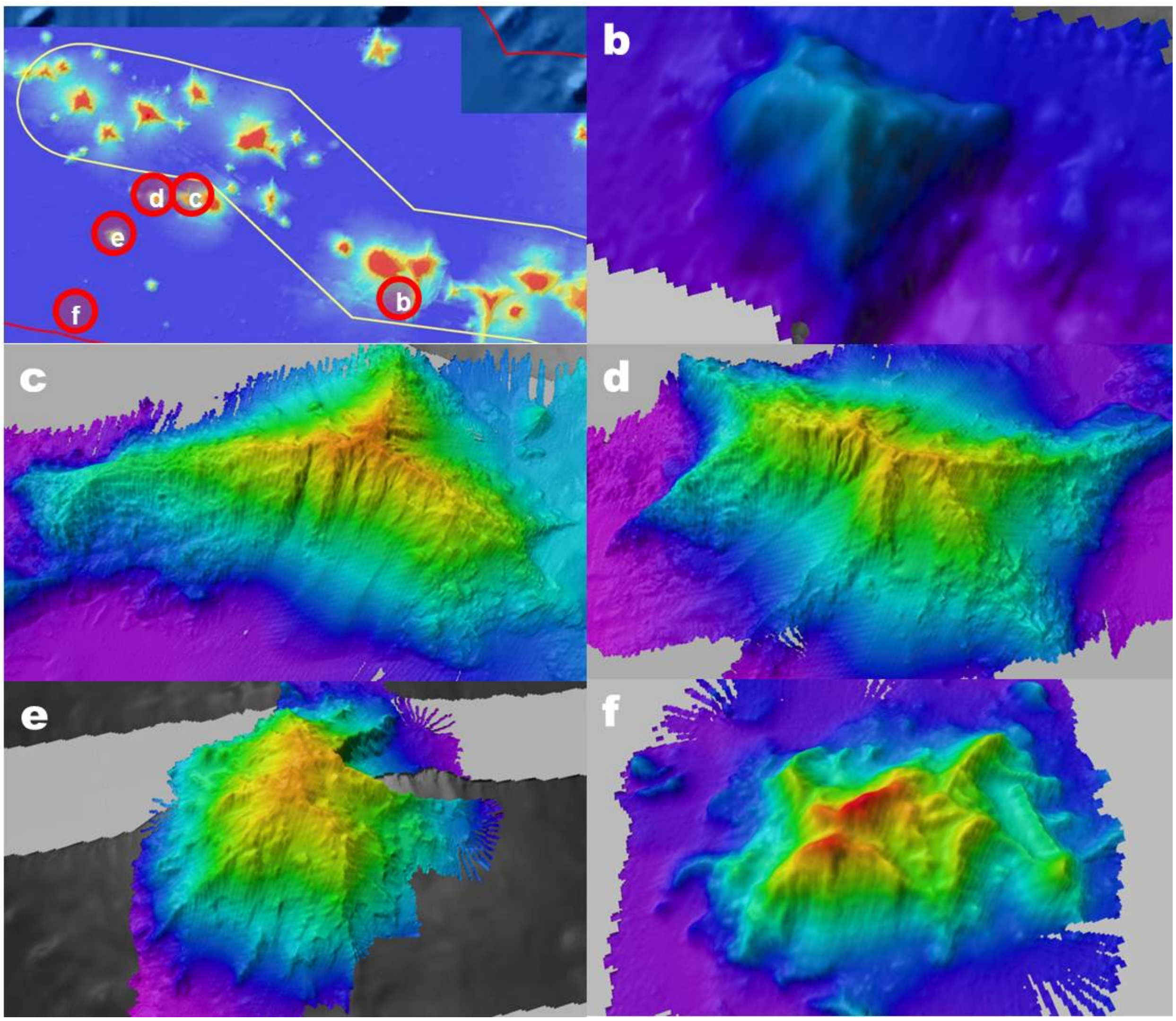

Figure 7. *Map showing the locations of the five seamounts that were mapped for the first time during EX-16-03, and images of the bathymetry of those seamounts.* The five seamounts are, (b) an unnamed seamount inside the PMNM west of Pioneer Bank Ridge, (c & d) two unnamed seamounts west of Salmon Bank, (e) Castellano Seamount, and (f) an unnamed seamount southwest of Castellano Seamount.

6.4 Education and Outreach

The expedition was the focus of over 600 media stories and NOAA received a total of 22 media inquiries during the course of the expedition. Live feeds of the expedition were continuously streamed throughout the expedition at the Maui Ocean Center, the Waikiki Aquarium, and the Mokupāpapa Discovery Center. Additionally, the live video feeds of the expedition were streamed over the Internet and garnered over 125,000 views through the end of dive operations on March 11. In addition to serving as a working space for scientists, the Exploration Command Centers (ECCs) at both the Inouye Regional Center (IRC) and the University of Hawaiʻi at Mānoa (UH) received regular visits from school groups and other visitors. The ECC at the IRC received approximately 20-30 visitors a day, with over 50 visitors on peak days.

The science leads were interviewed live for Hawaiʻi Public Radio's (HPR's) talk shows *Bytemarks Café* (February 17) and *The Conversation* (February 19) prior to the expedition, as well as attended a phone interview by an HPR reporter on March 14. Over 20 educators, including participants from the U.S., American Samoa, and Germany, attended the ONMS education webinar conducted on February 17, prior to the expedition on February 17 was attended by over 20 educators, including participants from the United States, American Samoa and Germany. The OER education webinar conducted on February 18 was attended by over 50 educators, including participants from the United States, Guam, Portugal and Brazil.

On March 3, the expedition team participated in a Reddit AMA session (https://www.reddit.com/r/science/comments/48rry9/science_ama_series_we_are_engineers_and), and answered close to 70 questions. Over 3,200 individual viewers visited the AMA session. On March 10, the expedition team participated in a phone conversation with expedition leaders of the Polynesia Voyaging Society's double-hulled voyaging canoe *Hōkūle'a*, which was sailing around the world using traditional wayfinding. The conversation compared the objectives and technologies of both missions and was streamed live over the Internet.

7. Data Deposition and Archival

All links to the data repositories were checked to ensure functionality at the publishing of this report (4/15/2020), if you are having trouble connecting to any document or service, email ex.expeditioncoordinator@noaa.gov.

The EX-16-03 Data Management Plan can be found in **Appendix A** of this report. Additionally, it can be found in Appendix B of the EX-16-03 Project Instructions, available at: https://repository.library.noaa.gov/view/noaa/10632

7.1 OER Data Discoverability Tools

All data collected by NOAA Ship *Okeanos Explorer* are archived and publically available within 90 days of the end of each cruise via the National Center for Environmental Intelligence (NCEI) online archives. Data can be accessed via the following websites:

- OER Digital Atlas at https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm
- OER ROV Data Archives at https://service.ncddc.noaa.gov/rdn/oer-rov-cruises/ex1603

Products created during the cruise, including the ship track, shaded bathymetry, dive locations and tracks, specimen collection data and images, ships meteorological and oceanographic sensor data, and status reports can be viewed on the interactive OER Digital Atlas.

Additional data requests, including Daily Situation Reports, internal operation records, and data from previous archived expeditions can be sent to: oer.info.mgmt@noaa.gov

7.2 Sonar Data

Sonar data collected onboard NOAA Ship *Okeanos Explorer* undergoes quality assurance/quality control (QA/QC) after every cruise and is then made publicly available through NCEI and the following websites:

- EM 302 bathymetry data, supporting informational logs, and ancillary files are available with the NCEI (formerly NGDC) Interactive Bathymetry Data Viewer at: http://maps.ngdc.noaa.gov/viewers/bathymetry/
- EM 302 water column data are available with the NCEI (formerly NGDC) Interactive Water Column Sonar Data Viewer at: http://maps.ngdc.noaa.gov/viewers/water_column_sonar/
- NCEI map tool with tracklines showing all publicly available geophysical surveys: https://maps.ngdc.noaa.gov/viewers/geophysics/
- Subbottom data, supporting data, and informational logs are available in the NCEI Data Archives accessible at https://www.ngdc.noaa.gov/

7.3 Physical Samples

Biological samples collected during NOAA Ship *Okeanos Explorer* expeditions are archived in the collections of the USNM. Here, they are catalogued, curated, and made publicly available.

