Sponsored Projects

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Sponsored Projects

The NOAA Office of Ocean Exploration and Research

Introduction

By Nathalie Valette-Silver, Stephen R. Hammond, Frank Cantelas, Chris Beaverson, Adrienne Copeland, Katharine Egan, Amanda N. Netburn, Margot Bohan, Yvette Jefferson, and Joyce Woodford

NOAA's Office of Ocean Exploration and Research is the only federal program dedicated to exploring the deep ocean, closing gaps in our basic understanding of US deep waters and seafloor, and delivering ocean information needed to strengthen the economy, health, and security of our nation. To accomplish its mission, OER conducts ocean exploration expeditions and campaigns using NOAA Ship *Okeanos Explorer* and a variety of other ships, engages in formal partnerships as well as national and international alliances, and sponsors ocean exploration and technology innovation and development projects. Sponsored projects include competitive grants, cooperative agreements, and unsolicited projects that align with NOAA and OER missions.

In fiscal year 2019, OER published a Federal Funding Opportunity (FY19 FFO) that invited proposals for exploration in ocean waters under US jurisdiction, including the US EEZ and areas mapped by, or of interest to, the US Extended Continental Shelf (ECS) project. Important marine habitats as well as potential living and nonliving resources within the EEZ and ECS are neither fully explored nor characterized. Funded FY19 FFO grants are addressing these knowledge gaps and, in doing so, are providing information that will help support the nation's Blue Economy.

FY19 FFO projects focused on (1) discovery of microorganisms, sponges, corals, and other organisms with biopharmaceutical or biotechnical potential; (2) acquisition of baseline ocean environmental information to better inform decision-making where future ocean energy development or critical mineral extraction may occur; and (3) finding and characterizing shipwrecks and submerged cultural resources that played a role in America's historical ocean-based economy. In FY19, OER funded eight such FFO projects (Figure 1) and three technology projects through the National Oceanographic Partnership Program competition.

NOAA's Cooperative Institute for Ocean Exploration, Research, and Technology (CIOERT) continued to conduct exploration and research focused on OER's priorities. FY19–FY20 will mark the end of a highly successful 10-year OER/CIOERT collaboration that led to major marine biology discoveries, including new species and habitats and the development of instruments that advanced ocean exploration.

Also in 2019, through a competitive process, NOAA selected the University of Rhode Island to host an exploration-focused cooperative institute. In this Ocean Exploration Cooperative Institute (OECI), URI will lead a consortium of four graduate degree-granting institutions, one ocean exploration nonprofit, and several task-specific partners to support and enhance core NOAA Ocean Exploration priorities. Significantly, OECI aims to leverage science, technology, and outreach/education capacities that do not currently exist within NOAA. An OECI priority is to transition away from the current methods of deep ocean exploration by developing and deploying smaller and less expensive ROVs and AUVs.

Finally, during FY19, ongoing grants continued to support marine science discoveries as well as ocean exploration technology innovations. Highlights from selected seagoing projects conducted during fiscal year 2019 follow.

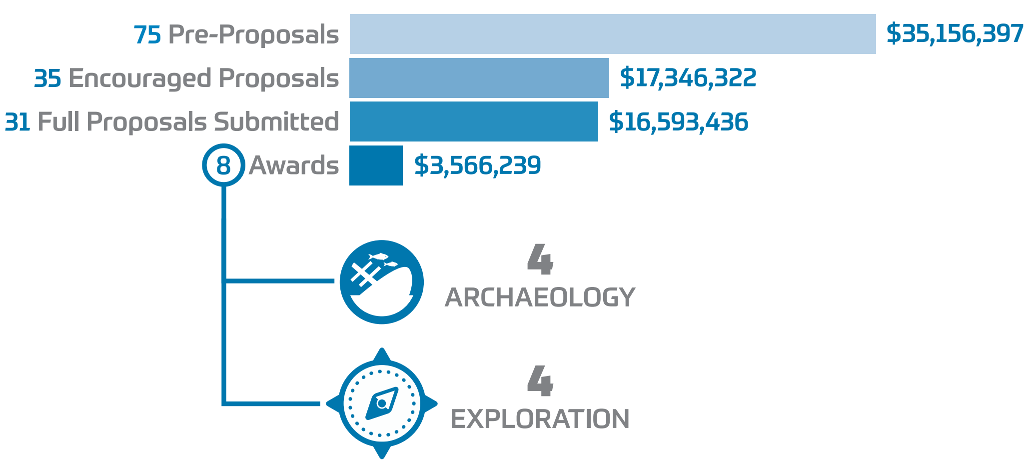


FIGURE 1. FY19 FFO grant projects statistics. *Image credit: Matthew King, NOAA OER*

Cooperative Institute for Ocean Exploration, Research, and Technology

By Joshua Voss and Shirley Pomponi

NOAA's Cooperative Institute for Ocean Exploration, Research, and Technology (CIOERT) is led by Florida Atlantic University's (FAU) Harbor Branch Oceanographic Institute in partnership with NOAA's Office of Ocean Exploration and Research, University of North Carolina Wilmington (UNCW), University of Miami, and SRI International. CIOERT's vision is to transform the way we explore our ocean basins through novel approaches and technology. Disciplined innovation is applied to continually improve, extend, and strengthen NOAA's exploration, research, and operational capabilities. CIOERT serves OER strategic priorities in three theme areas: (1) exploration of continental shelf edge frontiers, (2) research on vulnerable coral and sponge ecosystems, and (3) development of advanced underwater technologies.

