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New Frontiers in Ocean Exploration

The E/V *Nautilus*, NOAA Ship *Okeanos Explorer*, and R/V *Falkor* 2017 Field Season

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FRONT COVER. A large *Deepstaria enigmatica* scyphozoan jellyfish is imaged up close at 974 m depth off of San Benedicto Island, Revillagigedo Archipelago, Mexico, on E/V *Nautilus* cruise NA092. This specimen, measuring approximately 55 cm across, was approached in almost complete darkness and remained undisturbed for several minutes, at which point it closed its umbrella and turned to present itself in high detail. An intricate network of anastomosing canals, assumed to be part of its digestive tract, is clearly visible. *Image credit: D. Fornari (WHOI-MISO Facility) and OET*

PREFERRED CITATION
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Interior of a gas-rich pillow basalt off the west coast of Socorro island, Revillagigedo Archipelago, Mexico, from E/V *Nautilus* cruise NA092. *Image credit: D. Fornari (WHOI-MISO Facility) and OET*

Working with Video to Improve Deep-Sea Habitat Characterization

By Peter J. Etnoyer, Mashkoor Malik, Derek Sowers, Caitlin Ruby, Rachel Bassett, Jennifer Dijkstra, Nikolai Pawlenko, Susan Gottfried, Kristen Mello, Mark Finkbeiner, and Angela Sallis

Introduction

Videos collected from ROVs empower people to explore the ocean from any location. Beyond the immediate value of revealing the mysteries of the deep ocean, video footage provides a rich data source that contributes to our fundamental understanding of the physical, biological, and chemical properties of explored ocean areas. NOAA's Office of Exploration and Research and its partners are improving video data management to extract the highest scientific value from these hard-to-obtain surveys of the deep. In addition to making video data publicly available through the OER Video Portal (https://www.nodc.noaa.gov/oer/video), OER and its partner organizations are adding substantial scientific value to video data through development of species identification guides, improved scientific annotations, application of a standard classification scheme, citizen scientist engagement, and improved marine habitat assessment and characterization (Figure 1).

Identifying Deepwater Species

One of the most exciting things about an ROV dive is the potential to capture a rare or even previously unknown marine animal on video. During CAPSTONE, OER science advisor Christopher Kelley worked closely with the OER Data Management Team, led by NOAA's National Centers for Environmental Information, to develop a way to share images and information about the deepwater animals encountered by NOAA's ROV *Deep Discoverer*. This collaboration led to the development of the Benthic Deepwater Animal Identification Guide, an online collection of in situ images of deepwater animals taken from video frame grabs that have been identified by a team of taxonomic experts. The guide, organized according to taxonomic groupings and displaying multiple images of the different genera and species, is available at http://oceanexplorer.noaa.gov/okeanos/animal_guide/animal_guide.html.

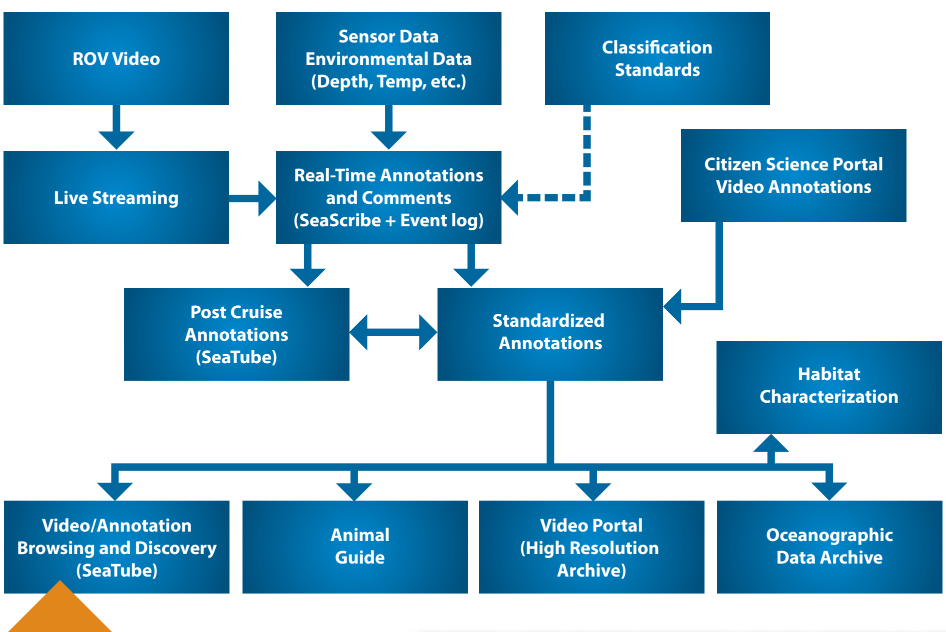


Figure 1. Conceptual diagram of connections between video data collection, annotation, and management.

