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Cruise Report: EX-14-02 Leg 3
Exploration of the Gulf of Mexico 2014 (ROV and Mapping)

Gulf of Mexico

Pascagoula, Mississippi to St. Petersburg, Florida
April 10, 2014, to May 1, 2014

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Abstract

EX-14-02 Leg 3 was the final cruise in a series of ocean exploration cruises that together comprised the *Exploration of the Gulf of Mexico 2014* expedition. During 22 days at sea, 16 successful telepresence-enable remotely operated vehicle (ROV) dives were conducted in two different areas of the Gulf of Mexico: 1) the northwestern part of the basin, characterized by a thick accumulation of sediments which have been altered by intrusions of salt, and 2) the central part of the Florida Escarpment, the western edge of a thick carbonate platform, and the adjacent outer shelf. All 16 dives were identified by management groups or support management interests from within the region. Dive 01 was conducted on April 12, 2014, and Dive 16 was conducted on April 29, 2014. Highlights from the Northwestern Gulf of Mexico Dives included investigation of three historic shipwrecks, possible extension ranges of a few deep-sea coral types, *Paleodictyon* 'burrows,' and the discovery of a chronometer at Monterrey Wreck Site A. Highlights from the Western Florida Escarpment Dives included incredible deep-sea coral diversity (at least 23 species) during one of the deep escarpment dives; the discovery of two potential new species of crinoids; and close-up imagery documenting a sea urchin eating an octocoral—an observation rarely, if ever, captured on camera. In addition to ROV dives, a suite of deepwater mapping sonars were used to acquire data from the water column, seafloor, and sub-seafloor. Over 18,600 km^2 of largely previously unmapped seafloor were targeted and mapped. More than 70 scientists and students participated in these dives from shore, providing their input and expertise to help characterize these areas and guide the exploration. Data collected from this expedition will help improve scientific understanding of the deep-ocean habitats of U.S. Gulf of Mexico waters, the U.S. continental margin, and the connections between these communities throughout the Gulf of Mexico Basin.

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1. Introduction

By leading national efforts to explore the ocean and make ocean exploration more accessible to the public, the NOAA Office of Ocean Exploration and Research (OER) is filling gaps in the basic understanding of deep waters and the seafloor, and 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 NOAA, national, and international goals to better understand and manage the ocean and its resources.

Using modern exploration tools and technology, OER explores unknown areas of the deep ocean. NOAA Ship *Okeanos Explorer* is one such tool. Working in close collaboration with government agencies, academic institutions, and other partners, OER conducts deep-sea exploration expeditions using advanced technologies on *Okeanos Explorer*, by mapping and characterizing areas of the ocean that are either partially explored or unexplored. Collected data about deep waters and the seafloor—and the resources they hold—establishes a foundation of information and fills gaps of 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 understanding of ocean resources, promoting the protection of the marine environment, and enhancing the economy, health, and security of our nation. As the only federal program solely dedicated to ocean exploration, OER is uniquely situated to lead the delivery of essential deep-ocean information to managers, decision-makers, scientists, and the public, through federal investments in order to meet national priorities.

2. Expedition Overview

From April 10, 2014, to May 1, 2014, OER and partners conducted a three-part, telepresence-enabled ocean exploration expedition on *Okeanos Explorer* to collect baseline information and improve knowledge about unexplored and poorly understood deep-water areas of the Gulf of Mexico. *Exploration of the Gulf of Mexico 2014* (EX-14-02) Leg 3 was part of a series of three expeditions contributing to these goals. This expedition focused on in the Gulf of Mexico south of Louisiana and Mississippi as well as the Western Florida Escarpment. Along with the two preceding mapping cruises (EX-14-02 Leg 1 and EX-14-2 Leg 2), EX-14-02 Leg 3 was designed to provide timely, actionable information based on reliable and authoritative science.

2.1 Rationale for Exploration

Despite its importance to U.S. national energy, food, transportation, and recreational economies, significant gaps remain in our basic understanding of the deep sea portion of the Gulf of Mexico. In the years before this expedition, scientists and managers identified poorly known areas within the Gulf of Mexico that are larger than the states of Connecticut, Delaware, and Rhode Island. The 2014 Gulf of Mexico Expedition continues NOAA's and partners efforts to reduce the unknown by conducting baseline ecosystem characterizations that support a variety of research, management, economic, and educational activities. The data collected provides critical deep-ocean baseline environmental intelligence to governments, universities, corporations, non-governmental organizations, and the public. The Gulf of Mexico contains a wide range of habitats and interesting geological features ranging from brine pools to coral gardens, and canyons to mud volcanoes. The Gulf of Mexico also contains significant submerged cultural heritage sites that have yet to be studied. NOAA Ocean Exploration explored many of these habitats. Over the course of the three legs during the *Exploration of the Gulf of Mexico 2014* expeditions (https://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/welcome.html, last accessed March 2021).

As part of the planning for this Leg 3 expedition, NOAA Ocean Exploration collaborated with the scientific and management communities to assess the exploration needs and data gaps in unknown and poorly known areas of the Gulf of Mexico. Input was received from multiple NOAA programs, including Flower Garden Banks National Marine Sanctuary (FGBNMS), the National Centers for Coastal and Ocean Science (NCCOS), the National Systematics Laboratory, and OER; the Gulf of Mexico Fisheries Management Council (GMFMC); and federal agencies including the Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE), and the U.S. Geological Survey (USGS). To define the operating area for this expedition, NOAA considered the May 2011 NOAA Workshop on Systematic Telepresence-Enabled Exploration in the Atlantic Basin (https://oceanexplorer.noaa.gov/about/what-we-do/media/atl-basin-workshop-2011-summary.pdf, last accessed March 2021). Throughout EX-14-02 Leg 3, live video and data from remotely operated vehicle (ROV) dives and multibeam operations were shared in real time with shore-based participants and the public.

Data and information from this expedition will help improve scientific understanding of the deep-ocean habitats of U.S. Gulf of Mexico waters and the U.S. continental margin, as well as the connections between benthic and water column ecological communities throughout the

Gulf of Mexico Basin. It will also inform management plans for habitat areas of particular concern (HAPCs), marine protected areas (MPAs), and U.S. National Marine Sanctuaries; support local scientists and managers seeking to understand and manage deep-sea resources; and stimulate subsequent exploration, research, and management activities.

This expedition also contributed to the ongoing collaboration with the NOAA Office of National Marine Sanctuaries (ONMS) Maritime Heritage Program, BOEM, USGS, and the NOAA National Marine Fisheries Service (NMFS) Deep Sea Coral Research and Technology Program (DSCRTP).

2.2 Objectives

The expedition addressed scientific themes and priority areas identified by NOAA scientists and resource managers, GMFMC, BOEM, USGS, and the broad ocean science community. The primary objective of the expedition was to survey deepwater areas off the coasts of Louisiana, Mississippi, Alabama, and Florida to provide baseline information to support local science and management needs. Objectives and the full details of the EX-14-02 Leg 3 mission plan can all be found in Elliott (2014). This expedition's priorities focused on the following objectives and operations:

1. Science:
    a. Identify and explore the diversity and distribution of benthic habitats and features (e.g., seeps, deep corals and related benthic ecosystems, canyons).
    b. Conduct ROV dives along the Sigsbee Escarpment and in adjacent deepwater canyons.
    c. Locate and characterize Underwater Cultural Heritage (UCH) sites and features (e.g., shipwrecks—resulting data will be used to assess eligibility for the National Register of Historic Places).
    d. Ground truth acoustic seep data and characterize associated habitat.
    e. Deploy Argo Floats.

2. ROV:
    a. Reintegrate the ROV into the ship's systems.
    b. Test and use the ROV for telepresence-enabled exploration.
    c. Conduct daytime ROV dives on exploration targets.
    d. Conduct ongoing training of pilots.
    e. Maintain ongoing system familiarization and documentation.
    f. Train pilots to take high-quality images and navigate the new ROV.
    g. Continue to apply, develop, and/or refine system checklists, standard operating procedures (SOPs), spares lists, etc.
    h. Continue training in ROV launch and recovery operations.

i. Continue to train the bridge crew on ROV operations and use of the ship's dynamic positioning (DP) system.

3. Telepresence (very small aperture terminal [VSAT] 20 megabits per second [Mbps] ship-to-shore; T1 shore-to-ship):
   a. Test terrestrial and high-speed satellite links.
   b. Test and refine ship-to-shore communications and operations procedures that engage multiple Exploration Command Centers (ECCs).
   c. Engage the new ECC located at Harbor Branch Oceanographic Institute (HBOI), and other ECCs unfamiliar with *Okeanos Explorer* telepresence operations (Texas A&M University Galveston [TAMUG], Meadows Center at Texas State University).
   d. Test and refine operating procedures and products.
   e. Engage a broad spectrum of the scientific community and public in telepresence based exploration.
   f. Integrate ROV Track system into ship's network and establish file backup procedures.
   g. Work with NOAA Network Operations Center (NOC) to harden the video network path.
   h. Test new pathways for the Internet1 accessible video stream.
   i. Continue to use the real-time Really Simple Syndication (RSS) feed to generate public engagement.
   j. Support live interaction between ship and shore for education and media events.

4. ECCs:
   a. Support distributed participation from the ocean exploration community at multiple shoreside locations through telepresence.
   b. Train participating scientists on how to use online collaboration tools and technologies to conduct remote science.
   c. Refine/update SOPs.
   d. Continue ongoing system familiarization and training.
   e. Test new online collaboration tools SOPs.

5. Mapping Operations:
   a. Support nighttime mapping operations and data gap filling.
   b. Support ROV dive planning by producing mapping products.
   c. Acquire water column data with the EK60 and EM 302 sonars.
   d. Acquire sub-bottom data.
   e. Conduct mapping operations during transits.
   f. Conduct training of new mapping watchstanders.
   g. Create daily standard mapping products.

6. Conductivity, temperature, depth (CTD) operations:
    a. Conduct CTD/rosette casts as needed.

7. Expendable Bathythermograph (XBT) operations:
    a. During mapping operations, XBT casts collected at regular intervals of 2-4 hours or more often, as data quality requires.

8. Data Management:
    a. Provide a foundation of publicly-accessible data and information products to foster further exploration, research, and management activities.
    b. Provide daily cumulative multibeam products to shore for operational decision-making purposes.
    c. Record two channels of streamed ROV dive video footage onboard the ship.
    d. Begin configuration and installation of new shipboard Data Warehouse software.
    e. Evaluate and, if necessary, revise video data consolidation scripts generated during EX-14-02 Leg 1. Document scripts into video post-processing SOP.
    f. Confirm integration and data quality of ROV environmental sensors.
    g. Update ROV camera codes and Virginia Institute of Marine Science (VIMS) documentation with overwinter modifications.
    h. Integrate automated frame export for captured video feeds (preliminary data product).

3. Participants

EX-14-02 Leg 3 included onboard mission personnel as well as shore-based science personnel who participated remotely via telepresence technology. See **Tables 1** and **2** for lists of onboard and shore-based personnel who supported EX-14-02 Leg 3.

Table 1. EX-14-02 Leg 3 onboard mission team personnel.

Name (First, Last)	Title	Affiliation
Kelley Elliott (now Suhre)	Expedition Manager	OER, Acentia
Jamie Austin	Science Co-lead	University of Texas at Austin
Stephanie Farrington	Science Co-lead	HBOI, Florida Atlantic University (FAU), Cooperative Institute for Ocean Exploration (CIORT)
Jared Drewniak	Telepresence Video Lead	NOAA National Coastal Data Development Center (NCDDC)
Brendan Reser	Telepresence Data Lead	OER, ERT, Inc.
Elizabeth ‘Meme’ Lobecker	Mapping Watch Lead	OER, ERT, Inc.
Jeffery Marshall	Mapping Watch Lead	NOAA Atlantic Hydrographic Branch (AHB)
Brian Bingham	Dive Supervisor	University Corporation of Atmospheric Research (UCAR)

Dave Wright	ROV Engineer	UCAR
Jeff Williams	ROV Engineer	UCAR
Bobby Mohr	ROV Engineer	UCAR
Jeff Lanning	ROV Engineer	UCAR
Karl McLetchie	ROV Engineer	UCAR
Todd Gregory	ROV Engineer	UCAR
Joshua Carlson	ROV Engineer	UCAR
Chris Ritter	ROV Engineer	UCAR
Dan Rogers	ROV Engineer	UCAR
Art Howard	ROV Engineer	UCAR
Ed McNicol	Telepresence Engineer	UCAR
Roland Brian	Telepresence Engineer	UCAR

Table 2. EX-14-02 Leg 3 shore-based science team members.

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3.1 Participating Institutions

The following section lists institutions and organizations that were core participants during EX-14-03 Leg 3.