In 2019, CIOERT's efforts to explore and characterize mesophotic coral reef ecosystems via ROV and technical diving (Figure 1) continued with four research cruises. Chief Scientists Joshua Voss and John Reed led a team of 20 researchers and graduate students from FAU Harbor Branch and the UNCW Undersea Vehicles Program (UVP) aboard R/V *F.G. Walton Smith* to explore the Florida Keys National Marine Sanctuary (FKNMS) and the Pulley Ridge Habitat Area of Particular Concern (HAPC). The expedition completed 18 ROV dives and conducted benthic surveys designed to assess potential hard bottom habitats at mesophotic depths that had recently been identified by NOAA multibeam mapping in the region. Large areas of mesophotic coral habitat were confirmed near the Key Largo Management Area outside of the current marine protected areas. Stony coral, soft coral, black coral, and sponge samples were also collected from both shallow and mesophotic depths in the Upper Keys, Lower Keys, and Dry Tortugas to assess genetic connectivity across the region. Finally, given the current dramatic outbreak of stony coral tissue loss disease in South Florida and the wider Caribbean, the surveys also assessed coral health status. Fortunately, no tissue loss disease was observed among mesophotic corals in the region (Figure 2). The results of this expedition will provide key information and data as FKNMS implements its Restoration Blueprint.

CIOERT researchers John Reed and Stephanie Farrington completed their eighth expedition with NOAA Fisheries and the UNCW UVP team aboard NOAA Ship *Pisces* in June 2019. Benthic and fish communities in marine protected areas from Florida to the Carolinas were explored and characterized during 33 ROV dives, and multibeam mapping was completed in seven areas including inside the Oculina Bank HAPC. These cruises were designed to identify key mesophotic reef resources and habitats in the southeast US region and to provide data and information that supports management decisions by NOAA and the South Atlantic Fishery Management Council.

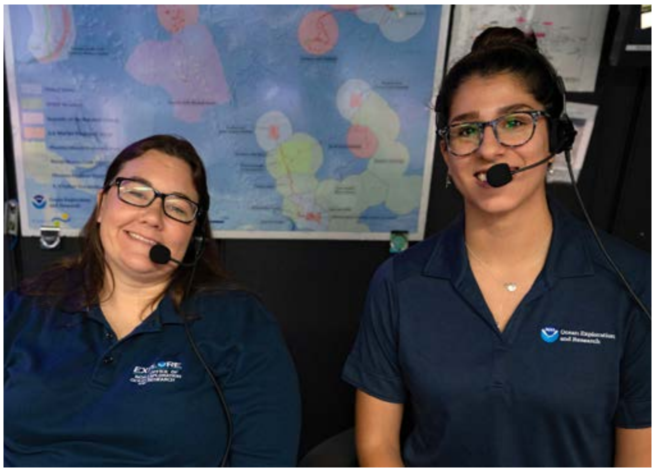
CIOERT-supported graduate students Alexis Sturm and Ryan Eckert successfully completed an expedition aboard M/V *Caribbean Kraken* to assess shallow and mesophotic

FIGURE 1. Technical divers prepare to deploy during CIOERT's Florida Keys National Marine Sanctuary expedition. *Image credit: Voss Lab, CIOERT, FAU Harbor Branch*

FIGURE 2. Alacranes Reef demonstrated impressive coral cover and no active coral disease during CIOERT's July 2019 expedition. *Image credit: Voss Lab, CIOERT, FAU Harbor Branch*

FIGURE 3. Samples collected by ROV from the extensive coral communities in the Flower Garden Banks National Marine Sanctuary during the telepresence expedition will be used to assess genetic connectivity across the northwest Gulf of Mexico and tropical western Atlantic. *Image credit: GFOE*

FIGURE 4. Stephanie Farrington from FAU Harbor Branch and Kimberly Galvez from CIOERT partner University of Miami prepare for a live interaction with FAU Harbor Branch Oceanographic Institute during the 2019 Southeastern US Deep-sea Exploration.



coral reef connectivity in the southern Gulf of Mexico. The expedition focused on two unique coral reef ecosystems, Alacranes Reef and Bajos del Norte, that may contribute coral and sponge larvae to downstream coral ecosystems in Flower Garden Banks and the Florida Keys (Figure 2). A Mexican National Protected Area and UNESCO Biosphere Reserve, Alacranes Reef is situated at the edge of Campeche Bank 140 km to the north of the Yucatán Peninsula. Bajos del Norte is a relatively uncharacterized site near the Yucatán Channel that may be important for coral reef connectivity given its location near the conjunction of the Caribbean Sea and the Gulf of Mexico.

With support from the NOAA Office of National Marine Sanctuaries, FAU Harbor Branch partnered with the Global Foundation for Ocean Exploration, Flower Garden Banks National Marine Sanctuary (FGBNMS), Boston University, and the New York City College of Technology during a telepresence-enabled expedition in the northwest Gulf of Mexico (Figure 3). The mission was the first to use GFOE's portable satellite communications system, which allowed high-resolution video from ROV *Yogi* to be streamed in real time and enabled diverse opportunities for live interactions and community engagement. Samples of sponges, stony corals, and black corals were also collected to expand CIOERT's genetic connectivity research objectives. The expedition focused on banks currently under consideration in the proposed expansion of FGBNMS, providing compelling data and images to support this important management objective.

CIOERT researchers served as key contributors during NOAA Ship *Okeanos Explorer*'s 2019 Southeastern US Deep-sea Exploration expedition. Stephanie Farrington served as the expedition's biology science lead (Figure 4), and Shirley Pomponi, Cris Diaz, and John Reed anchored a team of faculty and graduate students who participated daily from FAU Harbor Branch's Exploration Command Center. The expedition provided multiple telepresence outreach opportunities for college and high school students, including very successful live interactions with the *Okeanos Explorer*.