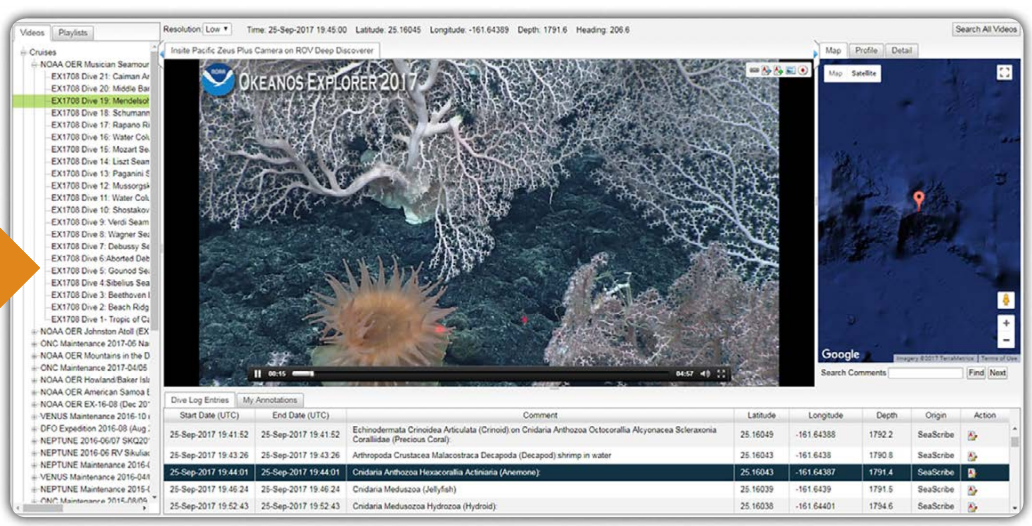


Figure 2. Example screen from the annotation software SeaTube showing the user interface that enables video playback, position, and time-stamped observations. *Image credit: NOAA OER and ONC*

Improving Video Annotation

When scientists want to focus on certain organisms or features within a video such as deep-sea corals, they need tools to efficiently locate relevant video segments. Searching through video requires textual descriptions known as video annotations. Since 2010, OER has been inviting experts to participate remotely in the ROV dives to provide these video annotations. In 2017, OER partnered with Ocean Networks Canada to implement annotation software tools that provide an end-to-end annotation workflow for the scientists to create, review, and validate video observations. SeaScribe is an online annotation tool that both shore-based and shipboard participants can access concurrently during an ROV dive. SeaTube is a cloud-based video archive and browsing interface that enables playback of previously recorded videos and entry of new annotations (Figure 2). These tools reduce post-cruise annotation time and improve the utility of OER video for enhanced insight into explored areas. Annotations are thus providing a rich data set that can be "mined" by many different scientists for different purposes.

Applying Standard Classification to Video

Scientifically relevant annotations enhance the value of video data. NOAA scientists have been researching the application of the Coastal and Marine Ecological Classification Standard (CMECS; Box 1) for classification of deep-sea environments through video annotations. Annotating video with CMECS vocabulary improves the data's compatibility with other coastal and marine data sets and has the potential to unify the current, varied methods used among the deep-sea exploration community for habitat and substrate classification. Three different, but complementary, research efforts explored the application of CMECS to OER video data from the Pacific Ocean, the Gulf of Mexico, and the US Atlantic continental margin.

1. Pacific Ocean. NOAA's Deep Coral Ecology Laboratory processed 32 ROV dives and more than 6,400 ROV video still images to classify dive transects using a simple CMECS annotation scheme in order to understand the application of CMECS to deep-sea coral research (Bassett et al., 2017). To test this scheme, the study classified substrate, geoform, and water column CMECS components from three deep-sea benthic surveys in the Pacific Ocean in 2015, including telepresence-enabled cruises with NOAA Ship *Okeanos Explorer* in Hawai'i and E/V *Nautilus* off southern California. The primary outcome of the study was the discovery that CMECS geoform and water column components can be captured by field-based exploration teams with little modification to standard procedures. The ROV routinely collects parameters such as depth, temperature, salinity, and oxygen that can be employed to characterize water column attributes using standard CMECS classes.