- University of New Hampshire (UNH)—Center for Coastal and Ocean Mapping (CCOM)—Jere A. Chase Ocean Engineering Lab, 24 Colovos Road, Durham, NH 03824 USA
- University of Rhode Island (URI), Graduate School of Oceanography, Inner Space Center (ISC), Narragansett, Rhode Island, 02882
- NOAA, National Oceanographic Data Center, NCDDC, Stennis Space Center, MS, 39529
- NOAA, Office of Coast Survey (OCS), Hydrographic Surveys Division, Atlantic Hydrographic Branch, 439 W. York St., Building 2, Norfolk, VA 23510
- University Corporation for Atmospheric Research (UCAR), Joint Office for Science Support (JOSS), P.O. Box 3000, Boulder, CO 80307
- NOAA Pacific Marine Environmental Laboratory (PMEL), 7600 Sand Point Way NE, Seattle, WA 98115
- USGS, Woods Hole Science Center, 384 Woods Hole Road, Quissett Campus, Woods Hole, MA 02543-1598
- The University of Texas at Austin, John A. and Katherine G. Jackson School of Geosciences, Institute for Geophysics, J.J. Pickle Research Campus, Building 196 (ROC), 10100 Burnet Road (R2200), Austin, TX 78758-0999
- Cooperative Institute for Ocean Exploration, Research and Technology (CIOERT), HBOI at Florida Atlantic University (FAU), 5600 US 1 North, Fort Pierce, FL 34946

4. Methodology

To accomplish its objectives, EX-14-02 Leg 3 used:

- Dual-bodied ROV system (ROVs *Deep Discoverer* and *Seirios*) to conduct daytime seafloor and water column surveys.
- Sonar systems (Kongsberg EM 302 multibeam sonar, Knudsen 3260 sub-bottom profiler, and Simrad EK60 split-beam sonar) to conduct mapping operations at night and when the ROVs were on deck.
- A 20 mbps high-bandwidth satellite connection to provide real-time ship-to-shore

communications (telepresence).

All environmental data collected by NOAA are covered by a data management plan to ensure they are archived and publicly accessible (https://nosc.noaa.gov/EDMC/nao_212-15.php, last accessed March 2021). The data management plan for EX-14-02 Leg 3 is in Appendix A.

4.1 ROV Seafloor Surveys

ROV dive operations supported the expedition objectives in Section 2.2 and included high-resolution visual surveys of seafloor and water column habitats as well as geological and biological sampling. During each dive, the ROVs descended to within inches of the seafloor and then moved from waypoint to waypoint, documenting the geology and biology of the area. Each ROV dive was approximately 7-10 hours as conditions and logistics permitted. Dives were primarily conducted during the day (operations described in detail by Quattrini et al., 2015 and Kennedy et al., 2019). Additional information about the general process of site selection, collaborative dive planning, scientific equipment on the ROVs, and the approach to benthic exploration used on *Okeanos Explorer* can be found in Kennedy et al. (2019).

Onboard and shore-based scientists identified each encountered organism to the lowest taxon possible based on data available during the real-time assessment. Additionally, the shore-side scientists provided geological interpretations of the observed substrate throughout each ROV seafloor survey.

For water column exploration, a series of transects were performed during vehicle ascent following the completion of the benthic/seafloor exploration. Transects primarily targeted the deep scattering layer and the waters directly above and below the layer. Water column exploration was conducted on Dive 10 of the expedition. Specific transect depths and times are noted in the dive summary for Dive 10 (see Section 7.1.1).

4.2 Sampling Operations

No sampling operations were completed during EX-14-02 Leg 3.

4.3 Acoustic Operations

Acoustic operations included Kongsberg EM 302 multibeam, Simrad EK60, and Knudsen sub-bottom profiler. A full description of the readiness of these systems can be found in Lobecker, James, & Rose (2014), accessible here: https://DOI.org/10.25923/d0ha-gy79 (last accessed

March 2021). The schedule of mapping operations included overnight transits and whenever the ROVs were on deck. Lines were planned to maximize edge-matching of existing data or filling of data gaps in areas with incomplete bathymetry coverage. In regions with no existing data, exploration transit lines were planned to optimize potential discoveries. Targeted mapping operations were conducted in areas near or south and southeast of FGBNMS, Keathley Canyon, the Sigsbee Escarpment, and the Western Florida Escarpment.

4.3.1 Multibeam Sonar (Kongsberg EM 302)

Multibeam seafloor mapping data were collected using the Kongsberg EM 302 sonar, which operates at a frequency of 30 kilohertz (kHz). Multibeam mapping operations were conducted during all overnight transits between ROV dive sites. Multibeam data quality was monitored in real time by acquisition watch standers. Ship speed was adjusted to maintain data quality as necessary.

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

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

Background data used to guide exploratory multibeam mapping operations included OER/*Okeanos Explorer* cruises EX-11-05, EX-11-06, EX-12-02 Leg 1, EX-12-02 Leg 2, Ex-12-03 Leg 3, EX-12-03, EX-14-02 Leg 1, and EX-14-02 Leg 2. Non-OER/*Okeanos Explorer* background multibeam bathymetry included data collected by the Extended Continental Shelf (ECS) project, R/V *Atlantis* cruise 18-02, existing data in the National Geophysical Data Center archives (https://maps.ngdc.noaa.gov/viewers/bathymetry, last accessed March 2021), and Sandwell et al. (2014) satellite altimetry bathymetric data.

4.3.2 Sub-Bottom Profiler (Knudsen Chirp 3260)

The primary purpose of the Knudsen Chirp 3260 (3.5 kHz) sonar is to image sediment layers underneath the seafloor to a maximum depth of about 80 m below the seafloor, depending on the specific sound velocity of the substrate. The sub-bottom profiler was operated simultaneously with the multibeam sonar during mapping operations to provide supplemental information about the sedimentary features underlying the seafloor. Some data holidays exist during times of inclement weather, and as onboard personnel were troubleshooting positioning data inputs.

4.3.3 Split-Beam Sonars (Simrad EK60)

In 2014, *Okeanos Explorer* was equipped with one EK60 (18 kHz) split-beam transducer. This sonar was used continuously throughout EX-14-02 Leg 3, during both overnight mapping and daytime ROV operations. The sonar provided calibrated target strength measurements of water column features such as dense biological layers and schools of fish. This sonar also helped detect the presence of gaseous bubble plumes in the water column.

EK60 calibration was conducted on March 2 and 3, 2014, offshore of Key West, FL. The files are included in the EX-14-02 Leg 1 EK60 dataset found here: http://DOI.org/10.7289/V5PC308T (last accessed March 2021).

4.3.5 Expendable Bathythermograph (XBT) Systems

XBTs were collected every two to four hours and applied in real-time using SIS (). Sound speed at the sonar head was determined using Reson SVP-70 probe mounted near the multibeam transducer. Sound speed at the surface was also measured by flow-through thermosalinograph (TSG) data.

4.4 Conductivity, Temperature, and Depth (CTD)

CTD measurements were collected with the integrated ROV CTD system. This system records CTD as well as additional sensors on every dive. Additional sensors installed on the CTD include measured light scattering (LSS), dissolved oxygen (DO), and oxygen reduction potential (ORP).

4.5 Sun Photometer Measurements

OER gathers limited at-sea measurements aboard *Okeanos Explorer* to support a NASA-led, long-term research effort that assesses marine aerosols. As time allowed on cloud-free days, onboard personnel collected georeferenced sun photometer measurements for the Maritime Aerosol Network (MAN) component of the Aerosol Robotic Network (AERONET). AERONET is a network of sun photometers that measure atmospheric aerosol properties around the world. MAN complements AERONET by conducting sun photometer measurements on ships of opportunity to monitor aerosol properties over the global ocean.

5. Clearances and Permits

Pursuant to the National Environmental Policy Act (NEPA), OER is required to include in its planning and decision-making processes appropriate and carefully considered potential environmental consequences of actions. The companion manual for NOAA Administrative Order 216-6A (https://www.nepa.noaa.gov/docs/NOAA-NAO-216-6A-Companion-Manual-03012018.pdf, last accessed March 2021) describes the agency's specific procedures for NEPA compliance.

An environmental review memorandum was completed for all NOAA Ship *Okeanos Explorer* expeditions in 2014, in accordance with Section 4 of the Companion Manual, in the form of a categorical exclusion (CE) worksheet. Based on this review, a CE was determined to be the appropriate level of NEPA analysis necessary, as no extraordinary circumstances existed that required the preparation of an environmental assessment or environmental impact statement. A copy of the CE Evaluation Worksheet can be found in Appendix B.

6. Schedule and Map

EX-14-02 Leg 3 was a total of 22 days at sea, from April 10 to May 1, 2014. It departed from Pascagoula, Mississippi, and returned to port in St. Petersburg, Florida. See **Table 3** for a day-by-day breakdown of EX-14-02 Leg 3. There were 18 planned dives with 16 dives achieved (see **Table 6** for details). One dive had to be cancelled due to inclement weather, and one dive could not be conducted due to strong currents and winds. See **Figure 1** for a map of EX-14-02 Leg 3's track, dive sites, and bathymetry collected.

Table 3. EX-14-02 Leg 3 schedule.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				4/10 Depart dock, Pascagoula, Mississippi.	**4/11** Transit mapping to Dive 01.	**4/12** Dive 01, GB648. Overnight transit mapping.

4/13 Dive 02, GB907. Overnight transit mapping.	**4/14** Dive 03, NW Gulf Mid-Depth, overnight transit mapping.	**4/15** Dive cancelled, heavy seas, 24 hour mapping operations.	**4/16** Dive 04, Keathley Canyon Site KC2, overnight mapping operations.	**4/17** Dive 05, Monterrey Shipwrecks A & C, overnight mapping operations.	**4/18** Dive 06, Keathley Canyon KC3, overnight mapping operations.	**4/19** Dive 07, Monterrey Shipwreck B, overnight mapping operations.
4/20 Dive 08, Keathley Canyon UTIG, overnight mapping operations.	**4/21** Dive 09, Bryant Canyon Shallow, overnight mapping operations.	**4/22** Dive 10, Bryant Canyon Deep, overnight mapping operations.	**4/23** Dive 11, NW Gulf Deep, overnight mapping operations.	**4/24** Dive 12, WR0325, overnight mapping operations.	**4/25** 24-hour mapping operations, transit to Western Florida Escarpment. Three Argo floats deployed.	**4/26** Dive 13, Large Mound Deep, overnight mapping operations.
4/27 Dive 14, Many Mounds Deep, overnight mapping operations.	**4/28** Dive 15, Many Mounds South Shallow, overnight mapping operations.	**4/29** Dive 16, Many Mounds North Shallow, overnight mapping operations.	**4/30** Transit mapping operations.	**5/1** Arrive in-port, St. Petersburg, Florida.		

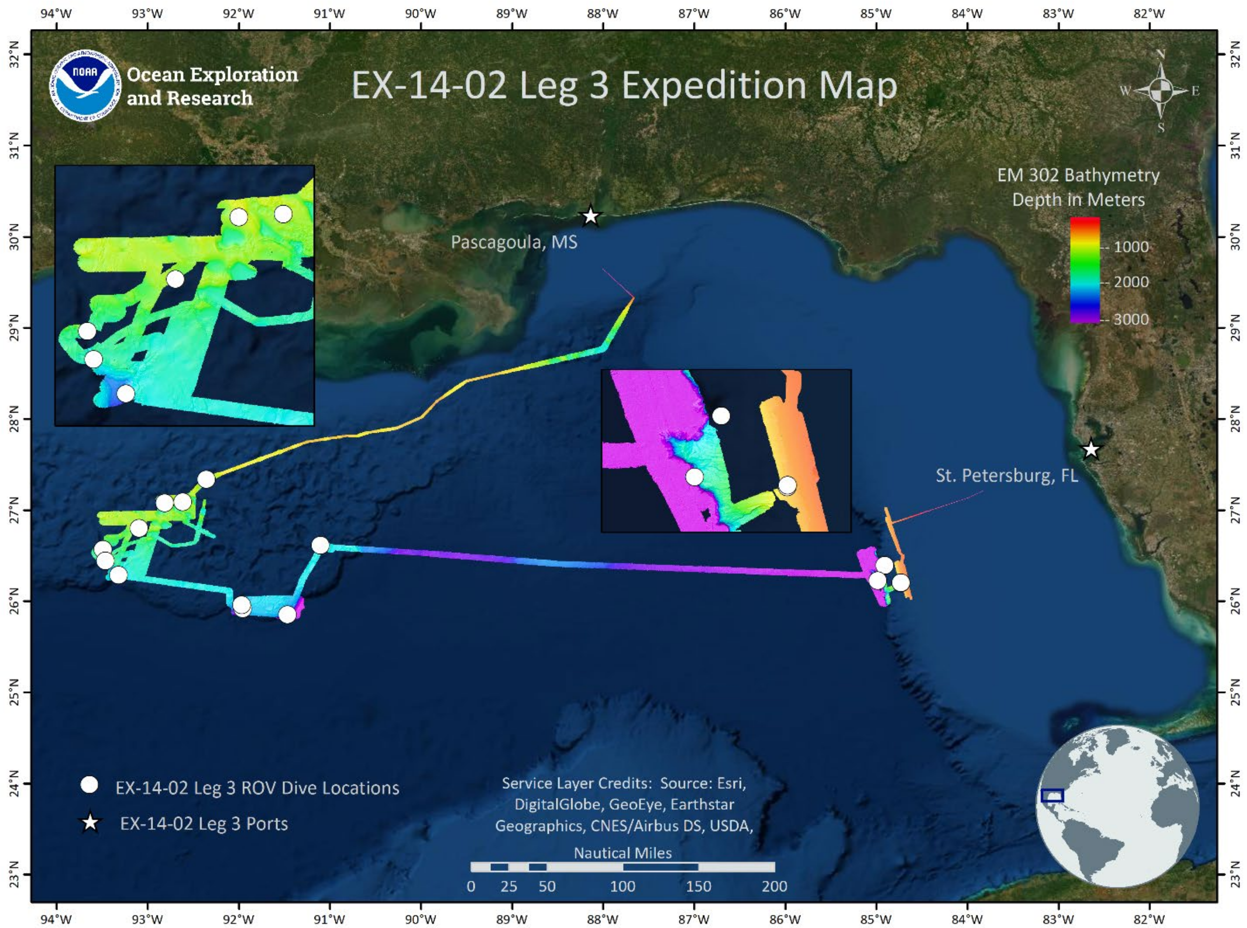

Figure 1. Map showing EX-14-02 Leg 3's ports (white stars), 16 ROV dive sites (white circles), and EM 302 bathymetry (rainbow). ROV Dives 05 and 07 have been excluded due to UCH restricted access.