- Biological samples of invertebrate organisms are archived in the Invertebrate Zoology Collections found here: https://naturalhistory.si.edu/research/invertebrate-zoology
- Information on how to request access to these samples can be found here: https://naturalhistory.si.edu/research/invertebrate-zoology/collections-access/specimen-loans
- Biological samples of fishes are archived in the Division of Fishes of the Vertebrate Zoology Collections found here: https://naturalhistory.si.edu/research/vertebrate-zoology/fishes
- Information on how to request access to these samples can be found here: https://naturalhistory.si.edu/research/vertebrate-zoology/fishes/collections-access/specimen-loans

Selected coral and sponge specimens were split; one aliquot was sent to the Bernice Pauahi Bishop Museum (BM) (https://www.bishopmuseum.org/collections-3/invertebrate-zoology/) and another sent to the USNM. If it had been determined that splitting would be too destructive to a particular specimen, it was provided to the USNM intact in order to provide public access to as many researchers as possible.

An additional small tissue sample for genetic analysis was taken of corals, sponges, and all other specimens when doing so would not effectively destroy the specimen. This tissue sample was preserved for later genomic DNA extraction at the OGL Center at Northeastern University (https://www.northeastern.edu/ogl/). Information on how to request access to these results and any remaining DNA samples can be found at: https://www.northeastern.edu/ogl/request-2/.

All geological samples collected during NOAA Ship *Okeanos Explorer* expeditions were sent to the Marine Geology Repository (MGR) at OSU (http://osu-mgr.org/noaa-ex/) where they were described from a petrology perspective (e.g. mineral content, texture, alteration, rock type), photographed, and made publicly accessible. The repository provides photographs (including microphotographs) and online metadata information about each geological specimen. Information on how to request access to these geological samples can be found here: http://osu-mgr.org/request-samples/.

An additional small tissue sample for genetic analysis was taken of corals, sponges, and all other specimens when doing so would not effectively destroy the specimen. This tissue sample was preserved for later genomic DNA extraction at the OGL Center at Northeastern University (https://www.northeastern.edu/ogl/). Information on how to request access to these results and any remaining DNA samples can be found at: https://www.northeastern.edu/ogl/order/.

7.4 Video Data

NOAA Ship *Okeanos Explorer* video data are publicly available shortly after each expedition. Highlight videos and still images can be found on the OER website at https://oceanexplorer.noaa.gov/okeanos/explorations/ex1603/welcome.html. Additionally, expedition video data can be found using the OER Video Portal at https://www.nodc.noaa.gov/oer/video/.

7.5 Environmental and Tracking Data

The *D2* environmental data collected during each dive were provided to the OER archive as raw Seabird HEX files. The *D2* tracking data were exported from Tracklink as text files. In order to make these data types more accessible to interested researchers, the science team processed all CTD and tracking data and merged them together in comma-separated values (CSV) files. These files were provided to both OER and NOAA's Deep Sea Coral Research and Technology Program (DSCRTP) for distribution.

7.6 Eventlog

During ROV dives, participating researchers communicated between ship and shore using the Eventlog. The Eventlog is a persistent chat room where all comments, discussions, and requests are logged and provided a UTC timestamp that can later be correlated to the operations, location, and data feeds collected by the ship. The chat server facilitated the first-order annotation of cruise activities, serving as a digital version of scientists' daily logs and enabling input from multiple users. Eventlog users were encouraged to use codes, which were three to five letter shorthand codes that were used to standardize and speed up the recording of observations in the Eventlog.

7.7 Survey of Opportunity Data

During the EX-16-03 expedition, data were collected for the National Aeronautics and Space Administration (NASA) led, long-term Maritime Aerosol Network (MAN) research effort. Mission personnel made observations (as time allowed) with a sun photometer instrument provided by the NASA MAN program. Resulting data were delivered to the NASA MAN primary investigator Alexander Smirnov by the expedition coordinator. All collected data were archived and made publically available at:
http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html

The full survey of opportunity description is available in **Appendix E** of this report.

8. Conclusion

EX-16-03 provided a great depth of baseline data and information to support the management and science needs of the Monument. Noteworthy highlights include:

- A total of eight ROV dives were conducted between Mokumanamana (or Necker) Island and an unnamed seamount southwest of Castellano Seamount, for a total of 40:55 h of bottom time and linear survey distance of 4.85 km. ROV surveys were performed at depths ranging between 648-4,292 m, including some of the deepest dives ever conducted in the Hawaiian Archipelago.
- High-density biological communities were documented at six of the eight surveyed dive sites. Overall, these findings support the hypothesis that high-density communities form over ridges and other steep topography. Additionally, high-density communities were found throughout the oxygen minimum layer (800-1000 m), as well as in waters approaching 4,000 m. The latter represents by far the deepest high-density community documented in the region, almost doubling the previous depth record. Collectively, these observations suggest that high-density communities are a lot more widespread than previously thought.
- A total of 34 specimens were collected including 14 geological samples, 13 biological samples and seven commensal organisms. The 13 biological specimens were all collected because they represent either new species or new records for the region. Future laboratory analyses of the rock samples will provide important insights into the geologic history of the features they were collected from.
- A total of 249 different types of organisms were identified from visual surveys, the majority of which represent undescribed species, thus highlighting the need for future taxonomic work in the region.
- High-resolution bathymetry data was generated for over 31,000 km^2 of ocean seafloor, including five seamounts in the NWHI that had not been previously mapped.
- One ROV dive was conducted to support the ECS project, during which two geological samples were collected that will provide insights into whether there is a connection between Mokumanamana (or Necker) Island and Necker Ridge.
- A total of 26 scientists and students participated on the expedition a regular basis, including participants from the U.S., Japan, Canada, Russia, and the Netherlands.
- Live video feeds broadcast over the Internet garnered over 125,000 views throughout the expedition. Additionally, live feeds were continuously streamed throughout the expedition at the Maui Ocean Center, the Waikiki Aquarium, and the Mokupāpapa Discovery Center.
- The expedition was the focus of over 600 media stories and NOAA received a total of 22 media inquiries throughout the expedition.
- Prior to the expedition the science leads were interviewed live for HPR’s talk shows *The Conversation* and *Bytemarks Café*.

- Over 70 educators—including participants from the U.S., American Samoa, Guam, Germany, Portugal, and Brazil—attended the education webinars conducted prior to the expedition.
- The expedition team participated in a Reddit AMA session and answered close to 70 questions. Over 3,200 individual viewers visited the AMA session.

9. Clearances and Permits

Expedition EX-16-03 was conducted under the Scientific Research Permit PMNM-2015-018 issued to OER and Kelley Elliott. The same permit was also used during the EX-15-04-L2 expedition to the PMNM in 2015. Permit PMNM-2015-025 was issued to CDR Mark Wetzler to conduct work in the PMNM. The permit was issued by the Co-Trustees of the PMNM Management Board and was effective for the period between July 1, 2015, and June 30, 2016. Additionally, a permit to conduct research in the Marshall Islands, Diplomatic Note No. 15-105, was issued. The permits for this expedition are located in Project Instructions for EX-16-03 (Kennedy, 2016).