CIOERT has also made strides in advancing technologies related to the Blue Economy. Using an amino acid-optimized nutrient medium, Shirley Pomponi and her colleagues at FAU Harbor Branch and Wageningen University & Research (Netherlands) have demonstrated a substantial increase in both the rate and number of cell divisions in nine marine sponge species. These results form the basis for developing marine invertebrate cell models to better understand early animal evolution and predict the impact of climate change on coral reef community ecology. Sponge cell lines can also be used to scale-up the production of sponge-derived chemicals for clinical trials and develop new drugs to combat cancer and other diseases.

Exploration of Gulf of Alaska Seamounts

By Katrin Iken

In July 2019, scientists from the University of Alaska Fairbanks led an expedition on R/V *Sikuliaq* to explore the seamounts in the northern Gulf of Alaska. This basin contains a chain of about 35 seamounts of volcanic origin that rise between 1,000 m and 3,500 m above the seafloor but whose summits typically reach only within 600–900 m of the sea surface. Seamounts in general interact with the surrounding deep-sea system by altering the deep water-column structure, which affects mixing and nutrient concentrations as well as the exchange of biota. These conditions can contribute to high biodiversity.

During 2019, we used the innovative imagery and specific sampling capacity of ROV *Global Explorer* (Oceaneering International) to examine the pelagic and benthic systems on the summits and deep slopes of Giacomini and Quinn Seamounts. We observed that both seamounts harbored vastly different communities on the deep slopes (2,500 m) compared with the summits. Deep slope fauna on both seamounts were less diverse and less abundant than summit fauna. Large glass sponges, sea cucumbers, and crabs were most common on the Giacomini slope. Similarly, the benthic community at the deep slope of Quinn seamount was almost barren, with only the occasional sea cucumbers and crabs.

Though only about 70 km apart, the benthic summit communities of Giacomini and Quinn Seamounts were distinct. Giacomini exhibited a much more diverse and dense coral fauna (Figure 1) that provided habitat for many associated taxa such as crabs and brittle stars (Figure 2). In contrast, the Quinn summit was rich in sea cucumbers, sea stars, and crabs as well as occasional corals. One reason for this observation could be that Quinn's summit is deeper (900 m) than Giacomini (650 m), but it could also indicate the isolation of the seamount summits and lack of propagule exchange, possibly due to circulation isolating rather than connecting seamount summits. Fish were consistently, although not always frequently, observed. Grenadiers (Macrouridae) were most common at deeper slope locations while rockfish (*Sebastes*) were most common on seamount summits. Observations of the strikingly patterned deep-sea sole on the summits (Figure 3) were noteworthy. The observation of several cusk eels (Ophidiidae) on the seamount slopes adds to the sparse record of this group in Alaska.

FIGURE 2. Deep-sea corals provide excellent habitat for associated species such as king crab and brittle stars. *Image credit: NOAA-UAF-Global Explorer*

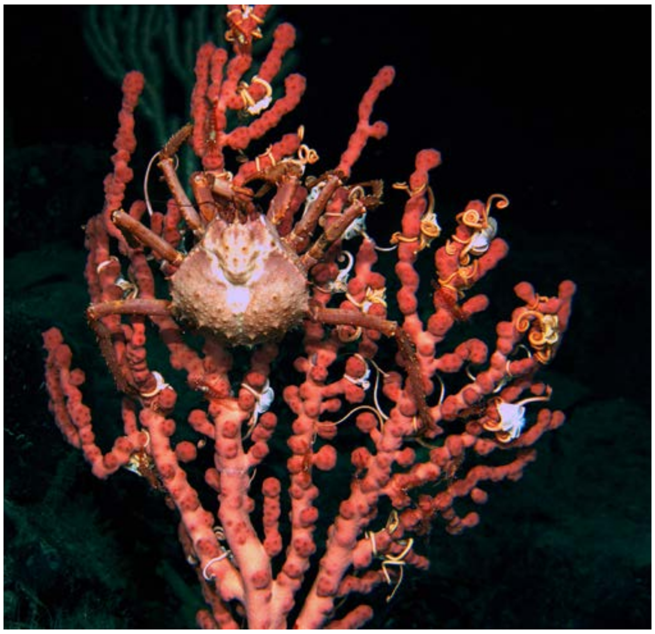


FIGURE 1. A rich assemblage of corals, anemones, sponges, and sea cucumbers on the top of Giacomini Seamount. Corals provide good vantage points for brittle stars and shrimp to capture food particles and prey. *Image credit: NOAA-UAF-Global Explorer*

FIGURE 3. Deep-sea sole (*Embassichthys bathybius*) are widely distributed across Alaskan waters, including on seamounts, but stand out with their stark black-white coloration and size (~30 cm). *Image credit: NOAA-UAF-Global Explorer*

Exploring for a Biogeographic Boundary Along the Emperor Seamount Chain: A Multidisciplinary Approach

By John R. Smith, Les Watling, Natalie Summers, E. Brendan Roark, Nicole Morgan, Becca Lensing, Scott C. France, Henrietta Dulai, Glenn S. Carter, Sarah Bingo, and Amy Baco-Taylor

The bathyal zone (800–3,500 m depth) is the least well-known depth zone in the ocean, yet it harbors considerable deep-sea coral and sponge diversity. The significant difference in bathyal fauna between the Aleutians and Hawaiʻi led us to propose that a transition occurs somewhere along the Hawaiian-Emperor seamount chain, the only continuous geomorphic feature between these two areas that can host bathyal benthos. However, water mass data implied there was no difference in temperature and salinity at bathyal depths anywhere along the chain. We suggested that currents moving east to west through the 500 km wide gap between Nintoku and Koko Seamounts would act as a "current wall," limiting the ability of larvae to emigrate either north or south.