7. Results[1]

Metrics for EX-14-02 Leg 3's major exploration and scientific accomplishments are summarized in **Tables 4** and **5**. More detailed results are presented in the subsections to follow. Mapping and ROV data from Dives 05 and 07, on April 17th and 19th, 2014, respectively, are publically restricted under UCH protocols.

[1] If you are unable to access the results noted here, contact ex.expeditioncoordinator@noaa.gov.

Table 4. Summary of exploration metrics for EX-14-02 Leg 3.

Exploration Metrics	Totals
Days at sea	22
Days at sea in U.S. waters	22
Linear km mapped by EM 302	4,443.0
Square km covered by EM 302	18,641.0
Square km covered by EM 304 in U.S. waters deeper than 200 meters	18,058.0
Vessel CTD casts	0
XBT casts	78
ROV dives	16
ROV dives in U.S. EEZ	16
Maximum ROV seafloor depth (m)	2879.1
Minimum ROV seafloor depth (m)	470
Total time on bottom (hh:mm:ss)	93:48:31
Water column survey time (hh:mm:ss)	01:15:00
Total ROV time (hh:mm:ss)	131:21:36

7.1 ROV Survey Results

Seafloor depth ranges explored during the 16 ROV surveys were between 470 and 2879.1 meters. During 16 dives, the ROVs spent a total of 93:48:31 hours on the bottom and 01:15:00 hours conducting water column exploration (see **Table 5** for more cumulative results and for dive-specific information for each of the dives). Over 230 different types of animals were documented.

In addition to benthic surveys, Dive 10 included five 15-minute transects occurring in 100-meter intervals between 800 and 1200 m.

Table 5. Summary information for the 16 ROV dives conducted during EX-14-02 Leg 3.

Date (yyyy mmdd)	Dive #	Site Name	On Bottom Latitude (degrees decimal minutes)	On Bottom Longitude (degrees decimal minutes)	Max Depth (m)	Dive Duration (hh:mm:ss)	Bottom Time (hh:mm:ss)
20140412	1	GB648	27°, 20.241' N	092°, 21.661' W	972.8	07:42:21	06:18:51
20140413	2	GB907	27°, 05.519' N	092°, 37.099' W	1266.7	5:26:56	3:52:47
20140414	3	NW Gulf Mid-Depth	27°, 04.679' N	092°, 48.998' W	1155.4	07:56:45	05:50:07
20140416	4	Keathley Canyon Site KC2	26°, 34.122' N	093°, 29.682' W	2003.6	08:13:27	06:02:08
20140417	5	Monterrey Shipwrecks A and C	N/A	N/A	N/A	N/A	N/A
20140418	6	Keathley Canyon KC3	26°, 26.536' N	093°, 27.980' W	2173.1	08:09:01	05:28:48
0140419	7	Monterrey Shipwreck B	N/A	N/A	N/A	N/A	N/A
20140420	8	Keathley Canyon UTIG	26°, 17.367' N	093°, 19.349' W	2652.4	08:19:48	05:20:56
20140421	9	Bryant Canyon Shallow	25°, 55.073' N	091°, 57.547' W	2591.4	08:02:41	05:16:36
20140422	10	Bryant Canyon Deep	25°, 57.651' N	091°, 58.208' W	2813.0	09:54:55	04:55:33
20140423	11	NW Gulf Deep	25°, 51.118' N	091°, 28.094' W	2879.1	07:59:32	04:46:02

20140424	12	WR0325	26°, 36.951' N	091°, 06.538' W	1930.1	07:58:38	05:46:35
20140426	13	Large Mound Deep	26°, 18.350' N	085°, 01.741' W	2208.9	07:28:37	05:13:17
20140427	14	Many Mounds Deep	26°, 13.569' N	084°, 59.734' W	2096.2	09:52:49	06:55:45
20140428	15	Many Mounds South Shallow	26°, 11.035' N	084°, 43.874' W	578.2	07:46:18	06:13:43
20140429	16	Many Mounds North Shallow	26°, 12.241' N	084°, 43.950' W	536.7	07:05:27	05:43:35

7.1.1 Select Highlights, Scientific Observations, and Representative Images by Dive

The following section contains science summaries by dive, representative images and selected highlights. Information about how to access the dive summaries for each ROV dive on this expedition can be found in Section 7.1.2.

Dive 01

The site for Dive 01 was nominated by BOEM. During the dive, fuve cold seep candidates were located and mapped visually. Many discrete locations of gas escape were encountered. At one carbonate hardground outcrop, gas escape was accompanied by escaping oil droplets. At one vent site, hydrate rinds formed around individual escaping bubbles. The most abundant species were living buccinid mussels (**Figure 2** and **Figure 3**), as well as shell halves and hash surrounding the base of outcrops. Corals were rare and low in diversity, with only three antipatharians (?*Tanacetipathes* sp. black corals) and two *Chrysogorgia* sp. (octocoral). There were also chemosynthetic *Lamellibrachia* sp. tubeworms with their respiratory organs exposed. Several species of fish were sighted including a batfish, some rattails, and cutthroat eels.

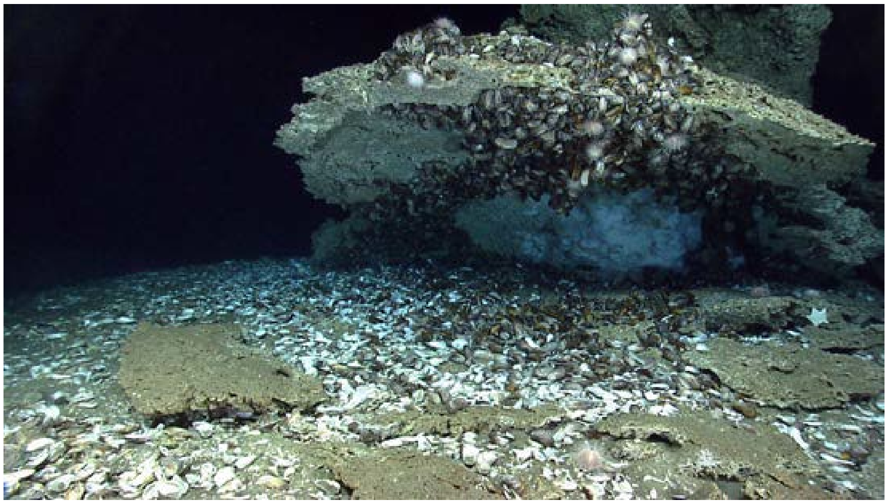

Figure 2. An overhang with buccinid mussels, white urchins, and methane ice accumulating underneath.

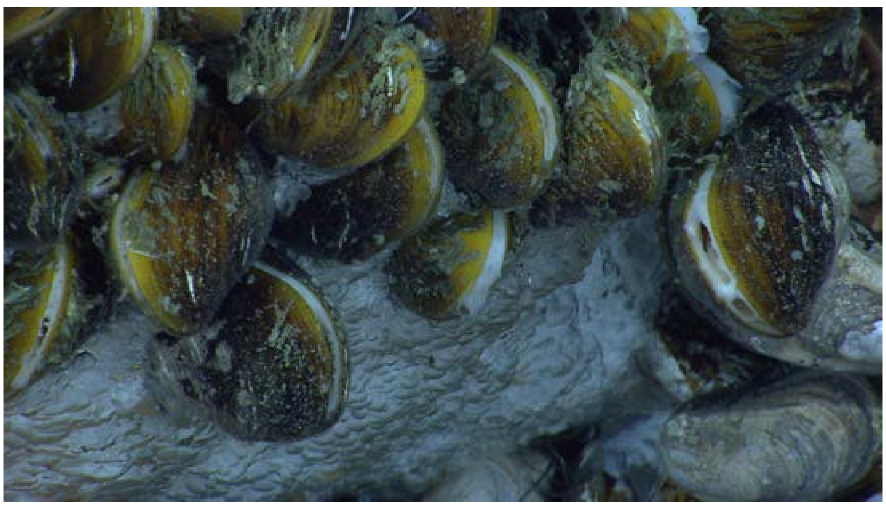

Figure 3. Methane ice engulfing the holdfasts of buccinid mussels.

Dive 02

Dive 02 found an irregularly shaped brine pool (**Figure 4** and **Figure 5**), complete with evidence for tributaries. At one location, gas was observed escaping directly from the bottom of the pool through the brine/seawater interface. The chemosynthetic polychaete (*Lamellibrachia* sp.) were very common, appearing on most of the rock structures around the brine pool, and were 10-30 cm long, indicating they were 100+ years old. Interestingly, a few *Siboglinum* Caullery (beard worms) were seen "growing" out of the surface of the brine pool, possibly showing the brine pool may fluctuate in depth (like a tide pool). Associated with a small carbonate hardground outcrop, multiple streams of escaping oil droplets (escaping at varying rates, but at rates of multiple droplets/min) were observed emanating from a living mussel bed. A gas stream was also observed. The fauna associated with the escaping gas and oil included:

buccinid mussels, chitons, *Alvinocaris* sp. shrimp, an unidentified white urchin that was common, *Lamellibrachia* sp., and *Chrysogorgia* sp. Stoloniferous octocorals were the first finding. There was a cluster of not previously seen small, white, unidentified ophioroids living between the mussels as well as Venus flytrap anemones (*Actinoscyphia aurelia*). A few cusk eels were also sighted during the dive.

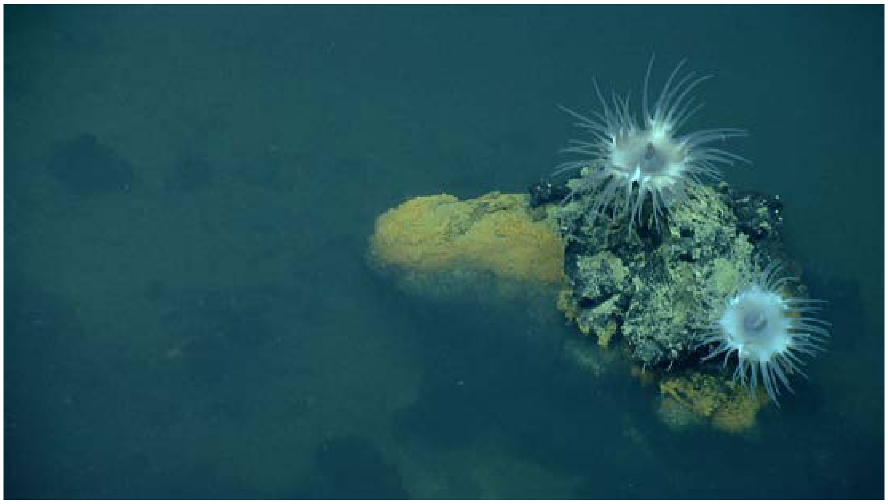

Figure 4. Unidentified anemones on an island outcrop in a brine pool.

Figure 5: The 'shoreline' of the brine pool.

Dive 03

The site for Dive 03, nominated by deep sea coral habitat modeler Brain Kinlan of NOAA, specifically targeted bamboo, black, and *Paramuricea* spp. corals. Most of Dive 03 involved moving slowly up a steep slope (**Figure 6**), featuring scattered (carbonate) hardground outcrops of varying size. Occasional concentrations of live mussels and clams, as well as bacterial mats were encountered, but escaping bubbles were observed only once. Generally disarticulated bivalve shells were ubiquitous, suggesting proximity to chemosynthetic communities. The steepness of the slope led to substantial visual evidence of downslope sediment movement, evinced by slide scars. The topographic high was generally characterized by pronounced hummocky topography. Seven of the 11 predicted corals in the models were observed on Dive 03, example in **Figure 7**. A total of six species of gorgonian were observed, including the target species: *Chrysogorgia* sp. and antipatharians (**Figure 7**); however, no bamboo corals were encountered.

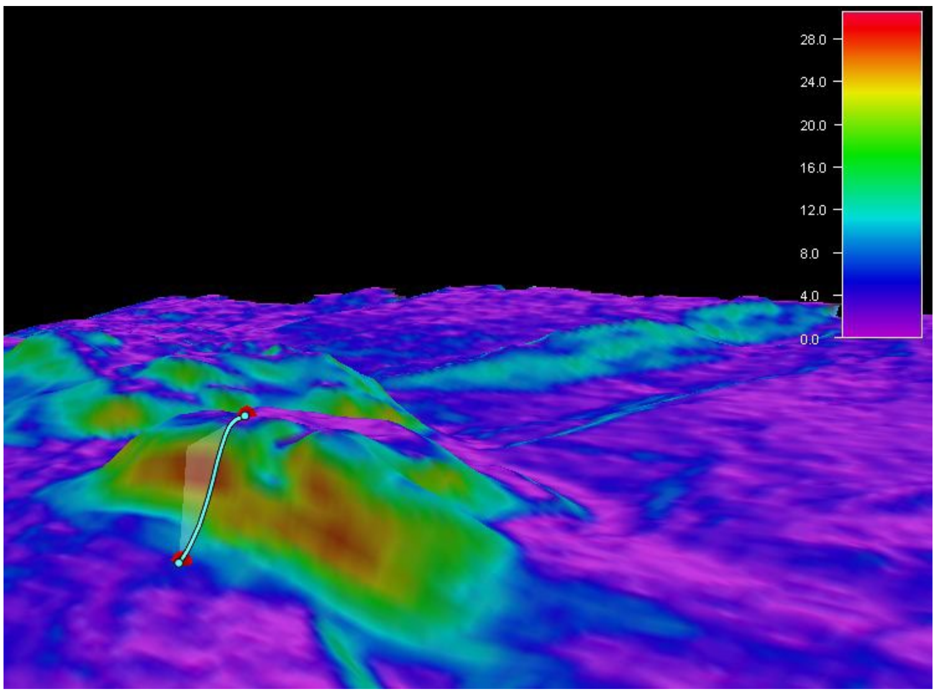

Figure 6. EM 302 bathymetry (colored by slope) and proposed ROV dive track (in cyan). Scale is percent grade.