In order to support or conduct Marine Scientific Research within the U.S. exclusive economic zone (EEZ), work funded, authorized, and/or conducted by NOAA must be compliant with the National Environmental Policy Act (NEPA). The NOAA Administrative Order (NAO) 216-6A Companion Manual (https://www.nepa.noaa.gov/docs/NOAA-NAO-216-6A-Companion-Manual-03012018.pdf) describes NOAA's specific obligations with regard to NEPA compliance. Among these is the need to review all NOAA-supported projects with respect to their environmental consequences. In compliance with NAO 216-6 and NEPA, a memorandum describing the project's scientific sensors' possible effects on the environment has been submitted for the project. As expected with ocean research with limited time or presence in the marine environment, the project has been determined to not have the potential to result in any lasting changes to the environment. As defined in Sections 5.05 and 6.03.c.3 (a) of NAO 216-6, this is a research project of limited size or magnitude or with only short-term effects on the environment and for which any cumulative effects are negligible, and, as such, the project is categorically excluded from the need to prepare a full-scale NEPA environmental assessment. The categorical exclusion met the requirements of NAO 216-6 and NEPA, and authorizes the Marine Scientific Research conducted for the project. The NEPA categorical exclusion letter—used for both this expedition and the 2015 expedition—is located in Project Instructions for EX-16-03 (Kennedy, 2016).

Prior to EX-15-04-L2, OER also completed an informal consultation with NOAA's National Marine Fisheries Service (NMFS) under Section 7 of the Endangered Species Act (ESA) of 1973 that addressed the potential impacts of NOAA Ship *Okeanos Explorer*'s activities on ESA-listed species and critical habitat within the operating area. A letter of concurrence (LOC) was received from NMFS on July 7, 2015, concurring with OER's determination that the activities of the expeditions would not adversely affect ESA-listed marine species, and would have insignificant effects on designated or proposed critical habitat. The LOC—used for both this expedition and the 2015 expedition—is located in Project Instructions for EX-16-03 (Kennedy, 2016).

10. Acknowledgements

The execution of the EX-16-03 expedition—and its many scientific accomplishments—is the product of teamwork between many collaborators, including both ship-based and shore-based personnel. Special thanks to the Expedition Coordinator, Brian Kennedy, for his relentless efforts in planning, coordinating, and overseeing all aspects of the mission. The spectacular seafloor images captured during the expedition would not have been possible without the exceptional talent, dedication, and passionate work by the ROV team (Karl McLetchie, Bobby Mohr, Jim Newman, Chris Ritter, Jeff Lanning, Joshua Carlson, Dan Rogers, Sean Kennison, Levi Unema, and Andy Lister) and video engineers (Roland Brien, Tara Smithee, Arthur Howard, and Eddie McNicol). Many thanks for all the hard work by the mapping team (Mashkoor Malik, Jason Meyer, and Bill Potts), whose mapping efforts provided a great wealth of information that not only supported the mission, but will also be invaluable to future work in the region. Andy O'Brien and Katherine Woodard provided exceptional support in managing the large amount of data and specimens collected during the expedition. The NOAA Ship *Okeanos Explorer*'s Commanding Officer, Mark Wetzler, and his crew (James Brinkley, Randy Collins, Fiona Matheson, Bryan Brasher, Bryan Prestone, Vincent Palazzolo, Jerrod Hazendorf, Rick Gabona, Kevin Lackey, Abraham McDowell, Dave Blessing, Mike Sapien, Rainier Capati, Kyle Fredericks, Nicky Applewhite, Will Johnson, Pedro Lebron, Mike Collins, Keith Speights, and William Sparks) exhibited superb skills and uttermost professionalism throughout the expedition. A hard-working, shore-based operation team—consisting of Nick Pawlenko, Kasey Cantwell, Catalina Martinez, Emily Crum, and Katie Wagner—further supported the mission. Additional support was provided by a large number of shore-based scientists and supporters, who contributed a great amount of information, expertise, and guidance throughout the expedition. Special thanks to Chris Kelley, Scott France, Bruce Mundy, Mary Wicksten, Andrea Quatrini, Tina Molodtsova, Michael Vecchione, Amy Baco-Taylor, Asako Matsumoto, Les Watling, Brian Boston, Patricia Fryer, Brendan Roark, Santiago Herrera, Randy Kosaki, Allen Andrews, Frank Parrish, Michael Parke, Thomas Hourigan, Deborah Glickson, Michael Garcia, Dave Jourdan, King Spencer, Ken Sulak, Randy Singer, Jeff Drazen, Diva Amon, Nicole Morgan, Lindsay Dhugal, Rich Mooi, Erik Cordes, Toni Parras, David Graham, Andy Collins, David Lovalvo, Samantha Brooke, Heidi Hirsh, Smith Sallie, Daniel Warren, and Kristen Mello for their valuable contributions.

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12. Appendices

Appendix A: Data Management Plan

Data Management Plan
Okeanos Explorer (EX1603): Hohonu Moana:
Exploring the Deep Waters off Hawai`I

OER Data Management Objectives

Continue integration and testing of telestream pipeline capture system; work with Telestream developers to resolve abortive captures; integrate audio into telestream video capture; transfer functionality from the old data warehouse to the new one; ensure successful transfer of data warehouse functionality (public hosting, dashboard, data consolidation, data processing) from legacy dell system to new replacement.

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1. General Description of Data to be Managed

1.1 Name and Purpose of the Data Collection Project

Okeanos Explorer (EX1603): Hohonu Moana: Exploring the Deep Waters off Hawai`I

1.2 Summary description of the data to be collected.

The ship will conduct 24 hour operations consisting of daytime ROV dives and evening/nighttime mapping operations including during transit. During this cruise we will conduct primarily 8 hour ROV dives with occasional 10 or 12 hour dives on particularly interesting or deep water dive sites, as staffing allows. ROV operations will focus in depths between 250 and 6,000 meters and will include high-resolution visual surveys and limited sample collection. Mapping operations will be conducted in 250m of water and deeper, and include transit and overnight multibeam, water column backscatter, and sub-bottom data collection. Opportunistic CTD rosette operations may be requested to collect more information about the environmental parameters at ROV dives sites, or opportunistically at selected sites where collecting the data is considered important to understanding the physical or chemical properties of the overlying water column. ROV and mapping operations will not be conducted in state waters.

1.3 Keywords or phrases that could be used to enable users to find the data.

expedition, exploration, explorer, marine education, noaa, ocean, ocean discovery, ocean education, ocean exploration, ocean exploration and research, ocean literacy, ocean research, OER, science, scientific mission, scientific research, sea, stewardship, systematic exploration, technology, transformational research, undersea, underwater, Davisville, mapping survey, multibeam, multibeam backscatter, multibeam sonar, multi-beam sonar, noaa fleet, okeanos, okeanos explorer, R337, Rhode Island, scientific computing system, SCS, single beam sonar, singlebeam sonar, single-beam sonar, sub-bottom profile, water column backscatter, archaeological, archaeology, conservation, conserve, crm, cultural resource management, historic, marine archaeology, maritime, maritime archaeology, nautical, nautical archaeology, preserve, protect, protection, submerged cultural heritage, submerged cultural resource, uch, underwater cultural heritage, oceans, Battle of Midway, World War II, Japanese Aircraft Carrier Kaga, Kwajelein, Marshall Islands, Midway Islands, Papahanaumokuakea Marine National Monument, PMNM, Hawaiian Archipelago, Northwest Hawaiian Islands, CAPSTONE, Middle Bank, deepwater corals, deepwater sponges, manganese crust habitats

1.4 If this mission is part of a series of missions, what is the series name?

Okeanos ROV Cruises

Okeanos Explorer (EX1603): Hohonu Moana: Exploring the Deep Waters off Hawai`I

1.5 Planned or actual temporal coverage of the data.

Dates: 2/23/2016 to 3/18/2016

1.6 Planned or actual geographic coverage of the data.

Latitude Boundaries: 8.26 to 30.83

Longitude Boundaries: 167.4 to -157.9

1.7 What data types will you be creating or capturing and submitting for archive?

Sub-Bottom Profile data, Water Column Backscatter, XBT (raw), Cruise Plan, Cruise Summary, Data Management Plan, Highlight Images, Quick Look Report, Bottom Backscatter, Dive Summaries, EK60 Singlebeam Data, ADCP, Expedition Cruise Report, Highlight Video, Images, Multibeam (image), Multibeam (processed), Multibeam (product), Multibeam (raw), NetCDF, Raw Video (digital), Sample Logs, SCS Output (compressed), SCS Output (native)