A 32-day multidisciplinary expedition was mounted in July–August 2019 with biologists joining chemical, physical, and geological oceanographers to address this issue and provide additional baseline data from this remote region. In addition to a trial dive at Hess Rise, we conducted 10 ROV dives on seven Emperor seamounts, from Suiko in the north to Koko in the south, using the Schmidt Ocean Institute's R/V *Falkor* and ROV *SuBastian* (e.g., Figures 1 and 2). Dive depths ranged from 2,400 m to 1,800 m and 1,000 m to 1,200 m and were live-streamed with narration by the onboard scientists (32,500 views, 51 hours posted).

Over 230 specimens were collected, including 82 octocorals, 22 sponges, and 126 other invertebrates. Animals were identified and recorded from the video images on each dive to estimate the frequency and distribution of taxa. Hydrographic samples were taken to understand the longer-term history of local water mass characteristics and their variability. Geological samples (31) were also acquired for geochemical analysis and dating to fill some gaps in this little-visited part of the Hawaiian-Emperor chain. Acoustic Doppler current profiler surveys were conducted to characterize the velocity structure of the current regime. Additionally, a comprehensive marine geophysical program, consisting of gravimeter and magnetometer measurements and >20,000 km^2 of multibeam bathymetric surveys, was carried out to guide study site selection, provide project context, and aid future missions and studies.

We consistently found species with known northern distributions until we dove near the southern end of the gap where the octocorals and sponges were characteristic of the central Pacific fauna that was regularly observed during NOAA's Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE). Many of the animals observed on the northern Emperor seamounts had not been seen before and are likely new species that may not be related to those from the Aleutian Ridge. From the perspective of our biogeographic objectives, the cruise was a huge success. However, we must now explain how such a boundary can be created and persist. For that, we await the analyses of numerous water, current, and fossil coral samples acquired on the cruise.

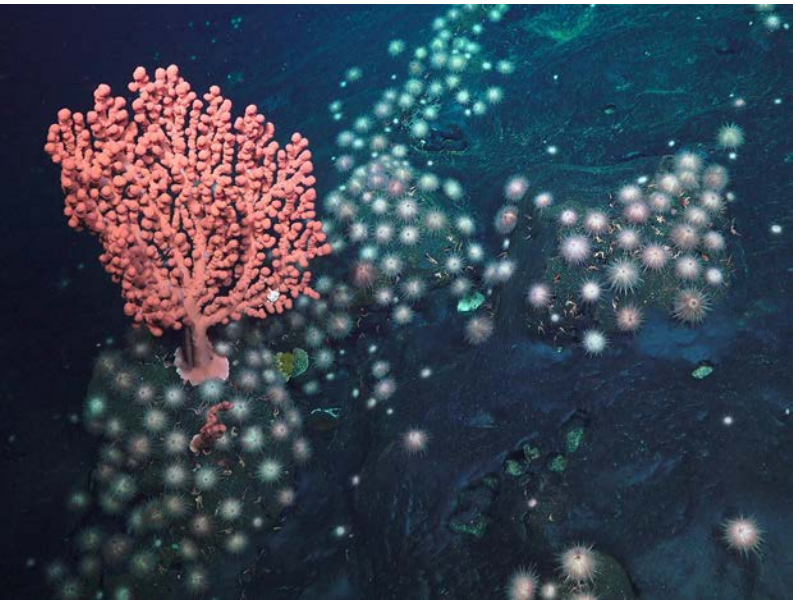


FIGURE 1. *Paragorgia arborea* (bubblegum coral) and regular urchins were observed on polymetallic crust substrate at Suiko Seamount (1,350 m depth). *Image credit: Schmidt Ocean Institute*

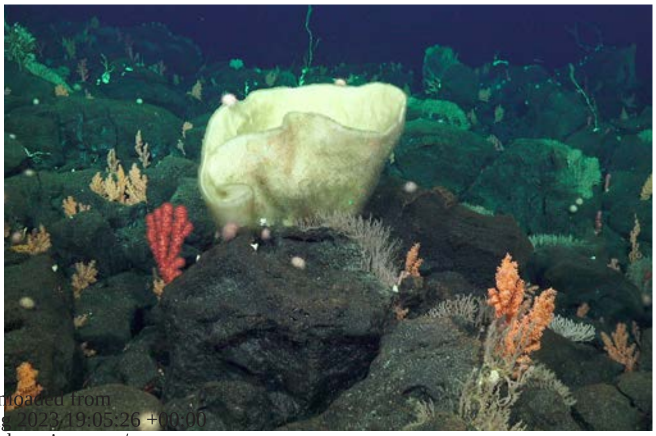


FIGURE 2. A community of bubblegum (red) and red tree (orange) coral, regular urchins, a large vase sponge *Rossellidae* (center, white), and clusters of an unknown hydroid (gray) were found growing on volcanic substrate at Jingu Seamount (1,396 m depth). *Image credit: Schmidt Ocean Institute*

Search for Life Under Ice Overcomes Challenges to Explore Arctic Vents

By Christopher R. German

A multinational team of 36 researchers set sail on the Norwegian icebreaker *Kronprins Haakon* on September 19, 2019, from Svalbard, Norway, as part of the Hot Vents in an Ice-Covered Ocean (HACON) expedition to investigate biogeographical connections and biogeochemical interactions in this remote ocean.

Deploying the hybrid ROV/AUV *Nereid Under Ice* (*NUI*) developed by Woods Hole Oceanographic Institution (Figure 1), the scientists wanted to investigate competing hypotheses concerning the genetics of hydrothermal vent fauna at the Arctic Ocean's Gakkel Ridge. Would the fauna show genetic similarities to vent fauna in the Norwegian-Greenland Sea or to chemosynthetic fauna from the far side of the Arctic near the Aleutians, or were they entirely new species?