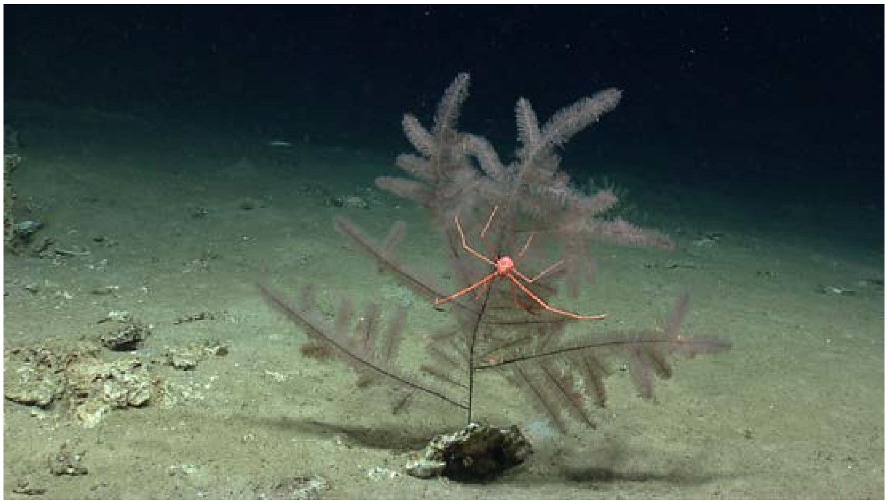

Figure 7. A squat lobster on a black coral.

Dive 04

Dive 04 was designed as a transect that ran from the west side of the thalweg (main channel) of Keathley Canyon, in approx.2,000 m, across the thalweg and upward, this was across two west-facing slopes and an intervening bench. The thalweg was characterized by soft, unconsolidated sediment (**Figure 8**). In the thalweg, holothurians were the dominate fauna (*Enypniastes* spp.). There were a few asteroids (Goniasteridae family, likely *Tethiaster grandis*), a few thread shrimp, a ragged bigscale (*Scopelogadus* sp.), and a halosaur (common). The higher, steeper, longer slope became progressively steeper to the east. Rubble increased in both size and frequency as the slope was transected. The uppermost part of the slope in places was near-vertical. Comatulid crinoids (unattached to the bottom) were abundant, and all appeared to be the same species. There also were more *Hyalonema* sp. (stalks and living specimens, **Figure 9**), as well as living bamboo corals, cerianthid anemones, *Paramuricea* sp., and rare *Paragorgia* sp. (bubblegum coral) octocorals.

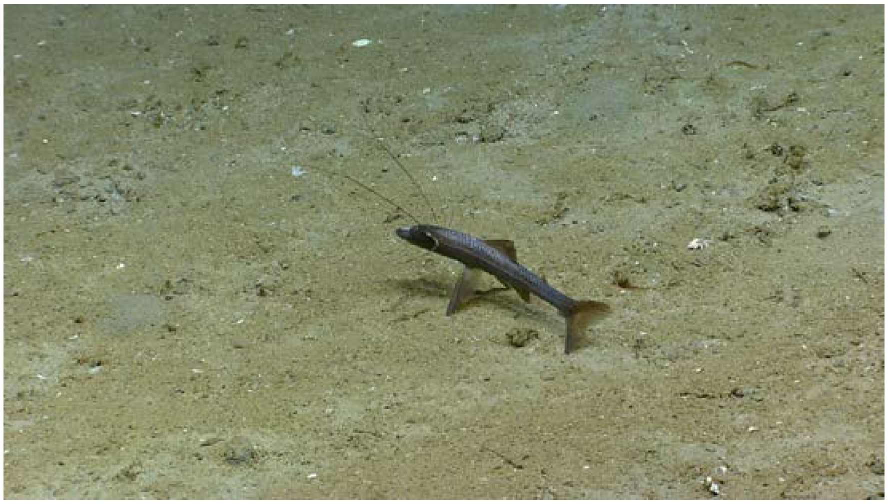

Figure 8. A tripod fish rests on the soft, unconsolidated sediment.

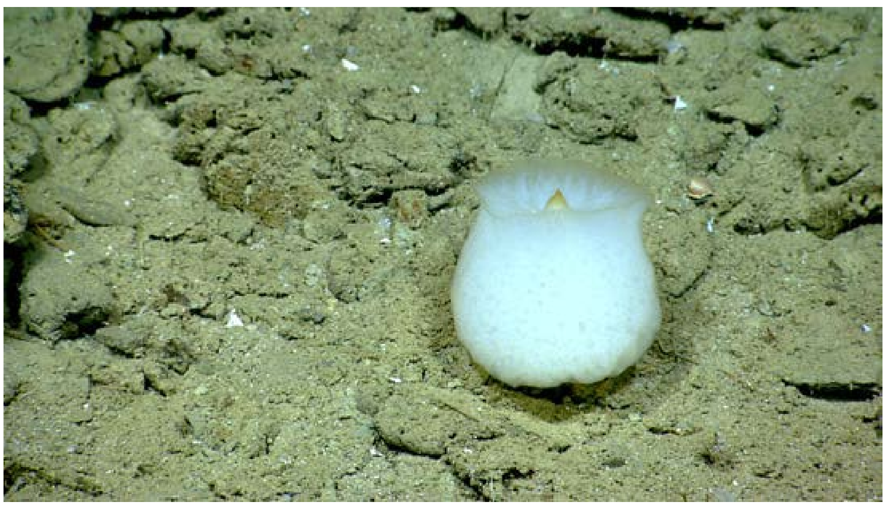

Figure 9. *Hyalonema* sp. on consolidated sediment/rubble.

Dive 05

Dive 05 revisited two shipwrecks previously discovered: Monterrey A was visited by *Okeanos Explorer* in 2012, and Monterrey C was visited by E/V *Nautilus* in 2013. There is a third associated wreck site (Monterrey B) in the vicinity of these two wrecks. All wreck sites were initially identified as side-scan sonar anomalies from a survey conducted in October 2011 by Shell Oil. Both wrecks were investigated again in great detail, involving slow perimeter visualizations. The vehicles transited nearly one hour in the water between the two wrecks on a single dive. While both wrecks were fairly barren of biological life, there were some chemosynthetic *Lamellibrachia* sp. tubeworms and *Alvinocaris* sp. shrimp present along with flytrap anemones. **Figure 10** shows the bow of Monterrey C and **Figure 11** shows glass bottles found inside the perimeter of the wreck. Additional background on the Monterrey Shipwreck

Project can be found here: https://core.tdar.org/collection/65518/the-monterrey-shipwreck-project-three-early-19th-century-wrecks-in-the-northern-gulf-of-mexico (last accessed April 2021)

Figure 10. Bow of Monterrey C ship wreck.

Figure 11. Glass bottles associated with the wreck site.

Dive 06

Dive 06 was conducted approximately 20 kilometers (km) south of Dive 04. The initial view of the seafloor, at 2,130 m, showed unconsolidated sediment with pronounced oscillatory ripples. An increase in hummocky seafloor associated with (carbonate?) hardground and layered outcrops of more consolidated material was observed as the dive progressed. The terrain looked like a partially sediment laden landslide of a debris field. **Figure 12** displays a deep-sea lizard fish perched on the unconsolidated sediment. *Paleodictyon* holes (**Figure 13**) were seen at one location on a hard-bottom face, which was a major highlight of this dive. This is likely the first record to-date of *Paleodictyon* holes documented in the Gulf.

Figure 12. A deep-sea lizard fish (*Bathysaurus* sp.) lays on unconsolidated sediment.

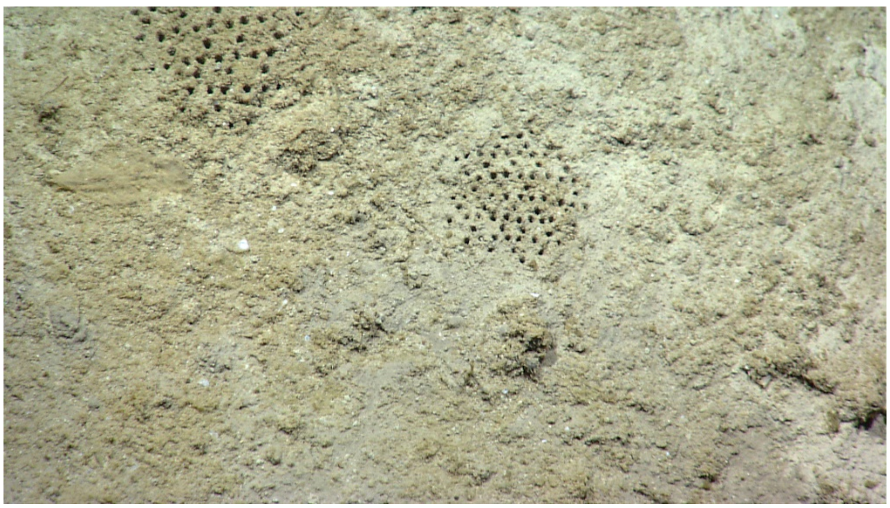

Figure 13. *Paleodictyon* holes were seen on a hard-bottom face.

Dive 07

Dive 07 conducted the same type of detailed visualization on Monterrey B (**Figure 14** and **Figure 15**) as was done on Monterrey A and Monterrey C during Dive 05. This dive targeted a small wooden vessel from the early 19th century in roughly 1,300 m of water. It is the smallest of the three Monterrey shipwrecks. Both Dive 05 and Dive 07 represent the kind of reconnoitering necessary for diagnostic artifact recovery from these wrecks in 2015 (or later). The dive began with a slow transit starting at the stern, moved along the starboard side to the bow, and then returned to the stern along the port side. All visible artifacts were carefully inspected and recorded, and the associated colonizing organisms were identified or described. Artifacts and features of particular interest included an iron gudgeon and pintle; a cast iron ship's stove; two cántaros (water storage jars from Yucatán); large glass bottles; ceramic

tableware; navigational instruments; bales and stacks of hides; large white blocks (hypothesized to potentially be tallow, copal, or rubber); and intact wooden boxes, which may still contain their original contents. Biological observations on and near the Monterrey B wreck included sea cucumbers, crustaceans (including shrimp, squat lobsters, and crabs), corals, tubeworms, isopods, polychaetes, anemones, ship worms, clams, eels, sea spiders, bivalves, brittle stars, spoon worms, limpets, and bacterial mats. There were only a few *Lamellibrachia* sp. tubeworms.

Figure 14. Anchor of Monterrey B wreck.


Figure 15. Timber of Monterrey B wreck being consumed by worms.

Dive 08

Dive 08 focused on the westward-facing slope near Keathley Canyon's deepwater entrance. Until the last 15-20 min of the dive, the bottom was characterized as a sediment seafloor; ripples, consistently suggesting intermittent downslope/down-canyon currents, were often present. Throughout the dive, there were many unidentified shrimp, *Benthodytes typica* (swimming holothurian) and Echiura (spoon worm) feeding marks. Hexactinellid tube sponges (?*Euplectella*-type) were common (**Figure 16**), all with osculum facing towards the north (up-canyon). Encrusting bryozoans were observed (**Figure 17**). Towards the top of a second slope and the end of the dive, a more hummocky seafloor was encountered, with abundant, nodular (carbonate) hardground outcrops sighted, and one *Paramuricea* sp. octocoral with associated goose neck barnacles.

Figure 16. A *Euplectella*-type glass sponge facing up-canyon.

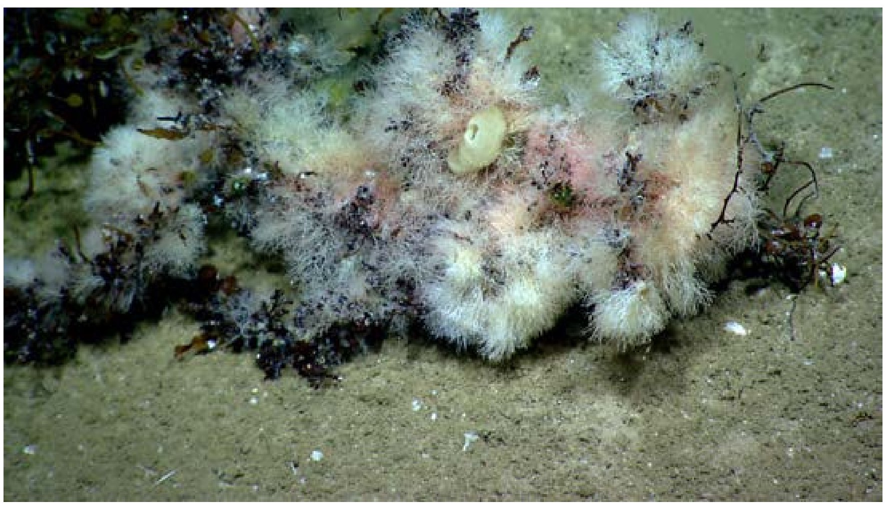

Figure 17. A bryozoan covered in pieces of debris.