1.8 What platforms will be employed during this mission?

NOAA Ship Okeanos Explorer, Deep Discoverer ROV, SEIRIOS Camera Sled

2. Point of Contact for this Data Producing Project

Overall POC:	Brian Kennedy
Title:	Expedition Coordinator
Affiliation/Dept:	NOAA Office of Ocean Exploration and Research
E-Mail:	brian.kennedy@noaa.gov
Phone:	401-874-6150

3. Point of Contact for Managing the Data

Data POC Name:	Susan Gottfried
Title:	OER Data Management Coordinator
E-Mail:	susan.gottfried@noaa.gov

4. Resources

4.1 Have resources for management of these data been identified? True

4.2 Approximate percentage of the budget devoted to data management. (specify % or "unknown")

unknown

5. Data Lineage and Quality

5.1 What is the processing workflow from collection to public release?

SCS data shall be delivered in its native format as well as an archive-ready, documented, and compressed NetCDF3 format to NCEI-MD; multibeam data and metadata will be compressed and delivered in a bagit format to NCEI-CO.

5.2 What quality control procedures will be employed?

Quality control procedures for the data from the Kongsberg EM302 is handled at UNH CCOM/JHC. Raw (level-0) bathymetry files are cleaned/edited into new data files (level-1) and converted to a variety of products (level-2). Data from sensors monitored through the SCS are archived in their native format and are not quality controlled. Data from CTD casts and XBT firings are archived in their native format and are not quality controlled. CTDs are processed into profiles for display only on the Okeanos Atlas.

6. Data Documentation

6.1 Does the metadata comply with the Data Documentation Directive? True

6.1.1 If metadata are non-existent or non-compliant, please explain:

6.2 Where will the metadata be hosted?

Organization: An ISO format collection-level metadata record will be generated during pre-cruise planning and published in an OER catalog and Web Accessible Folder (WAF) hosted at NCEI-MS for public discovery and access. The record will be harvested by data.gov.

URL: www.ncddc.noaa.gov/oer-waf/ISO/Resolved/2016/

Meta Std: ISO 19115-2 Geographic Information with Extensions for Imagery and Gridded Data will be the metadata standard employed; a NetCDF3 standard for oceanographic data will be employed for the SCS data; the Library of Congress standard, MAchine Readable Catalog (MARC), will be employed for NOAA Central Library records.

6.3 Process for producing and maintaining metadata:

Metadata will be generated via xml editors or metadata generation tools.

7. Data Access

7.1 Do the data comply with the Data Access Directive? True

7.1.1 If the data will not be available to the public, or with limitations, provide a valid reason.

Not Applicable

7.1.2 If there are limitations, describe how data are protected from unauthorized access.

Account access to mission systems are maintained and controlled by the Program. Data access prior to public accessibility is documented through the use of Data Request forms and standard operating procedures.

7.2 Name and URL of organization or facility providing data access.

Org: National Centers for Environmental Information

URL: explore.noaa.gov/digitalatlas

7.3 Approximate delay between data collection and dissemination. By what authority?

Hold Time: data are made available as soon as possible after the mission end

Authority:

7.4 Prepare a Data Access Statement

No data access constraints, unless data are protected under the National Historic Preservation Act of 1966.

8. Data Preservation and Protection

8.1 Actual or planned long-term data archive location:

Data from this mission will be preserved and stewarded through the NOAA National Centers for Environmental Information. Refer to the Okeanos Explorer FY16 Data Management Plan at NOAA's EDMC DMP Repository (EX_FY16_DMP_Final.pdf) for detailed descriptions of the processes, procedures, and partners involved in this collaborative effort.

8.2 If no archive planned, why?

8.3 If any delay between data collection and submission to an archive facility, please explain.

8.4 How will data be protected from accidental or malicious modification or deletion?

Data management standard operating procedures minimizing accidental or malicious modification or deletion are in place aboard the Okeanos Explorer and will be enforced.

8.5 Prepare a Data Use Statement

Data use shall be credited to NOAA Office of Ocean Exploration and Research.

Appendix B: EX-16-03 Participants

Participation on EX-16-03 involved 21 at-sea mission personnel (**Table 6**) and 86 shoreside scientists (**Table 7**) engaging either by audio commentary or instant messaging vie the expedition chat room on a regular basis. At-sea personnel included the expedition coordinator, mapping specialists, ROV engineers, video engineers, data specialists, and on-board scientists. Shore-based science team members participated from remote ECCs and from their home locations. Lists of these participants are provided in the tables below. In addition to these participants, all NOAA Ship *Okeanos Explorer* expeditions are made possible with the work of the ship's dedicated crew, and the work of the shoreside operations team.

Table 6. *EX-16-03 At-sea Mission Personnel*

Name	Role	Affiliation
Kennedy, Brian	Expedition Coordinator	NOAA OER University Corporation for Atmospheric Research (UCAR)
Malik, Mashkoor	Mapping Lead	NOAA OER
Meyers, Jason	Mapping Watch Lead	UCAR
Wagner, Daniel	Science Team Lead	NOAA National Ocean Service (NOS)
Tree, Jonathan	Science Co-Lead	UH
McLetchie, Karl	ROV Dive Supervisor	UCAR/Global Foundation for Ocean Exploration (GFOE)
Carlson, Joshua	ROV Engineer	UCAR/GFOE
Kennison, Sean	ROV Engineer	UCAR/GFOE
Lanning, Jeff	ROV Engineer	UCAR/GFOE
Lister, Andy	ROV Engineer	UCAR/GFOE
Mohr, Bobby	ROV Engineer	UCSR/GFOE
Newman, Jim	ROV Engineer	UCAR/GFOE
Ritter, Chris	ROV Engineer	UCAR/GFOE
Rogers, Dan	ROV Engineer	UCAR/GFOE
Unema, Levi	ROV Engineer	UCAR/GFOE
Brian, Roland	Video Engineer	UCAR/GFOE

Howard, Art	Video Engineer	UCAR/GFOE
McNichol, Ed	Video Engineer	UCAR/GFOE
Smithee, Tara	Video Engineer	UCAR/GFOE
O'Brien, Andy	Data Manager	UCAR/GFOE
Woodard, Katherine	Sample Data Manager	General Dynamics Information Technology (GDIT)

Table 7. *EX-16-03 Shore-based Science Team*

Name	**Affiliation**	**Email**
Robert Allhouse	UUV Project Engineer	
Diva Amon	UH	divaamon@hawaii.edu
Allen Andrews	IRC, Pacific Islands Fisheries Science Center (PIFSC)	Allen.Andrews@noaa.gov
Steve Auscavitch	Temple University	steven.auscavitch@temple.edu
James Austin	University of Texas/Austin	
Amy Baco-Taylor	HBOI, Florida State University (FSU)	abacotaylor@fsu.edu
Roderick Blocksome	Nauticos, LLC	
Brian Boston	UH	
Samantha Brooke	NOAA	
Tamara Burke	Tami Kennedy & Associates	
Stephen Cairns	USNM	
Dwight Coleman	University of Rhode Island, Graduate School of Oceanography (URI, GSO)/Inner Space Center (ISC)	
Erik Cordes	Temple University	
Jennifer Crosby	Center for Coastal and Ocean Mapping (CCOM)	