To answer these questions, WHOI upgraded *NUI* to reach 5,000 m depth and gave it an ability to switch between AUV (survey vehicle) and ROV (seafloor imaging and sampling) modes during under-ice dives.

Despite technical challenges with *NUI*, and difficult ice conditions, the team was able to deploy a towed video camera from the Alfred Wegener Institute for Polar and Marine Research (Germany) to collect high-resolution digital images of the Aurora vent site, revealing two active black smokers and a diversity of vent fauna (Figure 2). Continuing away from the vents, these same surveys imaged a wide variety of habitats, from soft sediments surrounding rocky outcrops colonized by glass sponges and associated fauna to mysterious sinkholes and basalt mounds sometimes coated in fine or coarse rust-colored sediments and sometimes overlain by extensive sulfide mounds.

FIGURE 1. The WHOI-developed *Nereid Under Ice* (*NUI*) hybrid autonomous vehicle is ready to dive into the Arctic Ocean during the Hot Vents in an Ice-Covered Ocean (HACON) expedition. *Image credit: Stefan Buenz, Norges Artiske Universitet*

As the cruise ended, the team was able to dive *NUI* to ~4,000 m depth beneath the >90% ice cover that was closing in over the site and collect the first-ever samples of the glass sponge species that represent the dominant benthic fauna along Gakkel Ridge. These new samples will be critical to answering whether there is a viable pathway for gene flow of vent-endemic fauna into the Arctic from other ocean basins.

Despite the challenges of working in such a high-risk environment, the WHOI/Jet Propulsion Lab team have already begun making plans for a return trip to the Gakkel Ridge site with their international colleagues—ideally as early as summer 2021.

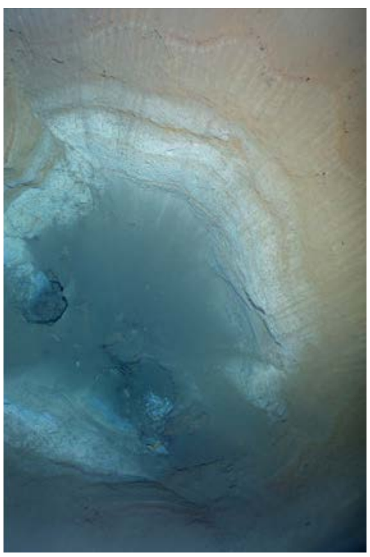



FIGURE 2. Images from Aurora Seamount explored by HACON. *Image credit: Eva Ramirez-Llodra, Norwegian Institute for Water Research*

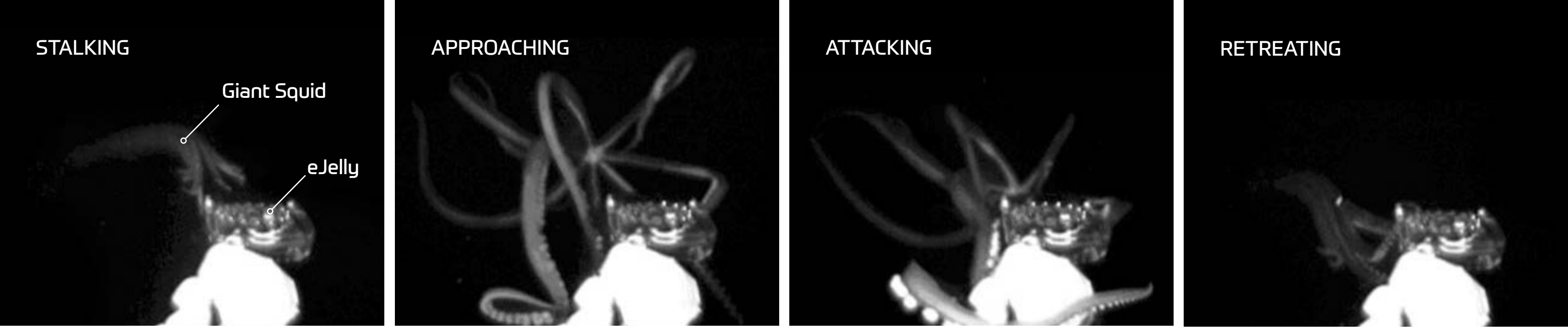


FIGURE 1. Images of the giant squid *Architeuthis dux,* filmed under near-infrared light using the *Medusa* camera system at ~700 m depth, showing the animal's approach to, attack of, and retreat from a simulated bioluminescent target. *Image credit: Edith Widder, Ocean Research & Conservation Association and Nathan Robinson, Cape Eleuthera Institute*

Journey into Midnight By Sönke Johnsen

"Journey into Midnight" was two-week research cruise on R/V *Point Sur* that explored biodiversity, vision, bioluminescence, and biophotonics in the northeast Gulf of Mexico. The science crew consisted of six co-PIs and their labs, plus a teacher-at-sea and a professional photographer. Working mostly at depths of 1,000–2,000 m, we completed 12 ROV dives, six *Medusa* (a drifting stealth camera system) deployments that collected 160 hours of video, and 15 midwater trawls. Significantly, we captured footage of a juvenile specimen of the giant squid *Architeuthis dux* (Figure 1). The second in situ footage of this squid ever and the first in US waters, it both generated intense national and international media coverage and demonstrated the value of stealth technology for deep-sea research. In addition, we discovered and measured what may be the blackest natural surface known—the skin of the deep-sea anglerfish *Oneirodes*. This skin, which is currently being assessed using electron microscopy and complex optical modeling methods, is as black as the blackest known technological substances and may provide insight into how to design these important materials. We also filmed one of the most impressive bioluminescent displays known, that of the threadfin dragonfish *Echiostoma barbatum*, showing that it emits light even from the tips of its fin rays.