Dive 09

Dive 09 examined a ridge along the “shallow” eastern flank of Keathley Canyon, at water depths of 2,400-2,600 m. Throughout the dive, there were holothurians and ophioroids present, along with unidentified shrimp and *Plesiopenaeus armatus* (deep relative of the royal red shrimp). Common to abundant throughout the dive were holothurians (*Benthodytes typica*, *Enypniastes*) and two different species of tripod fish. Cerianthids were common, with some flytrap anemones as well as Pennatulacea (*Umbellula* sp.). There were a few hexactinellid (*Euplectella*-type) sponges, all with osculum facing ~north (up-canyon). Holothurians (*Enypniastes* sp.), Psycropotidae, and *Euplectella*-type hexactinellids were also observed (**Figure 18**). Soft, un-rippled sediment gave way upslope to ~parallel gullies/rills/mega-furrows (several meters wide), with complex bases, oriented generally downslope. These drainage features were generally 3-5 m wide and an estimated 1-2 m deep (**Figure 19**). Small, circular depressions suggested mass removal in the shallow subsurface. At the crest of the ridge, layered outcrops were occasionally observed, supporting high backscatter. The furrowed area was mostly barren, but with some tube polychaetes and shrimp (*Portunus armatus*).

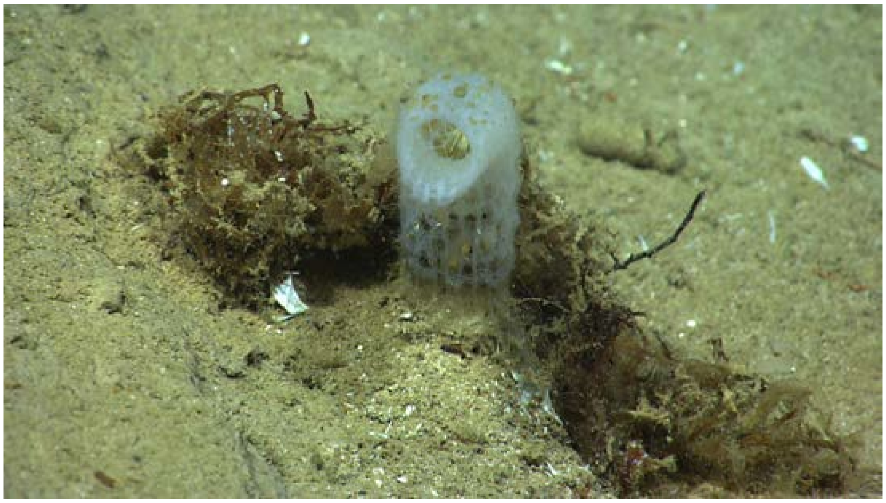

Figure 18. A *Euplectella*-type tube sponge faces up-canyon.

Figure 19. Parallel gullies/rills/mega-furrows are characteristic (common?) at this site.

Dive 10

Dive 10 consisted of two parts: midwater examinations at five discrete depths for pelagic flora and fauna on descent (**Figure 20**), and a deepwater transect up the western wall of Bryant Canyon. During the pelagic portions, a red jellyfish with “flower petal”-like tentacles and possibly a Narcomedusae were observed. Extensive hardground outcrops, and furrows similar to those found on Dive 09, were observed at depth. Hardgrounds and layered outcrops persisted, with occasional near-vertical slopes (**Figure 21**), until the top of the slope was reached. Rippled seafloor also occurred intermittently at this location. Ophioroids, holothurians (*Benthodytes typica* and *Benthothuria* sp.) were common. The rare orange sea star, *Dytaster* sp., was also observed.

Figure 20. A red jellyfish is seen during the pelagic transects.

Figure 21. Occasional near-vertical, almost barren, slopes were observed.

Dive 11

Dive 11, nominated by NOAA NCCOS deep sea coral modeler Brian Kinlan, specifically targeted bamboo, black, and *Paramuricea* spp. corals. The dive focused on part of the Sigsbee Escarpment wall. As the ROV began to move up the slope, the seafloor became stepped, characterized by nearly flat-lying outcrops/ridges of layered sediments exposed at the seafloor. One of the resistant layers looked like sandstone. Concretions of various shapes associated with this ridge were observed; some were hollow with likely Iron-rich rims, while others appeared cylindrical (again with Iron rich outer walls). A narrow ribbon of prominently rippled sediment hugged the bottom of a small ridge, suggesting the presence of intermittent contour-following currents. Prominent furrows oriented diagonally downslope appeared similar to those observed along the ridge on the east side of Bryant Canyon (Dive 09). Octocoral present on this dive included ?*Sibogagorgia* sp. (bubblegum coral) (**Figure 22**) and several species (>10 specimens) of branched and unbranched bamboo corals. Six-armed Brisingidae (sea stars) were common throughout the dive (**Figure 23**). Dive 11 found corals occurring in depth ranges 300 to 400+ m deeper than previous records suggested in the Gulf of Mexico.

Figure 22. A single ?*Sibogagorgia* sp. (bubblegum coral) resides on the hard ground.

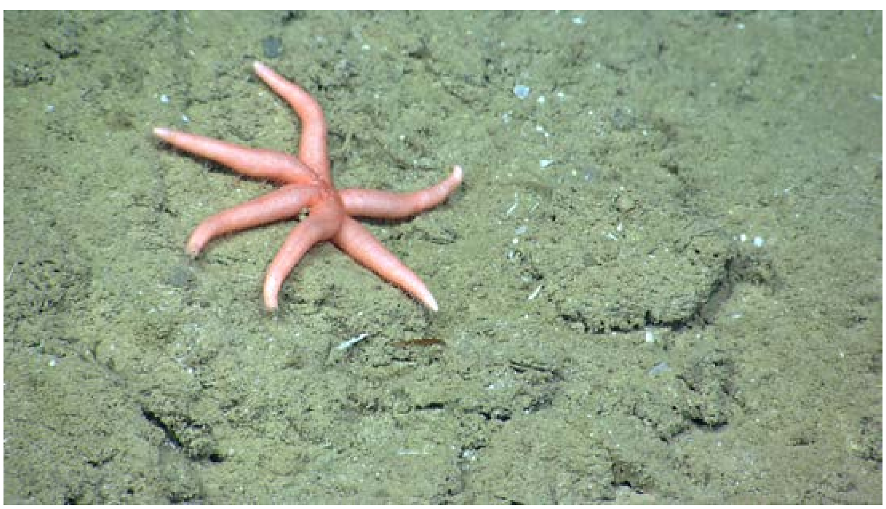

Figure 23. A rare six-armed sea star on hard-bottom substrate.

Dive 12

Site WR0325 was initially discovered in 2010 during an autonomous underwater vehicle (AUV) survey conducted by the Chevron Corporation. A side-scan sonar anomaly showed features that a previous similar anomaly suggested could be a historic shipwreck. Within minutes of observing the first part of this "wreck," it became clear that the feature was a natural phenomenon. Discussion between the onshore science team and the ship zeroed in on the likeliest explanation—that this feature was a flower-like extrusion of asphalt at the seafloor. The other sonar target proved to be another "tar lily" (**Figure 24**), likely caused by volatilization of the asphalt rising from the sub-seafloor upon its contact with seawater. The "tar lilies" were dominated by flytrap anemones, unidentified sponges, octocorals (*Paramuricea* sp. type B1), unidentified white variant, spiral coral (*Iridogorgia* spp.), *Paramuricea* spp., stoloniferous coral (purple and white), and branching bamboo corals (common). There were also a few chemosynthetic fauna, including *Lamellibrachia* sp. tubeworms (**Figure 25**) and shrimp (*Alvinocaris* sp.), as well as bacterial mats. Unidentified actinarians—similar to the ones found at brine pools and cold seeps—were also present.

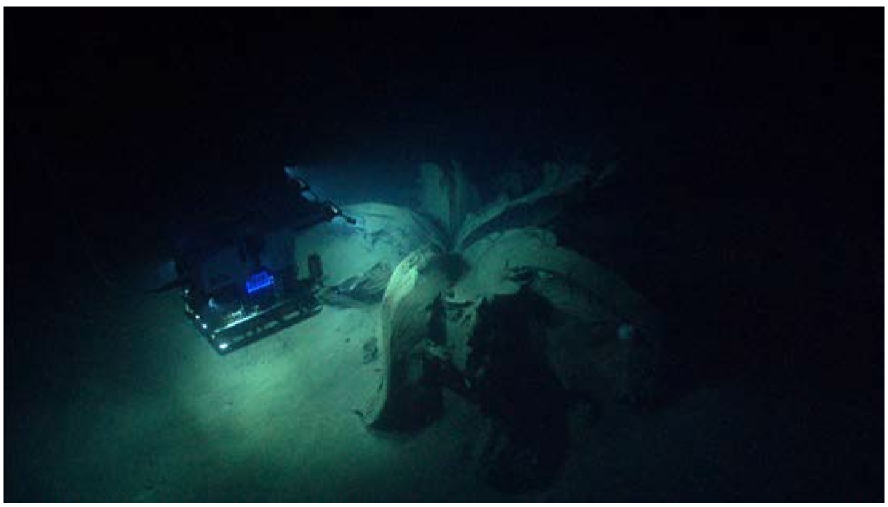

Figure 24. ROV *Seirios* captures ROV *Deep Discoverer* surveying the "Tar Lily."

Figure 25. *Lamellibrachia* sp. tubeworms grow from a crack in the "Tar Lily."

Dive 13

The primary objective of Dive 13 was to transit up the wall of a prominent, salient portion of the West Florida Escarpment to assess deepwater coral habitats. Throughout the dive, there was an abundance of a wide variety of octocorals. These octocorals included multiple species of bamboo corals—both branched and unbranched—namely ?*Jasonisis* sp. and *Keratosis* sp. The observed wall (**Figure 26**), which is the western edge of a massive shallow-water carbonate platform, alternated between vertical intervals (some as large as ~30m) and benches formed as a result of differential erosion of the layered rock wall. On the upper parts, cavernous porosity/caves/overhangs became more prominent. Anthropogenic debris sat on horizontal rock outcrops. Occasionally, chutes filled with clastic sediment led downward to accumulations of sediment on the benches. There were bubble gum corals, increasing in abundance and density toward the top of the wall. *Paracalyptrophora* sp., *Paramuricea* sp., spiral coral (*Iridogorgia* sp.), *Acanella* sp., and *Corallium* sp. were all present (**Figure 27**). After the dive, NOAA deep sea coral modelers (NOAA) noted that the dive encountered everything expected in their coral prediction model for this area.

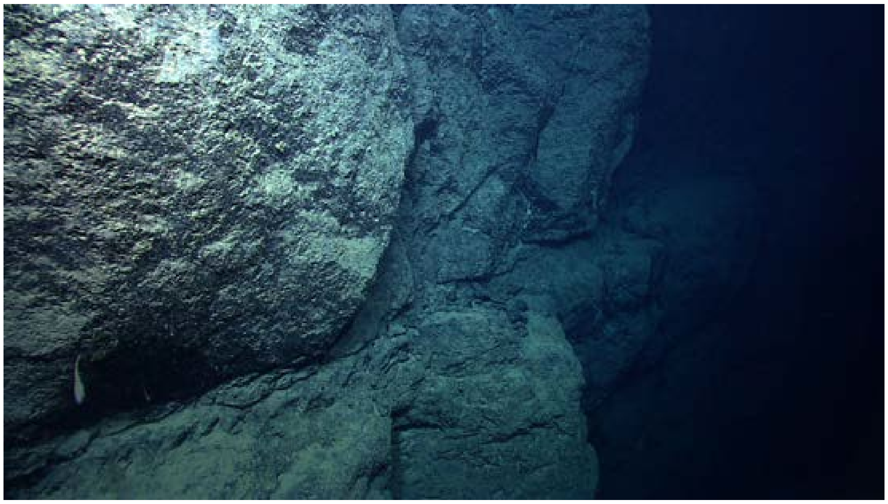

Figure 26. A near-vertical carbonate wall observed on Dive 13.

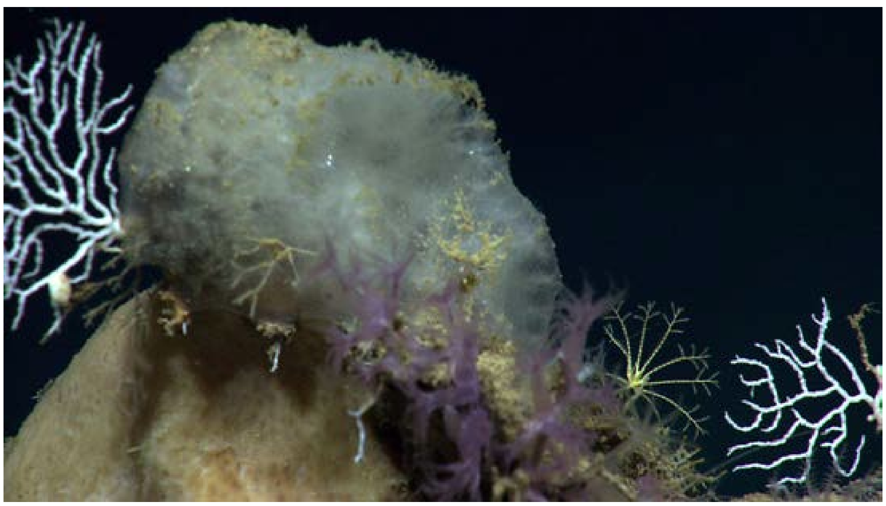

Figure 27. Sponges, bryozoans, crinoids, and stoloniferous corals all captured in a single image.