Melanie Damour	Bureau of Ocean Energy Management (BOEM)	
James D'Angelo	International Midway Memorial Foundation	
Alex DeCiccio	ISC	
Matt Dornback	NOAA	
Jeff Drazen	UH	jdrazen@hawaii.edu
Norman Estabrook	SEAWORD	
Peter Etnoyer	NOAA National Centers for Coastal Ocean Science (NCCOS)	
Tsao Fan	NOAA	
Benjamin Frable	Scripps Institution of Oceanography (SIO)	
Scott France	University of Louisiana at Lafayette (ULL)	france@louisiana.edu
Patricia Fryer	UH	
Mackenzie Garringer	UH	mgerring@hawaii.edu
Deborah Glickson	Florida Atlantic University (FAU) Harbor Branch Oceanographic Institute (HBOI)	
Maria Grenchik	Nauticos, LLC	
Santiago Herrera	University of Toronto & Woods Hole Oceanographic Institute (WHOI)	sherrera@alum.mit.edu
Heidi Hirsh	NOAA NMFS	
Thomas Hourigan	NOAA DSCRTP	
Robert Humphreys	NOAA NMFS	
Jack Irion	BOEM	
Jennifer James	Nauticos, LLC/Sea World	

David Jourdan	Nauticos, LLC	
Kevin Jerram	UNH CCOM	
Kelly Keogh	NOAA PMNM	
Spencer King	Nauticos, LLC	
Astrid Leitner	UH	aleitner@hawaii.edu
Lisa Levin	SIO	
Megan Lickliter-Mundon	NOAA/Texas A&M University (TAMU)	
Dhugal Lindsay	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	
Susan Loricchio	Nauticos, LLC	
Christopher Mah	USNM	brisinga@gmail.com
Jim Masterson	FAU/HBOI	
Asako Matsumoto	Planetary Exploration Research Center/Chiba Institute of Technology (PERC/CIT)	amatsu@gorgonian.jp
Russ Matthews	Edward E and Marie L Matthews Foundation	
Robert McGuinn	NOAA	
Jennifer McKinnon	East Carolina University	
Kristen Mello	CCOM	
Mary Miller	Exploratorium	
Tina Molodtsova	P.P. Shirshow Institute of Oceanology	tina@ocean.ru
Rich Mooi	California Academy of Sciences	
Holly Morin	URI, GSO/ISC	

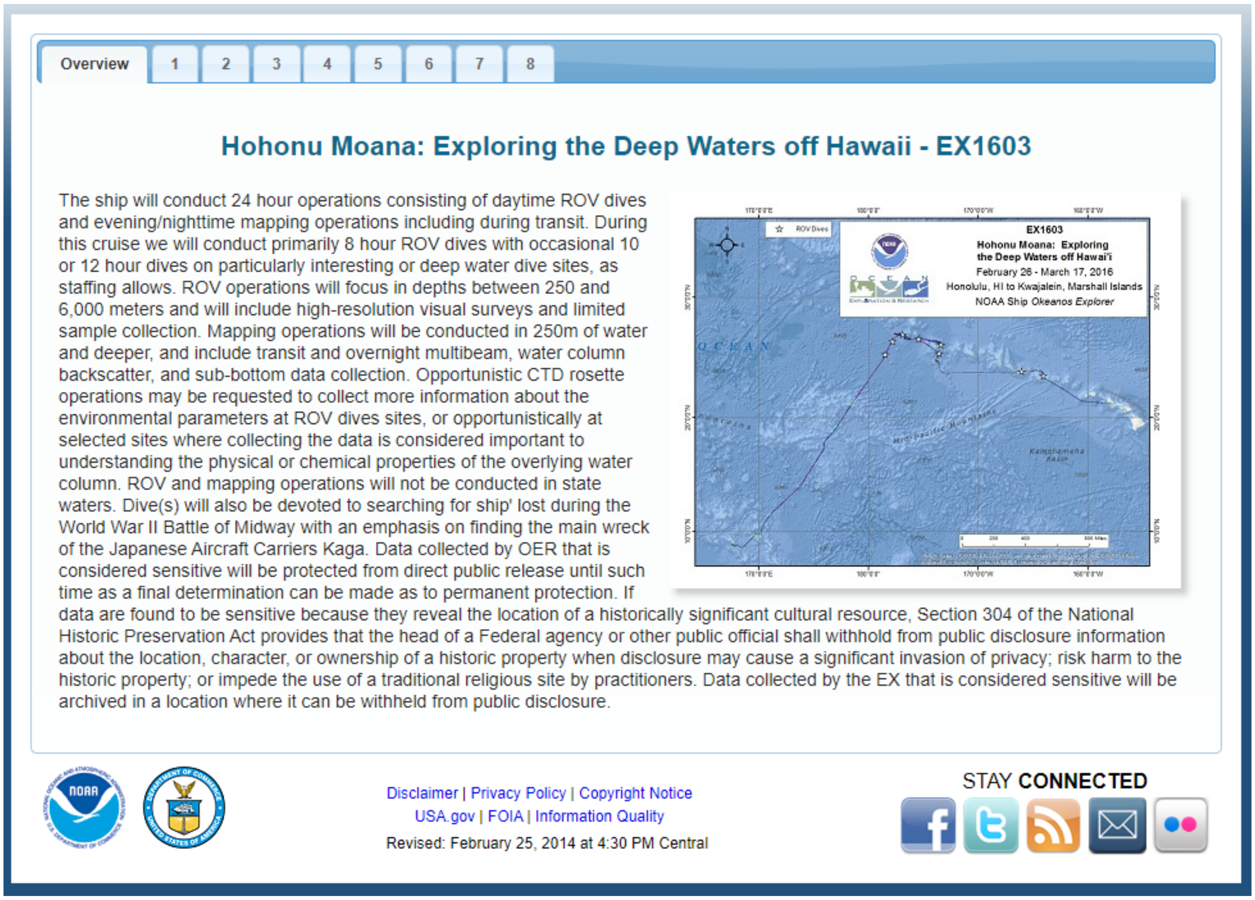
Nicole Morgan	FSU, HBOI	nbmorgan11@gmail.com
Hassan Moustahfid	NOAA U.S. Integrated Ocean Observing System (IOOS)	
Bruce Mundy	NOAA IRC	bruce.mundy@noaa.gov
Jim Noone	International Midway Memorial Foundation	
Risa Oram	NOAA PIFSC	
Jerry Ostermiller	Oregon Heritage Commission	
Michael Parke	NOAA IRC	Michael.Parke@noaa.gov
Toni Parras	NOAA PMNM	
Frank Parrish	NOAA NMFS Protected Resources Division (PRD)	Frank.Parrish@noaa.gov
Jonathan Parshall	Nauticos, LLC	
Brendan Roark	TAMU, Corpus Christi	broark@geos.tamu.edu
Christine Rodriguez	CGR Strategic Communications	
Richard Rogers	MAS	
Kenneth Rubin	UH	
Bruce Sarsfield	Conidae Marine, Inc.	
Leslie Sautter	College of Charleston	
Lonnie Schorer	The International Group for Historic Aircraft Recovery (TIGHAR)	
Tim Shank	WHOI	tshank@whoi.edu
Randal Singer	Florida Museum of Natural History (FLMNH)	rsinger@flmnh.ufl.edu
Jennifer Smith	SIO	

John R Smith	UH	jrsmith@hawaii.edu
Sallie Smith	Nauticos, LLC	
Adam Soule	Woods Hole Oceanographic Institute (WHOI)	
Evan Sutton	Nauticos, LLC	
Lindsay Veazey	UH	
Michael Vecchione	USNM/NMFS	VECCHIOM@si.edu
Thomas Vinson	Nauticos, LLC	
Les Watling	UH	watling@hawaii.edu
Daniel Warren	Oceaneering	
Mary Wicksten	TAMU	wicksten@bio.tamu.edu
Amanda Ziegler	UH	aziegler802@gmail.com
Victor Zykov	Schmidt Ocean Institute (SOI)	

Appendix C: ROV Dive Summaries

To view and download the full Dive Summaries and the accompanying data for each dive (**Fig. 8**), please visit: https://service.ncddc.noaa.gov/rdn/oer-rov-cruises/ex1603