Development of Innovative Techniques for Exploring Novel Submarine Springs on the Gulf of Mexico Outer Continental Shelf

By Emily R. Hall, Jim Culter, Jordon Beckler, Martial Talliefert, Frank Stewart, and Chris Smith

Studies of offshore submerged sinkhole and spring features (blue holes) have been limited, as they frequently exceed normal scuba limits, reaching depths of >130 m, and have openings too small for many submersibles to access. These blue holes host several commercially important and regulated fish species as well as protected species, and they are ecological hotspots with respect to species composition and diversity. To overcome the technological limitations and explore the geological, physical, and chemical environments of blue holes and the resulting biological distribution, we assembled an innovative sensor and sampling suite. The principal objectives of the project were to (1) repurpose and repackage existing high-tech marine biogeochemical instrumentation to create a benthic lander appropriate for exploration of these environments (Figure 1); (2) develop a multi-day logistical plan for safely deploying the platform in conjunction with geochemical, genomic, and macrofauna surveys; (3) employ this plan in the exploration of two blue holes at depths >100 m and develop a long-term plan for the systematic exploration of other blue holes on the West Florida Shelf; and (4) disseminate data and images through innovative means designed to captivate the public and garner future interest from scientists.

FIGURE 1. From the left, Jim Culter (co-PI from Mote Marine Laboratory), Nastassia Putin (postdoc from Georgia Tech), and Emily Hall (PI from Mote Marine Laboratory) stand around the benthic lander prior to deployment. *Image credit: Mote Marine Laboratory*

Microbial Stowaways: Exploring Shipwreck Microbiomes in the Deep Gulf of Mexico

By Leila Hamdan

During June–July 2019, an expedition to the northern Gulf of Mexico explored, for the first time, two wooden-hulled shipwrecks and began the study of microbial stowaways living on and around them to learn how shipwrecks shape microbial biodiversity in the deep sea. The University of Southern Mississippi (USM), in collaboration with the Bureau of Ocean Energy Management and the Naval Research Laboratory, led the expedition. The shipwrecks investigated were site 15711 at approximately 530 m depth in the Viosca Knoll lease area and site 15470 at approximately 1,800 m depth in the Mississippi Canyon lease area.

Deployed from R/V *Point Sur*, ROV *Odysseus* collected high-resolution images of diagnostic artifacts and hull construction features of the two nineteenth-century wooden-hulled sailing vessels to inform archaeological interpretations (Figures 1 and 2). Video and photos are being analyzed to develop archaeological site plans, vessel age estimations, and baseline characterizations. Digital imagery is being used to develop 3D photogrammetric models. The ROV collected sediment push cores for studies of microbiome composition, biodiversity and richness, and porewater geochemistry. Sediments are being examined to determine whether the shipwrecks enhance microbial biodiversity of the seabed. These data will be used in conjunction with machine learning to geospatially predict microbial assemblages around shipwrecks from the current study and from previous works. In addition, microbial recruitment experiment arrays were placed on the seafloor near the shipwrecks to study dispersal of microbial "stowaways" into the surrounding environment (Figure 3).

In December 2019, after four months on the seafloor, all microbiome recruitment arrays were recovered using an instrumented lander outfitted with an acoustic release. During the fieldwork, USM's Marine Education Center hosted an Ocean Science and Technology Camp (OSTC). The OSTC delivered an ocean science career-focused experience to 20 high school students from across the nation. Camp participants met with the research team and ship crew to learn about the lives and careers of marine scientists and engineers. The camp culminated with a live telepresence event during the exploration of site 15711.

The Microbial Stowaways project involves scientists from marine archaeology and microbial ecology. This collaboration is the first to address how shipwrecks impact the distribution of microbiomes across space and time.

FIGURE 1. Stern of shipwreck site 15470 with draft mark visible. *Image captured by ROV Odysseus, courtesy of Microbial Stowaways*

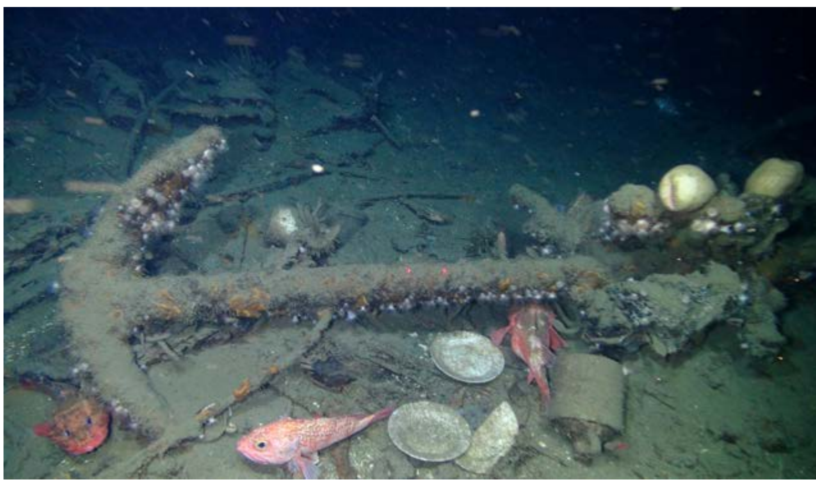


FIGURE 2. Image of the newly found anchor at shipwreck site 15711. *Image captured by ROV Odysseus, courtesy of Microbial Stowaways*

FIGURE 3. Leila Hamdan stands in front of the microbiome recruitment experiment array and lander. *Image credit: Justyna Hampel, The University of Southern Mississippi*