Dive 14

Dive 14, designed to cross a shallower, overlapping depth range, was also a search for deepwater coral habitats. At the landing, massive carbonate outcrops included areas where sections of broken sedimentary layers of varying thickness were being channeled downslope along nearly vertical joints of…. Patches of soft rippled sediment and meandering crevices/drainage pathways were filled with unconsolidated material. Downslope of the ROV landing location, the remainder of the slope continued to be characterized by a series of steps formed by massive carbonate layers broken by small benches formed by bedding planes. What looked like a stromatoporoid cross-section (Cretaceous?) was observed at 1,919 m. Some of the tops of these massive layers were characterized by fossil burrows, algal mats, and drainage channels. Other layers appeared more friable, and were filled with (fossil?) burrows. One layer appeared to be composed of flaser/lenticular beds (suggesting a tidal environment) in cross-section. Some soft sediment, slightly rippled and occasionally formed into ribbons, was also observed. Mollusk casts were observed just before the end of the dive. At least 23 species of coral were seen throughout the dive, including many young coral colonies, which suggests a healthy ecosystem that is ideal area for recruitment. There was also an increase in coral abundance at about 1,970 m. The corals seen on this dive included scleractinians (*Solenosmilia* sp., *Enallopsammia* sp., or *Madrepora* sp.), solitary cup coral (*Desmophyllum* sp. or other), octocorals (Primnoidae, *Swiftia* sp. [rare], *Paramuricea* sp., *Iridogorgia splendens* [common], *I. magnispiralis*, *Chrysogorgia* sp., *Metallogorgia* sp., *Sibogagorgia* sp. [common to abundant, including may recruits], and *Paragorgia* sp. [white and pink morphs]); bamboo corals (*Lepidisis*-type [unbranched], *Keratoisis* sp., *Isidella* sp., at least two other branching species [including one rare candelabra shaped bamboo]); stoloniferous octocorals (*Clavularia* sp. [purple and yellow morphs, **Figure 28**] and *Anthomastus* sp.), and antipatharians (*Stichopathes* sp., *Bathypathes* sp. [**Figure 29**], *Stauropathes* sp., and *Parantipathes* sp.).

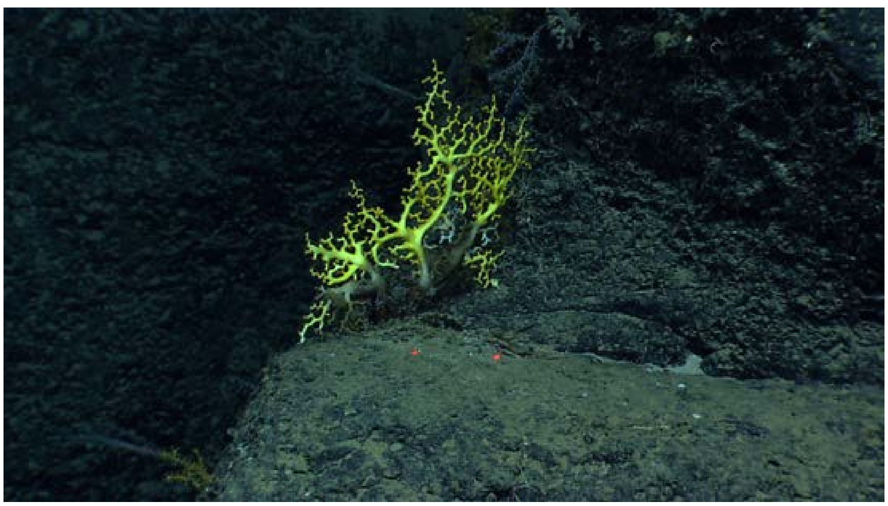

Figure 28. Antipatharian coral rests on the typical hard-bottom substrate as seen on Dive 14.

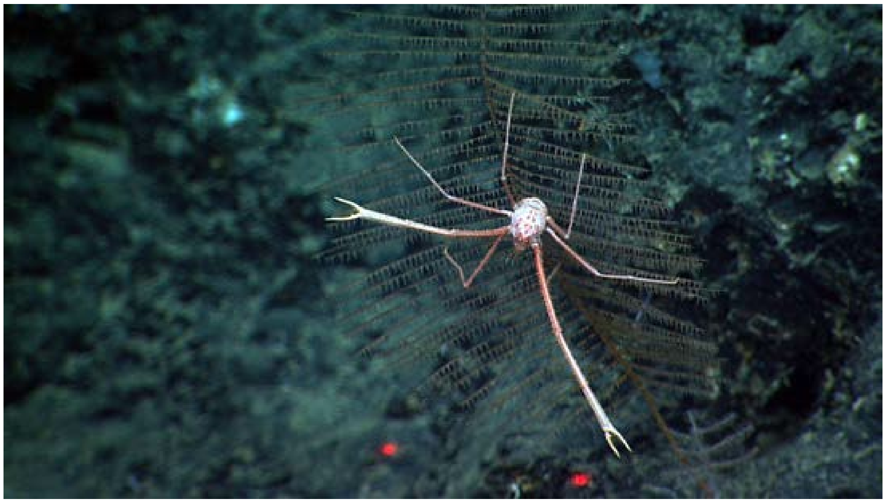

Figure 29. A squat lobster rests on a *Bathypathes* sp. black coral.

Dive 15

The primary objectives of Dives 15 and 16 were to characterize: 1) *Lophelia* and black coral associations on top of a number of mounds/bioherms known to occur in this vicinity, and 2) golden crab occurrences in the vicinity of these corals. On both dives, *Lophelia* was the dominant species and golden crabs were common.

Dive 15 ended up examining four bioherms, floored with platform carbonate similar to that seen on the West Florida Escarpment. Coral rubble (**Figure 30**) was ubiquitous, but little unconsolidated sediment was observed. While transecting the mounds/bioherms, there was 50-100 percent cover of *Lophelia pertusa* coral rubble throughout the dive (this rubble is normal on *Lophelia* bioherms). There was one mound that was 100 percent covered in standing dead coral, with 50-70 percent live cover in parts. This was on the northern side of a mound near Waypoint 4. The *Lophelia* (**Figure 31**) appeared to be on the leeward side of a ridge; the current was flowing over the top of the mound intensely enough to push the ROV.

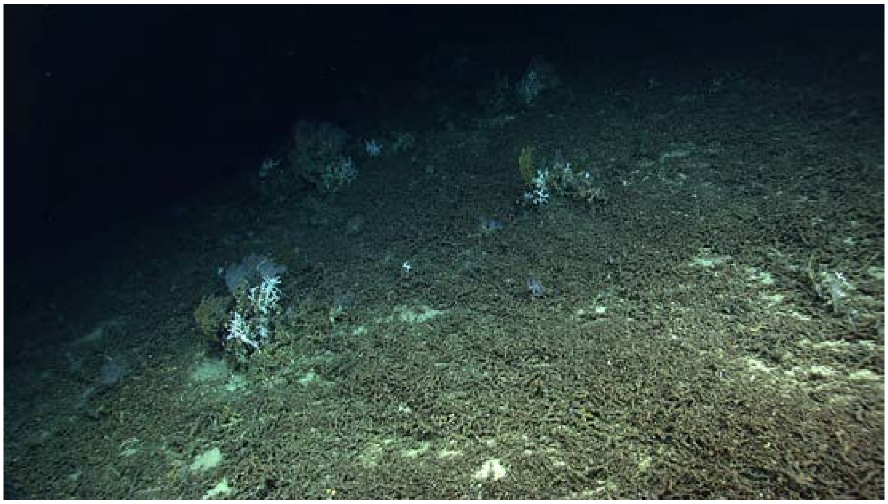

Figure 30. Coral rubble made up the ground cover on all the mounds during Dive 15.

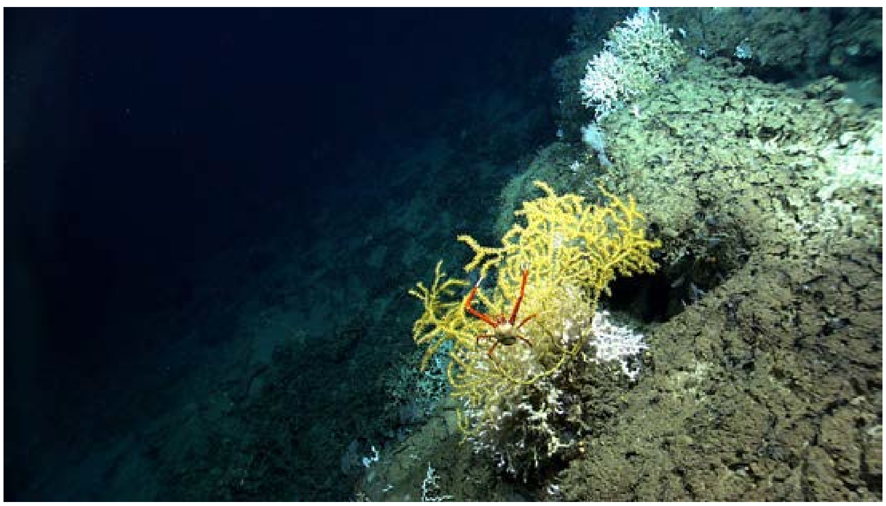

Figure 31. *Paramuricea* sp. and an *Emunida picta* rests on *Lophelia* sp. coral.

Dive 16

Dive 16 also examined multiple bioherms, but there was less evidence for hard (platform carbonate) substrate. Sand was much more common, filling interstices in the coral rubble. A prominent submarine dune covered with ripples confirmed the periodic occurrence of north-to-south bottom currents. While transecting the mounds, there was 50-100 percent cover of *Lophelia pertusa* (**Figure 32**) coral rubble (normal on *Lophelia* bioherms). A few mounds were 100 percent covered in standing dead coral, with 50-70 percent live cover in parts (mostly on the peaks). *Maderepora* sp. was common to abundant throughout. Octocorals (**Figure 33**) were observed during Dive 16. When ROV *Deep Discoverer* passed areas of exposed hard outcrops, they occurred on the northern sides of mounds between Waypoints 5 and 6. This was the only place where *Leiopathes* sp. was observed.

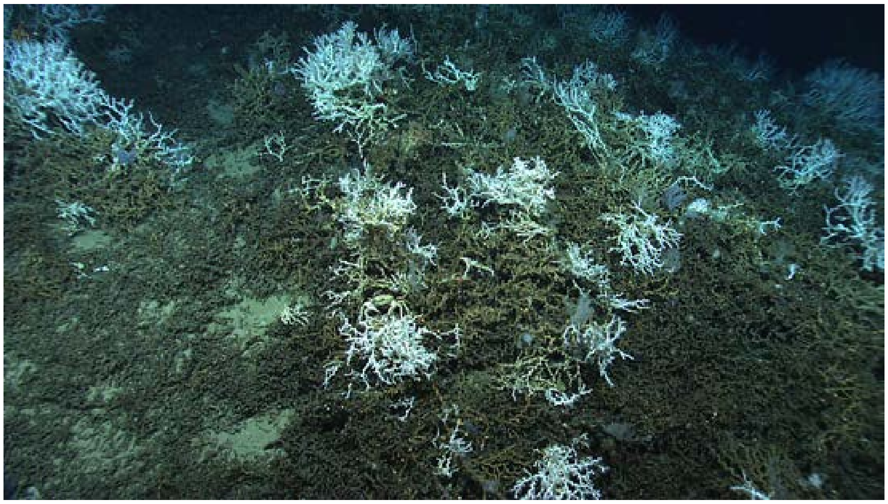

Figure 32. The top peak of a typical *Lophelia* mound was discovered.

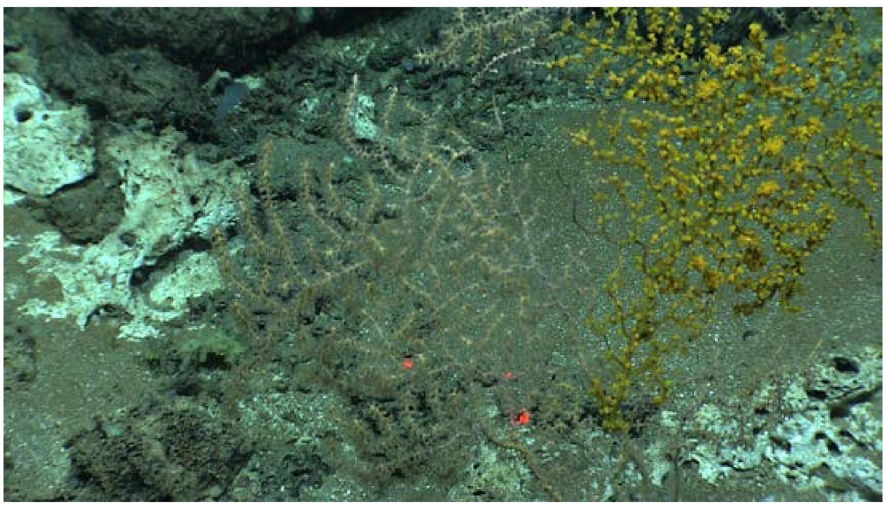

Figure 33. One of the few observed damaged octocorals being overgrown by zoanthids.