Figure 8. *A screenshot of the EX-16-03 Dive Summaries overview page.*



The ship will conduct 24 hour operations consisting of daytime ROV dives and evening/nighttime mapping operations including during transit. During this cruise we will conduct primarily 8 hour ROV dives with occasional 10 or 12 hour dives on particularly interesting or deep water dive sites, as staffing allows. ROV operations will focus in depths between 250 and 6,000 meters and will include high-resolution visual surveys and limited sample collection. Mapping operations will be conducted in 250m of water and deeper, and include transit and overnight multibeam, water column backscatter, and sub-bottom data collection. Opportunistic CTD rosette operations may be requested to collect more information about the environmental parameters at ROV dives sites, or opportunistically at selected sites where collecting the data is considered important to understanding the physical or chemical properties of the overlying water column. ROV and mapping operations will not be conducted in state waters. Dive(s) will also be devoted to searching for ship' lost during the World War II Battle of Midway with an emphasis on finding the main wreck of the Japanese Aircraft Carriers Kaga. Data collected by OER that is considered sensitive will be protected from direct public release until such time as a final determination can be made as to permanent protection. If data are found to be sensitive because they reveal the location of a historically significant cultural resource, Section 304 of the National Historic Preservation Act provides that the head of a Federal agency or other public official shall withhold from public disclosure information about the location, character, or ownership of a historic property when disclosure may cause a significant invasion of privacy; risk harm to the historic property; or impede the use of a traditional religious site by practitioners. Data collected by the EX that is considered sensitive will be archived in a location where it can be withheld from public disclosure.

Appendix D: Animals Observed

Animals observed during the eight ROV seafloor surveys of the expedition (**Table 8**). Note that all field identifications from video surveys should be considered provisional until they are confirmed by a taxonomic authority.

Table 8. *Animals Observed During EX-16-03.*

Phylum	Group	Lowest Identification	Dive No.
Anellida	Anellida	Polychaeta	1,2,8
Anellida	Polychaetes	Polynoidae	3,5,6,7
Anellida	Polychaetes	Sabellida	4,5,7
Arthropod	Crab	*Cyrtomania smithi*	6
Arthropod	Crab	Paguridae	2
Arthropod	Crab	*Strobopagurus* cf. *gracilipes*	4
Arthropod	Crab	Unidentified crab	6
Arthropods	Amphipod	Caprellidae	7
Arthropods	Barnacles	Balanidae	3,8
Arthropods	Barnacles	Scalpellidae	2,5,6,8
Arthropods	Polychelid	*Homeryon asper*	7
Arthropods	Pycnogonid	Colossendeidae	4,5
Arthropods	Shrimp	*Acanthephyra eximia*	6
Arthropods	Shrimp	Amphipoda	3
Arthropods	Shrimp	Aristeidae	6
Arthropods	Shrimp	?*Aristopenaeus* sp.	1
Arthropods	Shrimp	*Bathypalaemonella* sp.	4,6
Arthropods	Shrimp	*Heterocarpus laevigatus*	2,6
Arthropods	Shrimp	*Lebbeus* sp.	3,7,8
Arthropods	Shrimp	Mysida	2,3,6
Arthropods	Shrimp	Unidentified red shrimp	1,2,3,4,5
Arthropods	Squat lobsters	Chirostyloidae	2
Arthropods	Squat lobsters	*Gastroptychus* sp. *iaspis*	4,6,7
Arthropods	Squat lobsters	*Gastroptychus*/new genus	5
Arthropods	Squat lobsters	*Munida* sp.	6
Arthropods	Squat lobsters	*Munidopsis* cf. *albatrossae*	8
Arthropods	Squat lobsters	*Munidopsis* sp.	3,4,6,8
Arthropods	Squat lobsters	?*Pseudomunida fragilis*	2
Arthropods	Squat lobsters	*Pseudomunida* sp.	6
Arthropods	Squat lobsters	*Uroptychus* sp.	3,4,6,7
Bryozoans	Bryozoan	Bryozoan	3
Cnidarians	Actiniarians	*Actinoscyphia* sp.	2,6
Cnidarians	Actiniarians	Actinostolidae	3
Cnidarians	Actiniarians	*Exocoelactis* sp.	2,3,4,5,6
Cnidarians	Actiniarians	*Liponema* sp.	6
Cnidarians	Actiniarians	*Phelliactis* sp.	2,4,5,6,7
Cnidarians	Actiniarians	*Relacanthis* sp.	2,4,6

Phylum	Group	Lowest Identification	Dive No.
Cnidarians	Actiniarians	Unidentifed anemones	1,5,8
Cnidarians	Alcyonaceans	*Anthomastus* sp.	2,4,5,6,7
Cnidarians	Alcyonaceans	*Pseudoanthomastus* sp.	6
Cnidarians	Antipatharians	*Bathypathes alternata*	3,8
Cnidarians	Antipatharians	*Bathypathes* cf. *alternata*	2,3,5
Cnidarians	Antipatharians	*Bathypathes conferta*	3
Cnidarians	Antipatharians	*Bathypathes patula*	8
Cnidarians	Antipatharians	*Bathypathes* sp.	4,5,8
Cnidarians	Antipatharians	*Hexapathes* sp.	5
Cnidarians	Antipatharians	*Parantipathes* cf. *euantha*	3
Cnidarians	Antipatharians	*Stauropathes staurocrada*	2
Cnidarians	Antipatharians	*Stichopathes* sp.	5
Cnidarians	Antipatharians	*Trissopathes tetracrada*	2,3,5
Cnidarians	Ceriantharian	Ceriantharia	2,4,5,6
Cnidarians	Corallimorpharian	Corallimopharia	4,7
Cnidarians	Gorgonians	?*Acanella weberi*	7
Cnidarians	Gorgonians	*Acanthogorgia* sp.	2,6
Cnidarians	Gorgonians	*Bathygorgia* cf. *tasmaniensis*	8
Cnidarians	Gorgonians	*Bathygorgia* sp.	1,5,8
Cnidarians	Gorgonians	?*Calyptrophora angularis*	8
Cnidarians	Gorgonians	*Calyptrophora wyvellei*	2,4,6
Cnidarians	Gorgonians	?*Calyptrophora* sp.	6
Cnidarians	Gorgonians	?*Candidella gigantea*	7
Cnidarians	Gorgonians	*Candidella helminthophora*	7
Cnidarians	Gorgonians	*Chrysogorgia* cf. *pinnata*	8
Cnidarians	Gorgonians	*Chrysogorgia chryseis*	3,7
Cnidarians	Gorgonians	*Chrysogorgia flavescens*	3,5
Cnidarians	Gorgonians	*Chrysogorgia geniculata*	2,3,4,6,7
Cnidarians	Gorgonians	*Chrysogorgia* sp.	3,8
Cnidarians	Gorgonians	*Chrysogorgia* sp. (branched)	3,7,8
Cnidarians	Gorgonians	*Chrysogorgia* sp. (planar)	1,2
Cnidarians	Gorgonians	*Chrysogorgia* sp. (saddlebags)	3
Cnidarians	Gorgonians	*Chrysogorgia stellata*	2,4,6,7
Cnidarians	Gorgonians	*Chrysogorgia tricaulis*	7
Cnidarians	Gorgonians	?*Eknomisis* sp. (unbranched)	5
Cnidarians	Gorgonians	*Hemicorallium abyssale*	2
Cnidarians	Gorgonians	*Hemicorallium* sp.	3,4,6,7
Cnidarians	Gorgonians	*Iridogorgia bella*	6
Cnidarians	Gorgonians	*Iridogorgia magnispiralis*	3,5,6,7,8
Cnidarians	Gorgonians	*Iridogorgia* sp.	4
Cnidarians	Gorgonians	*Isidella* sp. (lyrate)	5,7,8
Cnidarians	Gorgonians	*Isidella trichotoma*	7
Cnidarians	Gorgonians	?*Isidella* sp.	1
Cnidarians	Gorgonians	*Jasonisis* sp.	3
Cnidarians	Gorgonians	*Jasonisis* sp.	6
Cnidarians	Gorgonians	Keratoisidinae	5