Submerged Paleolandscapes of the Northwestern Gulf of Mexico

By Amanda Evans

For two weeks in late May and early April, 2019, a team of marine archaeologists and marine geophysicists explored the outer continental shelf in the northwestern Gulf of Mexico for evidence of paleolandscapes submerged by rising seas since the Last Glacial Maximum. The team used a chirp sub-bottom profiler and a parametric sonar to record the seafloor and underlying strata (Figure 1). Building from previous exploration and survey work, the team targeted a 606 km^2 area (Figure 2), looking for evidence of paleovalleys buried below the modern seafloor. A total of 670 survey line kilometers were transited during the cruise; in addition to subbottom and parametric sonar data, the team collected magnetometer data for seafloor hazards identification and bathymetry data for correlation with sea level curves. The team is in the process of analyzing the collected data and selecting locations for vibracoring, to be conducted in spring of 2020. The data will result in a better map of the paleolandscape and a better understanding of the environments that were available to human populations when this portion of the continental shelf was exposed as dry land.

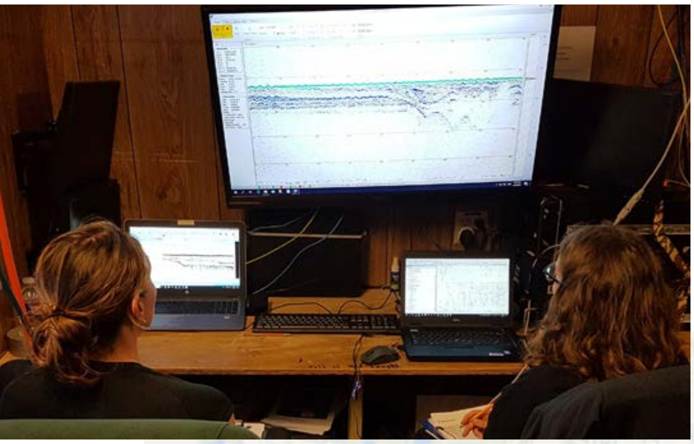
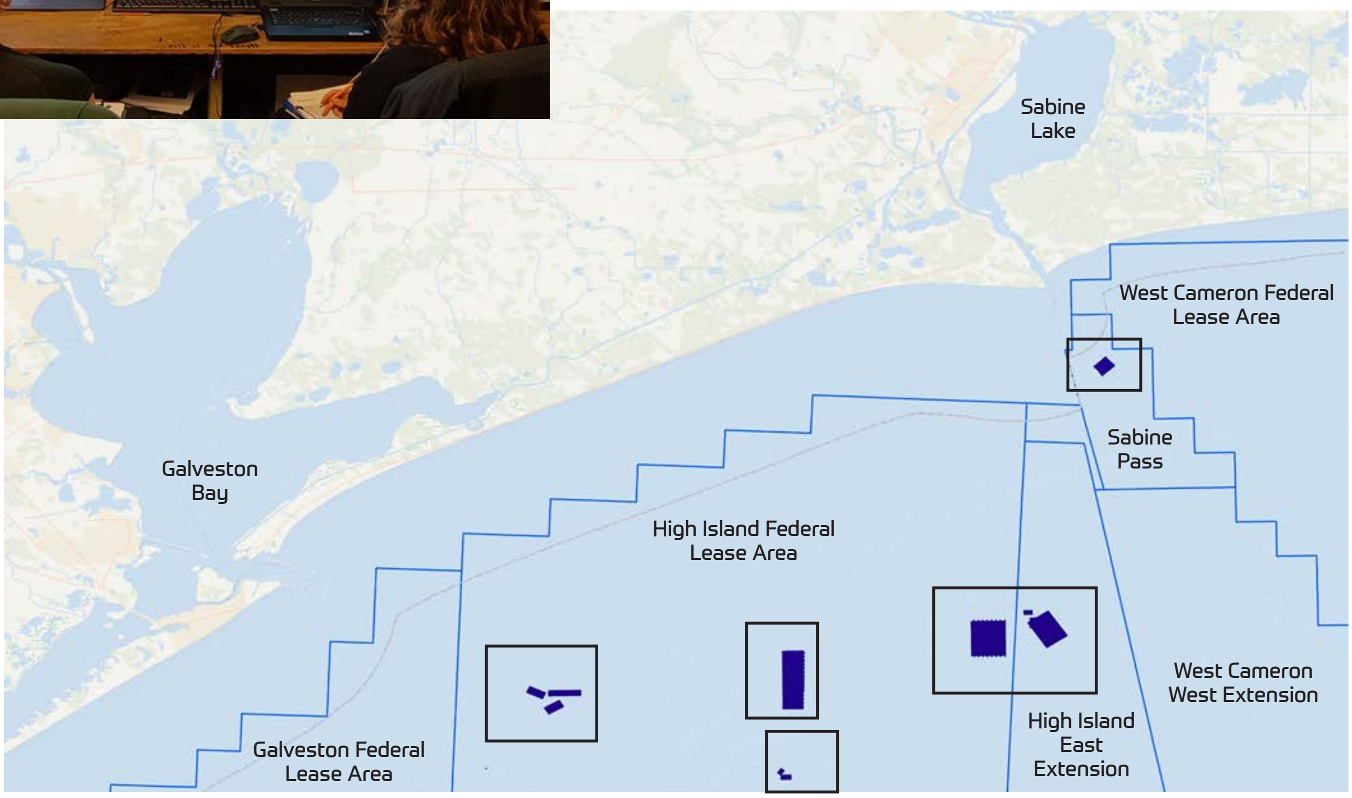


FIGURE 1. Amanda Evans (left) and Megan Metcalfe (right) monitor the parametric sonar during survey operations. *Image credit: Megan Metcalfe, Wessex Archaeology, UK*

FIGURE 2. A map showing the five general areas surveyed (black boxes) in the Gulf of Mexico, offshore Texas and Louisiana. The dark blue within the boxes is the actual survey lines completed.