7.1.2 Accessing ROV Data

OER Digital Atlas

ROV data from EX-14-02 Leg 3 are archived at the NOAA National Centers for Environmental Information (NCEI) and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm, last accessed March 2021). To access these datum, click on the Search tab, enter "EX1402L3" in the Enter Search Text field, and click Search. Click on the point that represents EX-14-02 Leg 3 to access data options. In the pop-up window, select the ROV Data Access tab for links to the ROV dive data, which has been organized by dive.

ROV Dive Summaries

Individual ROV dive summaries and associated ROV dive data are archived at NCEI and available on their *Okeanos Explorer* website (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm?cruiseNum=EX1402L3, last accessed March 2021).

ROV Dive Video

To search, preview, and download dive video for *Okeanos Explorer*, go to the OER Video Portal (https://www.nodc.noaa.gov/oer/video/, last accessed March 2021)

7.3 Acoustic Operations Results

During EX-14-02 Leg 3, multibeam mapping operations results included 4,443 linear km mapped and 18,641 km^2 covered (18,058 of these in U.S. waters deeper than 200 m).

Figure 34 displays the locations of EX-14-2 Leg 3 bathymetry with previous OER/*Okeanos Explorer* expedition's EM 302 bathymetry. Locations of water column anomalies, EX-14-02 Leg 3 ROV dives, and XBT deployments are also shown. **Figure 35** illustrates an example of a water column anomaly, likely a cold seep, observed in EM 302 water column data from EX-14-02 Leg 3. Both figures are from Lobecker et al. (2014), available here: http://DOI.org/10.7289/V5/MDR-OER-EX1402L3 (last accessed March 2021).

Additional information about the mapping conducted during EX-14-02 Leg 3, including data quality assessments, can be found in the EX-14-02 Leg 3 mapping data report by Lobecker et al. (2014), available here: https://DOI.org/10.25923/d0ha-gy79 (last accessed March 2021).

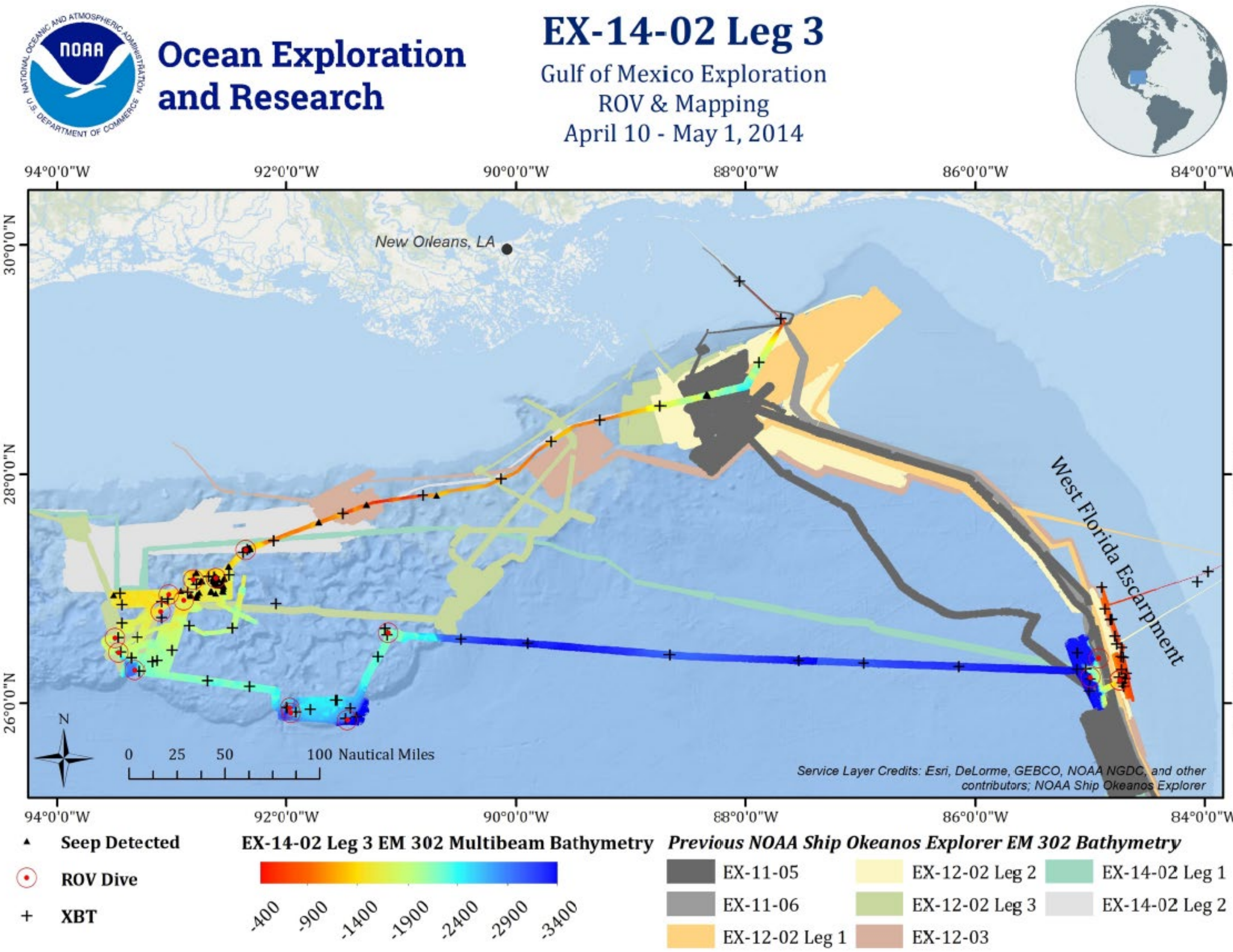

Figure 34. EX-14-02 Leg 3 EM 302 bathymetry, previous OER/*Okeanos Explorer* EM 302 bathymetry, seep locations, ROV dives, and XBT deployment locations.

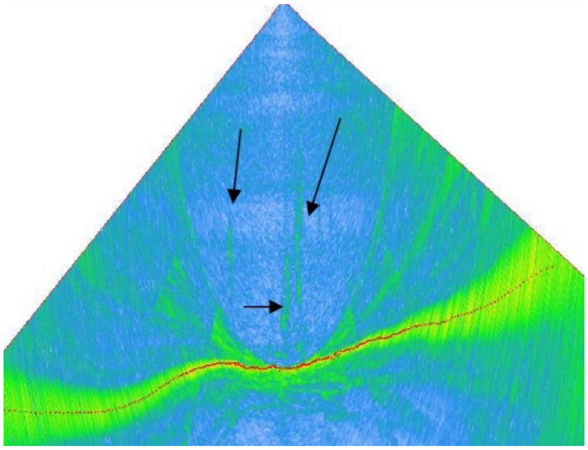

Figure 35. Multiple seeps (black arrows) detected with the EM 302 multibeam sonar, just prior to ROV Dive 03. EX-14-02 Leg 3 multibeam line 0024.

7.3.1 Acoustic Operations Data Access

Multibeam Sonar (Kongsberg EM 302)

The multibeam dataset for the expedition has been archived at NCEI and is accessible through their Bathymetric Data Viewer (https://maps.ngdc.noaa.gov/viewers/bathymetry/, last accessed March 2021). To access thearchived data, click on the Search Bathymetric Surveys button, select "NOAA Ship OKEANOS EXPLORER" from the Platform Name dropdown menu, and "EX1402L3" from the Survey ID dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download individual data sets.

EX-14-02 Leg 3 EM 302 water column backscatter data are also accessible at http://DOI.org/10.7289/V5BZ63ZX (last accessed March 2021).

Sub-Bottom Profiler (Knudsen Chirp 3260)

The sub-bottom profiler was not run during any of EX-14-02 Leg 3's ROV dive operations, but generally was operated during multibeam mapping operations. The data has been archived at NCEI and is accessible through their Trackline Geophysical Data Viewer (https://maps.ngdc.noaa.gov/viewers/geophysics/, last accessed March 2021). To access the data, select "Subbottom Profile" under Marine Surveys and click on Search Marine Surveys. In the pop-up window, select "EX1402_3" in the Filter by Survey IDs dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download data.

Split-beam Sonars (Simrad EK60)

EK60 18 kHz water column data for EX-14-02 Leg 3 are archived at NCEI and available through their Water Column Sonar Data Viewer (https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html, last accessed March 2021). To access these data, click on the Additional Filters button, deselect "All" next to Survey ID, and select "EX1402L3" from the Survey ID list. Click OK, and the ship track for the cruise will appear on the map. Click on the ship track for options to download data. The EK60 data can also be accessed at http://DOI.org/10.7289/V5GQ6VP8 (last accessed March 2021).

7.4 Conductivity, Temperature, and Depth (CTD) Measurements

CTD profile data from EX-14-02 Leg 3 are archived at NCEI and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm, last accessed March 2021). To access these data, click on the Search tab, enter "EX1402L3" in the Enter Search Text field, and click Search. Click on the point that represents EX-14-02 Leg 3 to access data options. In the pop-up window, select the Data Access tab for a link to download the CTD profile data. The Digital Object Identifier (DOI) Uniform Resource Locator (URL) for the oceanographic data package is https://DOI.org/10.7289/V5NC5Z7D (last accessed March 2021).

7.5 Sun Photometer Measurements

Sun photometer measurements are available through NASA's MAN (https://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html, last accessed March 2021). Access these data sets by searching the table for "2014," "Okeanos Explorer," and "Gulf of Mexico." Click on the links to download the data. (Note: There may be more than one entry for *Okeanos Explorer* in a region in a given year.)

7.5 Argo Deployments

Three Argo floats were deployed during EX-14-02 Leg 3 as part of an 'Exploration of Opportunity.' For further information please contact NOAA Atlantic Oceanographic Meteorological Laboratory (AOML).

7.7 Engagement

EX-14-02 Leg 3 engaged with audiences around the world, helping to open a window of understanding into the deep sea. The expedition was highlighted and shared on more than 150 different media venues in the U.S. and Europe, and the live video feeds received more than 700,000 visits during Leg 3. Through social media venues and the OER website's "Ask an Explorer" link, a tremendous number of comments have been shared by the public, expressing excitement about deep-ocean observations and thanking the expedition team for allowing them to "dive" with the EX-14-02 Leg 3 team.

- The live stream web pages on the OER website (oceanexplorer.noaa.gov) received over 188,600 views.
- EX-14-02 Leg 3 web content received over 112,800 views from April 10 - May 1, 2014.

8. Summary

EX-14-02 Leg 3 was the final voyage in a series of three cruises that comprised the *Exploration of the Gulf of Mexico 2014* expedition. Sixteen highly successful telepresence-enabled ROV dives were conducted in two different areas of the Gulf: (1) the northwestern part of the basin, characterized by a very thick (approx. 12-14 km) accumulation of sediments mobilized from below by evaporates/salt, and (2) the central part of the Florida Escarpment, the western edge of a thick carbonate platform, and the outer shelf located next to it. Dive 01 was conducted on April 12, and Dive 16 was conducted on April 29 of 2014.

All of these dives were identified by management groups (https://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/background/mgmt/welcome.html, last accessed March 2021) or supported management interests within the region. During the course of these dives, more than 230 different types of animals were documented.

Northwestern Gulf of Mexico Dives

ROV dives were conducted at a diversity of sites. In the northwestern Gulf of Mexico, dives were conducted at two cold seep sites, two deep-sea coral habitat areas of interest for deep-sea coral modeling, three historic shipwrecks (investigated during two dives), three sites in Keathley Canyon, two sites in Bryant Canyon, and two asphalt volcanoes.

Highlights of these dives included the discovery of asphalt volcanism (nicknamed “tar lilies”) in an area of the Gulf where it was not previously known to occur, discovery of a chronometer (a rare and significant finding for an early 19th century vessel) at Monterrey wreck Site A, and possible extension of the depth range of a few deep-sea coral types in the Gulf of Mexico.

Several rare observations also occurred, including *Paleodictyon* “burrows” in Keathley canyon; a rare orange sea star, *Dytaster* sp., in Bryant Canyon; and a dumbo octopus displaying a body posture that has never before been observed in cirrate octopods.

Western Florida Escarpment Dives

Four ROV dives were conducted at priority sites on the central part of the Western Florida Escarpment, including two dives investigating seafloor habitats in deep water along the escarpment and two dives documenting deep-sea coral habitat on the shelf in high-priority areas of fisheries management.

Highlights from these dives included incredible deep-sea coral diversity (at least 23 species) during one of the deep escarpment dives; the discovery of two potential new species of crinoids; and close-up imagery documenting a sea urchin eating an octocoral—an observation rarely, if ever, captured on camera.

During 22 days at sea, over 18,600 km^2 of largely previously unmapped seafloor were mapped, with mapping operations occurring overnight or when the ROVs were on deck. Over seven gigabytes of EK60 and sub-bottom datum were collected.

More than 70 scientists and students participated in these dives from shore, providing their input and expertise to help characterize these areas and further guide the exploration. Online coverage of the expedition included live video feeds, which were streamed to shore throughout, thus allowing hundreds of thousands of members of the public to join in the dives and virtually explore the ocean with the EX-14-02 Leg 3 mission team.

9. References

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Appendix A: EX-14-02 Leg 3 Data Management Plan

Data Management Plan

Okeanos Explorer (EX1402L3): Gulf of

Mexico Mapping and ROV Exploration

Data Management Objectives

Data management objectives: to provide a foundation of publicly accessible data and information products to spur further exploration, research, and management activities; to provide daily cumulative multibeam products to shore for operational decision making purposes; to record 2 channels of streamed video footage of ROV dives onboard the ship; to prepare for data warehouse upgrades; to evaluate a new video annotation tool brought aboard by the lead biologist; and to test production of a post-mission data product capturing environmental variables along a dive track corresponding to highlight images.