Phylum	Group	Lowest Identification	Dive No.
Cnidarians	Gorgonians	Keratoisidinae D-clade	3
Cnidarians	Gorgonians	Keratoisidinae (sparsely branched)	7
Cnidarians	Gorgonians	Keratoisinae (nodal sparse)	3
Cnidarians	Gorgonians	*Keratoisis* sp.	7
Cnidarians	Gorgonians	*Lepidisis* sp.	4,5,7
Cnidarians	Gorgonians	*Metallogorgia melanotrichos*	2,3,5,6
Cnidarians	Gorgonians	?*Narella bowersi*	3
Cnidarians	Gorgonians	*Narella dichotoma*	2,4,6,7
Cnidarians	Gorgonians	?*Narella macrocalyx*	3
Cnidarians	Gorgonians	*Narella* sp.	2,3,4,6,7
Cnidarians	Gorgonians	*Paracalyptrophora* sp.	7
Cnidarians	Gorgonians	*Paragorgia* sp.	3,4,5,6,7
Cnidarians	Gorgonians	*Paramuricea* sp.	2,4
Cnidarians	Gorgonians	*Pleurocorallium* sp.	3
Cnidarians	Gorgonians	*Pleurogorgia militaris*	3
Cnidarians	Gorgonians	*Pleurogorgia* sp.	8
Cnidarians	Gorgonians	Plexauridae	2,4,5,6
Cnidarians	Gorgonians	Primnoidae	2,4,8
Cnidarians	Gorgonians	*Rhodanirigorgia* sp.	7
Cnidarians	Gorgonians	Isididae (unbranched)	2,6,7,8
Cnidarians	Gorgonians	Primnoidae (unbranched)	7,8
Cnidarians	Gorgonians	*Victorgorgia nuttingi*	2,4,5,6
Cnidarians	Hydrozoans	*Aegina* sp.	5
Cnidarians	Hydrozoans	Corymorphidae	3,4,5
Cnidarians	Hydrozoans	Hydroidolina	2,3,4,5,7
Cnidarians	Hydrozoans	Hydromedusae	6,7
Cnidarians	Hydrozoans	*Paraphyllina* sp.	4
Cnidarians	Hydrozoans	Siphonophorae	6
Cnidarians	Hydrozoans	Tabulariidae	2,3
Cnidarians	Pennatulaceans	*Anthoptilum* sp.	2,3,5,6,7
Cnidarians	Pennatulaceans	*Halipteris* sp.	6,7,8
Cnidarians	Pennatulaceans	?*Kophobelemnon* sp.	4
Cnidarians	Pennatulaceans	*Pennatula inflata*	6
Cnidarians	Pennatulaceans	*Pennatula* sp.	2
Cnidarians	Pennatulaceans	?*Protoptilum* sp.	2
Cnidarians	Pennatulaceans	*Umbellula* sp.	5
Cnidarians	Pennatulaceans	Unidentified seapen	8
Cnidarians	Scleractinians	*Balanophyllia* sp.	2
Cnidarians	Scleractinians	*Desmophyllum/Javania* sp.	3
Cnidarians	Scleractinians	*Enallopsammia rostrata*	6
Cnidarians	Scleractinians	Scleractinia (unidentified cup coral)	6
Cnidarians	Siphonophore	Rhodalidae	2
Cnidarians	Zoanthids	*Bullagummizoanthus emilyacadiaarum*	7
Cnidarians	Zoanthids	Parazoanthidae	4
Cnidarians	Zoanthids	Zoantharia overgrowing *Hyalonema (Corynonema)* sp.	2
Ctenophores	Ctenophores	Ctenophora (pelagic)	3

Phylum	Group	Lowest Identification	Dive No.
Ctenophores	Ctenophores	Platyctenidae	2,5
Echinoderms	Asteroids	?*Apollonaster kelleyi*	2,4
Echinoderms	Asteroids	*Asthenactis* sp.	6
Echinoderms	Asteroids	*Brisinga* sp.	5,6
Echinoderms	Asteroids	Brisingidae	5
Echinoderms	Asteroids	*Calliaster* sp.	2,5
Echinoderms	Asteroids	*Ceramaster* cf. *bowersi*	8
Echinoderms	Asteroids	*Circeaster arandae*	7
Echinoderms	Asteroids	*Evoplosoma* sp.	3
Echinoderms	Asteroids	*Henricia pauperrima*	3,6,7
Echinoderms	Asteroids	*Hymenaster* sp.	6
Echinoderms	Asteroids	*Hippasteria muscipula*	7
Echinoderms	Asteroids	*Mediaster* sp.	6
Echinoderms	Asteroids	*Mediaster* sp./*Gilbertaster* sp.	6
Echinoderms	Asteroids	*Novodonia* sp.	6
Echinoderms	Asteroids	*Pteraster reticulatus*	6
Echinoderms	Asteroids	*Pteraster* sp.	6
Echinoderms	Asteroids	Solasteridae	8
Echinoderms	Crinoids	Antedonidae	4,5,7
Echinoderms	Crinoids	*Atelocrinus* sp.	4
Echinoderms	Crinoids	Bathycrinidae	8
Echinoderms	Crinoids	Comatulidae	2,4,5,6,7,8
Echinoderms	Crinoids	*Glyptometra lateralis*	3,5,6,7
Echinoderms	Crinoids	*Glyptometra* sp.	4,8
Echinoderms	Crinoids	*Naumachocrinus* sp.	3
Echinoderms	Crinoids	*Sarametra triserialis*	3,5,7
Echinoderms	Crinoids	Crinoidea (stalked)	3,4
Echinoderms	Crinoids	Thaumacrinus	6
Echinoderms	Echinoderms	Elpidiidae	1
Echinoderms	Echinoderms	?*Psychropotes* sp.	1
Echinoderms	Holothurians	Deimatiidae	6
Echinoderms	Holothurians	*Hansenothuria benti*	2
Echinoderms	Holothurians	*Peniagone* sp./*Amperima* sp.	4
Echinoderms	Holothurians	Psychropotidae	3
Echinoderms	Holothurians	Synallactida	8
Echinoderms	Holothurians	Holothuroidea (unidentified)	3
Echinoderms	Ophiuroids	Asteroschematidae	2,4,6,7
Echinoderms	Ophiuroids	Gorgonocephalidae	4
Echinoderms	Ophiuroids	Ophiocanthidae	2,3,4,5,6,7,8
Echinoderms	Ophiuroids	Ophiuridae	2,3,4,5,6,7,8
Echinoderms	Urchin	*Aspidodiadema* cf. *hawaiiensis*	2,6
Echinoderms	Urchin	*Caenopedina* sp.	7
Echinoderms	Urchin	Echinothuriidae	6
Echinoderms	Urchin	*Echinus* sp.	6
Echinoderms	Urchin	*Sperosoma obscurum*	2,7
Echinoderms	Urchin	*Tromikosoma hispidus*	5