Update on Co-Exploration: A Toolbox for Subsea Data Processing and Real-Time Information Interaction Over Acoustic Communications

By Carl L. Kaiser and Laura Lindzey

We are developing a suite of tools designed to significantly improve human-robot interactions in deep-sea exploration. This "co-exploration" combines onboard data processing, machine learning, heuristic anomaly detection, and a GIS-based user interface (Figure 1) to provide information in real time that previously required vehicle recovery.

Co-exploration is a collaboration between robot and human. Traditionally, the robot has all of the data but no context, and the human has all of the context but no data. For example, when searching for chemical anomalies, rather than transmitting all oxidation-reduction potential data to the user, the AUV sends only the magnitude and location of the largest anomalies. The human explorer then sends a request to the AUV to collect additional data from those sites such as bathymetry, photos, and other chemical data while converting data into information, for example, using unsupervised machine learning to classify seafloor types.

In the short term, co-exploration will lead to more efficient use of ship time, while in the long term, it will reduce risk from long-duration, shore-launched missions. Both will greatly speed the pace of discovery.

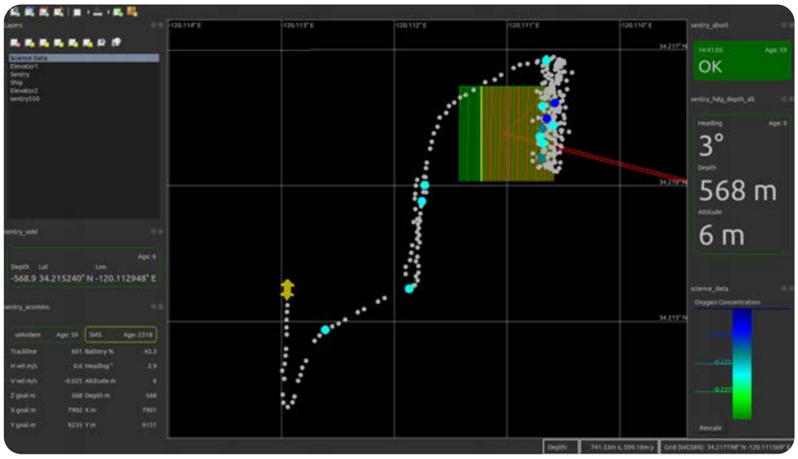


FIGURE 1. Early example of real-time chemical data being displayed in the GIS-based user interface. *Image credit: WHOI*

Improving Navigation for Long Endurance Underwater Robots

By Michael V. Jakuba, James W. Partan, and Christopher Dolan

With funding from the National Science Foundation and NOAA, we are developing a one-way travel-time inverted ultra-short baseline (OWTTIUSBL) acoustic navigation system intended for very low power operation on autonomous gliders and other vehicles. The system will allow arrays of autonomous vehicles to navigate in deep water with a precision significantly better than that achieved using periodic GPS fixes when at the surface along with dead-reckoning (Figure 1). In summer 2019, we installed a test article containing a prototype version of the system on ROV *Deep Discoverer* aboard NOAA Ship *Okeanos Explorer* and spent three dives collecting performance data at various depths, relative orientations, layback distances, and two source frequencies. The test article contained a Micro Modem-based system (the intended final embodiment) as well as a high rate data-acquisition system designed to collect raw passband data from a second array also mounted on the device. These data are currently being analyzed.

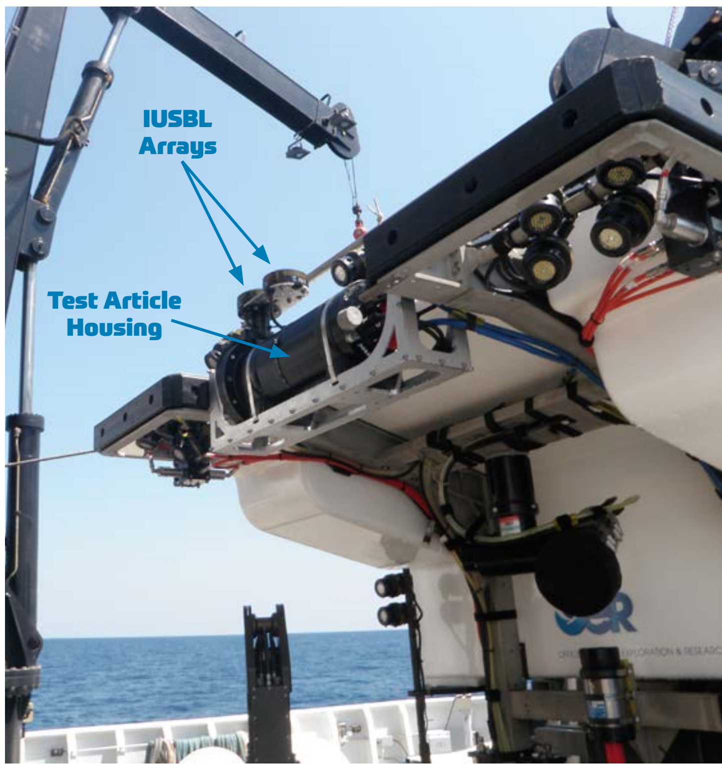


FIGURE 1. The OWTTIUSBL test article installed in the "brow" of ROV *Deep Discoverer*. *Image credit: M. Jakuba, WHOI*