1. General Description of Data to be managed

1.1 Name of the Dataset of Data Collection Project

Okeanos Explorer (EX1402L3): Gulf of Mexico Mapping and ROV Exploration

The overall goal of this cruise is to collect data to aid in the development of a baseline characterization of the targeted operating areas. Science objectives are to identify and explore the diversity and distribution of benthic habitats and features in the region; to conduct ROV dives along the Sigsbee Escarpment and in adjacent deep-water canyons; to locate and characterize underwater cultural heritage sites; to ground truth acoustic seep data and characterize associated habitat; to recover long deployment experiments from the seafloor; and to deploy Argo floats.

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

Okeanos Explorer

1.2 Keywords that could be used to characterize the data.

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, St. Petersburg, Pascagoula, Flower Garden Banks, FGBNMS, Sigsbee Escarpment, benthic habitat, benthic ecosystems, shipwreck, Argo float, expedition

1.4 Summary description of the data to be generated.

Multibeam mapping, single beam, water column sonar, sub-bottom profile, water column profile, ship sensor, ROV sensor, video and image data will all be collected during this mission.

1.5 Anticipated temporal coverage of the data.

Cruise Dates: 4/10/2014 to 5/1/2014

1.6 Anticipated geographic coverage of the data.

Latitude Boundaries: 30 to 24

Longitude Boundaries: -95 to -83

1.7 What platforms will be employed during this mission?

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

1.8 What data types will you be creating or capturing?

Cruise Summary, Data Management Plan, Highlight Images, Quick Look Report, CTD (raw), CTD (processed), CTD (product), Dive Summaries, Highlight Video, Mapping Summary, Multibeam (processed), Multibeam (product), Multibeam (raw), Sub-Bottom Profile data, Water Column Backscatter, XBT (raw), Bottom Backscatter, EK60 Singlebeam Data, SCS Output (compressed), SCS Output (native), Cruise Plan

1.8 What data types will you be submitting for archive?

Cruise Summary, Data Management Plan, Highlight Images, Quick Look Report, CTD (raw), CTD (processed), CTD (product), Dive Summaries, Highlight Video, Mapping Summary, Multibeam (processed), Multibeam (product), Multibeam (raw), Sub-Bottom Profile data, Water Column Backscatter, XBT (raw), Bottom Backscatter, EK60 Singlebeam Data, SCS Output (compressed), SCS Output (native), Cruise Plan

1.9 What volume of data is anticipated to be collected in the Project Time Frame?

7-10 TB

2. Points of Contact

2.1 Who is the overall point of contact for the data collection?

Kelley Elliott, Contractor (Acentia/2020 LLC), NOAA Office of Ocean Exploration and Research,

kelley.elliott@noaa.gov

2.2 Who is responsible for verifying the quality of the data?

Elizabeth Lobecker, Multibeam Mapping Expert, Contractor (ERT, Inc.), NOAA Office of Ocean Exploration and Research, elizabeth.lobecker@noaa.gov

2.3 Who is responsible for data documentation and metadata activities?

Susan Gottfried, Data Management Coordinator, NOAA National Coastal Data Development Center,

susan.gottfried@noaa.gov

2.4 Who is responsible for data storage and data disaster recovery activities?

NOAA National Data Centers (National Geophysical Data Center, National Oceanographic Data Center, NOAA Central Library)

3. Data Stewardship

3.1 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. Okeanos Explorer (EX1402L3): Gulf of Mexico Mapping and ROV Exploration

4. Data Documentation

4.1 Which metadata repository will be used to document this data collection?

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 NCDDC for public discovery and access. The record will be harvested by data.gov.

4.2 What additional metadata or other documentation is necessary to fully describe the data and ensure its long-term usefulness?

Additional metadata includes: Multibeam metadata to file level; Scientific Computing System (SCS) metadata; Machine Readable Catalog (MARC) metadata for Library items.

4.3 What standards will be used to represent data and metadata elements in this data collection?

ISO 19115-2 Geographic Information with Extensions for Imagery and Gridded Data will be the metadata standard employed; a NetCDF-4 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.

5. Data Sharing

5.1 What date will the data be made available to the public?

All non-sensitive data from this mission is expected to be documented, archived and accessible within 60-90 days post-mission through the NOAA National Data Centers and public access GIS map applications. Meteorological and Oceanographic (METOC) sensor data from the SCS, and CTD data are converted in a post-mission model into archive ready compressed NetCDF-4 format and stored within the NCDDC THREDDS open-access server. Any data considered sensitive due to protection of potential underwater cultural resources will be protected from public access under the Historic Preservation Act.

5.2 If the data are not to be made publicly available, under what authority are the data restricted?

Not Applicable

5.2a Access Constraints Statement?

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

5.2b Use Constraints Statement?

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

6. Initial Data Storage and Protection

6.1 Where and how will the data be stored initially (prior to archive submission)?

Data are recorded and stored on NOAA shipboard systems compliant with NOAA IT procedures. Data are moved from ship to shore using a variety of standard, documented data custody transfer procedures. Data are transferred to NOAA Data Centers using digital and physical data transfer models depending upon the data volume.

6.2 Discuss data back-up, disaster recovery, contingency planning and off-site storage relevant to this data collection.

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

6.3 Describe how the data will be protected from unauthorized access, how permissions will be managed and what process will be followed in the event of 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. Long-Term Archiving and Preservation

7.1 In what NOAA Data Center(s) will the data be archived and preserved?

Data from this mission will be preserved and stewarded through the NOAA National Data Centers. Refer to the Okeanos Explorer FY14 Data Management Plan at NOAA's EDMC DMP Repository (EX_FY14_DMP_Final.pdf) for detailed descriptions of the processes, procedures, and partners involved in this collaborative effort.

7.1a if you do not plan to archive in the NOAA Data Centers, what is your long-term strategy for maintaining, curating, and archiving the data?

Not Applicable

7.2 What transformations or procedures will be necessary to prepare data for preservation or sharing?

SCS data shall be delivered in its native format as well as an archive-ready, documented, and compressed NetCDF-4 format to NODC; multibeam data and metadata will be compressed and delivered in a bagit format to NGDC.

Appendix B: EX-14-02 Leg 3 Categorical Exclusion

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
OCEANIC AND ATMOSPHERIC RESEARCH
Office of Ocean Exploration
Silver Spring, MD 20910

March 24, 2013

MEMORANDUM FOR: The Record

FROM: John McDonough
Acting Director NOAA Office of Ocean Exploration and Research (OER)

SUBJECT: Categorical Exclusion for NOAA Ship *Okeanos Explorer* cruise EX1402, Leg 3

NAO 216-6, Environmental Review Procedures, requires all proposed projects to be reviewed with respect to environmental consequences on the human environment. This memorandum addresses the NOAA Ship *Okeanos Explorer's* scientific sensors possible affect on the human environment.

Description of Projects

This project is part of the Office of Ocean Exploration and Research's "Science Program." It will conduct remotely operated vehicle (ROV) operations and ocean mapping activities designed to increase knowledge of the marine environment. This project is entitled "EX1402 Gulf of Mexico Exploration" and will be led by Kelley Elliott, an Expedition Manager for NOAA OER. The work will be conducted in April and May at various locations in the Gulf of Mexico: an area to the south and southeast of Flower Garden Banks National Marine Sanctuary, including Keathley Canyon and adjacent parts of the Sigsbee Escarpment; and areas in on the West Florida Escarpment southwest of Tampa. A tandem 6,000 meter ROV system will be deployed and CTD rosette casts may be conducted during the expedition. The Kongsberg EM 302 multibeam (30 kHz), Kongsberg EK 60 singlebeam (18 kHz), and Knudsen 3260 Sub-Bottom Profiler (3.5 kHz) will be operated during the project. Additionally, expendable bathythermographs (XBTs) will be conducted in conjunction with multibeam data collection. Multibeam mapping operations will be conducted at all times during the transit.

Effect of Projects

As expected with ocean research with limited time or presence in the marine environment, this project will not have the potential for significant impacts. Knowledgeable experts who are aware of the sensitivities of the marine environment will conduct the at-sea portions of this project.

Categorical Exclusion

Printed on Recycled Paper

This project would not result in any changes to the human 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. As such, this project is categorically excluded from the need to prepare an environmental assessment.

Signed:_________________________ Date:________________

John McDonough, Acting Director

Appendix C: Revised Guidance and Standard Operating Procedure for OER sonar operations on NOAA Ship *Okeanos Explorer* in the vicinity of marine mammals and sea turtles

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Office of Ocean Exploration and Research
1315 East-West Hwy, SSMC3
Silver Spring, MD 20910 USA

March 7, 2014

MEMORANDUM FOR: The Record
NOAA Office of Ocean Exploration and Research

FROM: Craig W. Russell, Program Manager
NOAA/OAR/OER

SUBJECT: Revised Guidance and Standard Operating Procedure for OER Sonar operations on NOAA Ship *Okeanos Explorer* in the vicinity of marine mammals and sea turtles

This memorandum document and sets forth revised guidance for OER sonar operations on the NOAA Ship *Okeanos Explorer* in the vicinity of marine mammals and sea turtles.

In 2011, NOAA's Southwest Fisheries Science Center provided guidance to the Office of Ocean Exploration and Research (OER) on multibeam, splitbeam, and subbottom sonar use on the NOAA Ship *Okeanos Explorer* specific to OER expeditions within and in the vicinity of National Marine Sanctuaries and endangered whales in California for March 16-April 1, 2011.

OER continued to use that guidance as basis for mapping Standard Operating Procedures since the guidance was not operationally prohibitive. Since mid-2011, OER has conducted *Okeanos Explorer* sonar operations in the Atlantic basin, including the Gulf of Mexico. Although OER sought but never received additional guidance from the National Marine Fisheries Northeast Regional Office, we consulted NOAA's existing acoustic threshold guidance and determined, based on the best information available, that the EX's sonar surveys and mapping activities are not likely to have significant impacts on marine mammals or sea turtles of a direct or cumulative nature. Currently, OER operates mission systems on the *Okeanos Explorer* under a signed Categorical Exclusion.

With consideration given to best management practices that ensure encounters and impacts with marine mammals and sea turtles are minimized, OER will implement its *Okeanos Explorer* sonar mapping standard operating procedure as follows: sonars will be secured if (1) encountered marine mammals or sea turtles appear disturbed or (2) it is operationally efficient, or legally required to do so by permit, guidance, policy, or law. This SOP will be revisited as new information, guidance, or policy is obtained or provided.

Appendix D: Acronyms

AERONET—Aerosol Robotic Network
AHB—NOAA Atlantic Hydrographic Branch
AOML—NOAA Atlantic Oceanographic Meteorological Laboratory
AUV—Autonomous underwater vehicle
BOEM—Bureau of Ocean Energy Management
BSEE—Bureau of Safety and Environmental Enforcement
CCOM—Center for Coastal and Ocean Mapping
CE—Categorical exclusion
CIOERT—Cooperative Institute for Ocean Exploration, Research & Technology
CTD—Conductivity, temperature, depth
DO—dissolved oxygen
DOI—Digital Object Identifier
DP—Dynamic positioning
DSCRTP—NOAA Deep-Sea Coral and Research Program
ECC—Exploration Command Center
ECS—Extended Continental Shelf
ECU—East Carolina University
EEZ—Exclusive Economic Zone
FAU—Florida Atlantic University
Fe—Iron
FGBNMS—NOAA Flower Garden Banks National Marine Sanctuary
FSU—Florida State University
GEMS—Geoscience Earth & Marine Services
GMFMC—Gulf of Mexico Fisheries Management Council
HAPC—Habitat area of particular concern
HBOI—Harbor Branch Oceanographic Institute
ISC—Inner Space Center
JHC—Joint Hydrographic Center
JOSS—Joint Office for Science Support
kHz—Kilohertz
km—Kilometer
LSS—Light scattering
LSU—Louisiana State University
MAN—Maritime Aerosol Network
Mbps—Megabits per second
MPA—Marine protected area
NASA—National Aeronautics and Space Administration
NCCOS—NOAA National Centers for Coastal Ocean Science
NCDDC—NOAA National Coastal Data Development Center
NCEI—NOAA National Centers for Environmental Information
NEPA—National Environmental Policy Act

NMFS—NOAA National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
NOC—NOAA Network Operations Center
OAR—NOAA Oceanic and Atmospheric Research
OCS—NOAA Office of Coast Survey
OER—NOAA Office of Ocean Exploration and Research
ONMS—NOAA Office of National Marine Sanctuaries
ORP—Oxygen reduction potential
PMEL—NOAA Pacific Marine Environmental Laboratory
ROV—Remotely operated vehicle
RSS—Really Simple Syndication
SIS—Seafloor Information System
SOP—Standard operating procedure
TAMUG—Texas A&M University at Galveston
TSG—Thermosalinograph
UCAR—University Corporation for Atmospheric Research
UCH—Underwater Cultural Heritage
UConn—University of Connecticut
ULL—University of Louisiana at Lafayette
UNH—University of New Hampshire
URI—University of Rhode Island
URL—Uniform Resource Locator
USGS—U.S. Geological Survey
VIMS—Virginia Institute of Marine Science
VSAT—Very small aperture terminal
WHOI—Woods Hole Oceanographic Institution
XBT—Expendable bathythermograph