Phylum	Group	Lowest Identification	Dive No.
Fishes	Eels	Ilyophinae	4,6
Fishes	Eels	*Ilyophis* sp.	3
Fishes	Eels	*Nettastoma parviceps*	6
Fishes	Eels	*Synaphobranchus* sp. (?*affinis* or *kaupii*)	2,5
Fishes	Eels	*Synaphobranchus brevidorsalis*	3,5,7
Fishes	Eels	*Synaphobranchus* sp.	2,6,7
Fishes	Halosauridae	*Aldrovandia phalacra*	6
Fishes	Halosauridae	*Aldrovandia* sp.	2,6
Fishes	Halosauridae	*Halosauropsis* sp.	4
Fishes	Macrourids	*Bassozetus* sp.	3
Fishes	Macrourids	*Caelorhynchus* sp.	6
Fishes	Macrourids	*Coelorinchus tokiensis*	6
Fishes	Macrourids	*Coryphaenoides longicirrhus*	4,6
Fishes	Macrourids	*Gadomus* sp.	6
Fishes	Macrourids	*Kumba* sp.	3,4,7
Fishes	Macrourids	*Nezumia* sp.	6
Fishes	Macrourids	Macrouridae (unidentified)	4,6
Fishes	Ophidiidae	*Bassogigas* sp.	4
Fishes	Ophidiidae	Ophidiidae	4
Fishes	Other fishes	Alepocephalidae	1,4
Fishes	Other fishes	*Apristurus* sp.	2
Fishes	Other fishes	?*Bathysaurus mollis*	1
Fishes	Other fishes	*Cataetyx hawaiiensis*	5
Fishes	Other fishes	*Cyclothone* sp.	6
Fishes	Other fishes	*Diplacanthopoma* sp.	6
Fishes	Other fishes	Gonostomatidae	2
Fishes	Other fishes	*Laemonema* sp.	6
Fishes	Other fishes	*Lepidion* sp.	6
Fishes	Other fishes	*Neoscopelus* sp.	6
Fishes	Other fishes	*Solocisquama erythrina*	6
Mollusks	Aplacophoran	Aplacophora	7,8
Mollusks	Cephalopoda	Octopoda (pink)	1
Mollusks	Cephalopoda	Coleoidea (squid)	6
Mollusks	Gastropods	Brachiopoda	4,6
Mollusks	Gastropods	Gastropoda	2,6,7,8
Mollusks	Gastropods	*Gaza daedala*	8
Mollusks	Polyplacophora	Polyplacophora (Chiton)	7
Retaria	Foraminifera	Xenophyophora	6
Sponges	Demosponges	*Asbestopluma* sp.	2
Sponges	Demosponges	Cladorhizidae	2
Sponges	Hexactinellids	*Aspidoscupulia* sp.	3
Sponges	Hexactinellids	*Atlantisella* sp.	2,4,6
Sponges	Hexactinellids	Bolosominae	8
Sponges	Hexactinellids	*Bolosoma* sp.	8
Sponges	Hexactinellids	*Bolosoma* sp. A	2,3
Sponges	Hexactinellids	*Bolosoma* sp. B	3

Phylum	Group	Lowest Identification	Dive No.
Sponges	Hexactinellids	*Caulophacus (Caulodiscus)* sp.	8
Sponges	Hexactinellids	*Caulophacus (*new subgenus*)* sp.	5,7
Sponges	Hexactinellids	*Caulophacus (Oxydiscus)* sp.	3
Sponges	Hexactinellids	*Caulophacus* (unknown subgenus) sp.	7
Sponges	Hexactinellids	*Corbitella* sp.	2
Sponges	Hexactinellids	Corbitellinae (new genus)	4,7
Sponges	Hexactinellids	*Dictyaulus* sp.	2,6
Sponges	Hexactinellids	Euretiidae	4
Sponges	Hexactinellids	*Farrea* sp.	4,7
Sponges	Hexactinellids	*Farrea* nr. *occa*	6,7
Sponges	Hexactinellids	*Farrea* nr. *occa erecta*	2,4,6
Sponges	Hexactinellids	*Hyalonema (Corynonema)* sp.	1,2
Sponges	Hexactinellids	?*Hyalostylus* sp.	8
Sponges	Hexactinellids	Lyssacinosida	7
Sponges	Hexactinellids	Pheronematidae	3,5,7
Sponges	Hexactinellids	*Poliopogon* sp.	5,8
Sponges	Hexactinellids	*Poliopogon* sp. 4	5,7
Sponges	Hexactinellids	*Poliopogon* sp. A	7
Sponges	Hexactinellids	*Poliopogon* sp. B	3,5,7,8
Sponges	Hexactinellids	*Saccocalyx* sp.	2,4,6
Sponges	Hexactinellids	*Tretopleura* sp.	2,7
Sponges	Hexactinellids	*Tretopleura* sp. 1A	4
Sponges	Hexactinellids	*Tretopleura* sp. 1B	3,4
Sponges	Hexactinellids	*Walteria* cf. *leukarti*	5,7
Sponges	Hexactinellids	*Walteria* sp.	2,6
Tunicate	Ascidacea	Octanematidae	6
Tunicate	Ascidacea	*Pyrosoma* sp.	6

Appendix E: NASA 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 were 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 primary investigator, Dr. 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 F: Acronyms

3D—Three-dimensional
ADCP—Acoustic Doppler Current Profiler
AERONET—Aerosol Robotic Network
AMA—Reddit's Ask Me Anything
BM—Bernice Pauahi Bishop Museum
BOEM—Bureau of Ocean Energy Management
CAPSTONE—NOAA Campaign to Address Pacific monument Science, Technology, and Ocean NEeds
CCOM—Center for Coastal and Ocean Mapping
CIT—Chiba Institute of Technology
CSV—Comma-separated values
CTD—Conductivity, temperature, and depth
D2—ROV *Deep Discoverer*
DNA—Deoxyribonucleic acid
DO—Dissolved oxygen
DSCRPT—NOAA Deep Sea Coral Research and Technology Program
ECC—Exploration Command Center
ECS—Extended Continental Shelf
EEZ—Exclusive economic zone
ESA—Endangered Species Act
EX—NOAA Ship *Okeanos Explorer*
FAU—Florida Atlantic University
FeMn—Ferromanganese
FFS—French Frigate Shoals
FLMNH—Florida Museum of Natural History
GDIT—General Dynamics Information Technology
GFOE—Global Foundation for Ocean Exploration
HBOI—Harbor Branch Oceanographic Institute
HD—High-definition
HPR—Hawai'i Public Radio
HURL—Hawai'i Undersea Research Laboratory
IOOS—NOAA U.S. Integrated Ocean Observing System
IRC—NOAA Inouye Regional Center
ISC—Inner Space Center
JAMSTEC—Japan Agency for Marine-Earth Science and Technology
LED—Light-emitting diode
LLC—Limited liability company
LOC—Letter of concurrence
MAN—NASA's Maritime Aerosol Network
Mbps—Megabit-per-second
MGR—Marine Geology Repository

MHI—Main Hawaiian Islands
MPA—Marine protected area
NAO—NOAA Administrative Order
NASA—National Aeronautics and Space Administration
NCCOS—NOAA National Centers for Coastal Ocean Science
NCDDC—NOAA National Coastal Data Development Center
NCEI—National Centers for Environmental Information
NEPA—National Environmental Policy Act
NGDC—NOAA National Geophysical Data Center
NMFS—NOAA National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
NOS—NOAA's National Ocean Service
NWHI—Northwest Hawaiian Islands
OER—NOAA Office of Ocean Exploration and Research
OGL—Ocean Genome Legacy
OSU—Oregon State University
PCZ—Prime Crust Zone
PERC—Planetary Exploration Research Center
PI—Principal Investigator
PIFSC—NOAA Pacific Islands Fisheries Science Center
PMNM—Papahānaumokuākea Marine National Monument
POC—Point of contact
PRD—Protected Resources Division
QA/QC—Quality assurance/quality control
ROV—Remotely operated vehicle
SIO—Scripps Institution of Oceanography
SIS—Seafloor Information Software
SOI—Schmidt Ocean Institute
TAMU—Texas A&M University
TIGHAR—The International Group for Historic Aircraft Recovery
TSG—Thermosalinograph
UCAR—University Corporation for Atmospheric Research
UH—University of Hawaiʻi at Mānoa
ULL—University of Louisiana at Lafayette
URI, GSO—University of Rhode Island, Graduate School of Oceanography
USGS—U.S. Geological Survey
USNM—National Museum of Natural History, Smithsonian Institution
UTC—Universal Time Coordinated
WHOI—Woods Hole Oceanographic Institute
XBT—Expendable bathythermograph