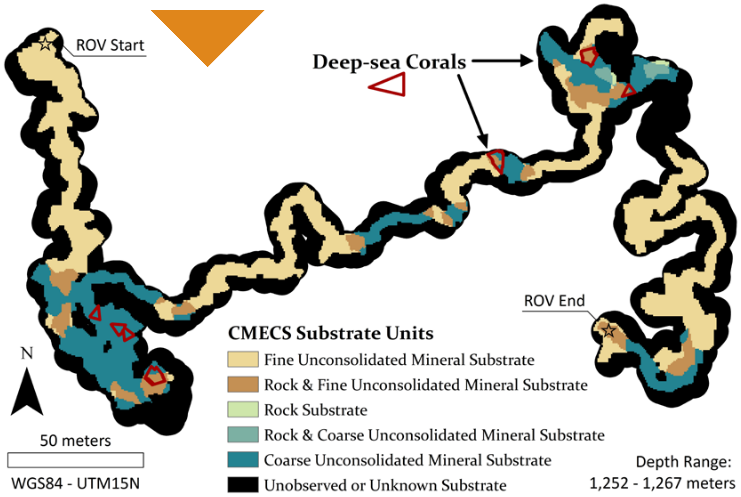
BOX 1. THE COASTAL AND MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS)

Compilation of disparate data collected by various government, academic, and collaborative institutions contributes significantly to knowledge of the world ocean. But how can such diverse data be organized into something that can be easily discovered, analyzed, compared, and used to support additional research, management, or exploration efforts? One strategy for effective data management is to implement a standardized method for classifying observed environmental features. For this reason, in 2012, the Federal Geographic Data Committee endorsed the Coastal and Marine Ecological Classification Standard (CMECS), which created a comprehensive framework of common terminology for classifying biological species, water column properties, and seafloor morphology and composition. CMECS provides a common language to describe estuarine, lacustrine, coastal, and offshore environments, enabling scientists and managers to integrate and use data from a variety of sources.

Many federal and state governments, nongovernmental organizations, and partnerships around the United States and internationally have adopted CMECS. In particular, CMECS is the required benthic classification for Renewable Energy and Marine Minerals programs at the Bureau of Ocean Energy Management. CMECS incorporates the use of provisional units, which allow researchers to add proposed new units to the standard as they are discovered. This flexibility is especially valuable in the deep ocean environment, where knowledge is increasing rapidly and new discoveries abound. Eventually, a peer review process will examine these units to inform future versions of the classification. For more information on CMECS go to: https://iocm.noaa.gov/cmecs.

The CMECS structure allows scientists to classify environments to varying levels of detail, which is especially useful in deep-sea environments where data coverage is low and access is limited. *Image credit: Federal Geographic Data Committee*

Figure 3. CMECS-compliant map layers allow scientists to spatially analyze ROV video content. Individual viewsheds (colored triangles) show the substrate type. Red polygons show deep-sea corals. The presence of deep-sea corals coincides with rocky and coarse unconsolidated mineral substrate for this particular dive. *Image credit: Caitlin Ruby, NOAA*



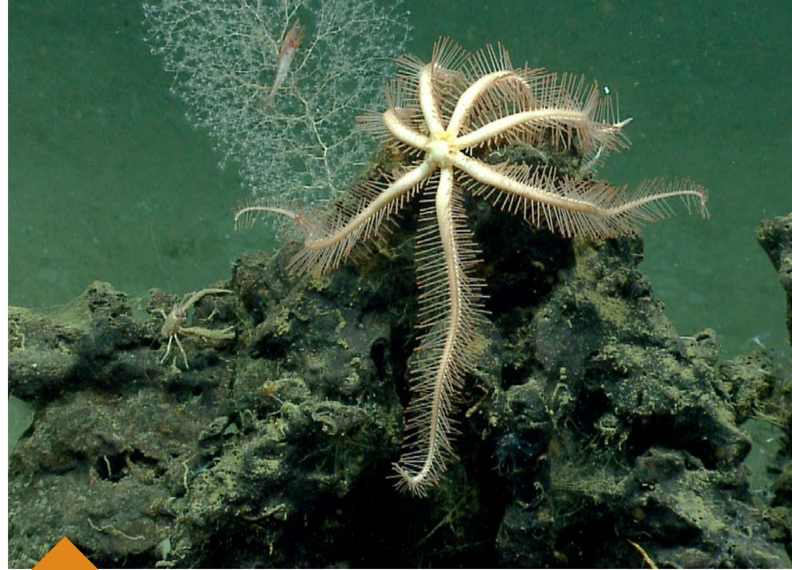
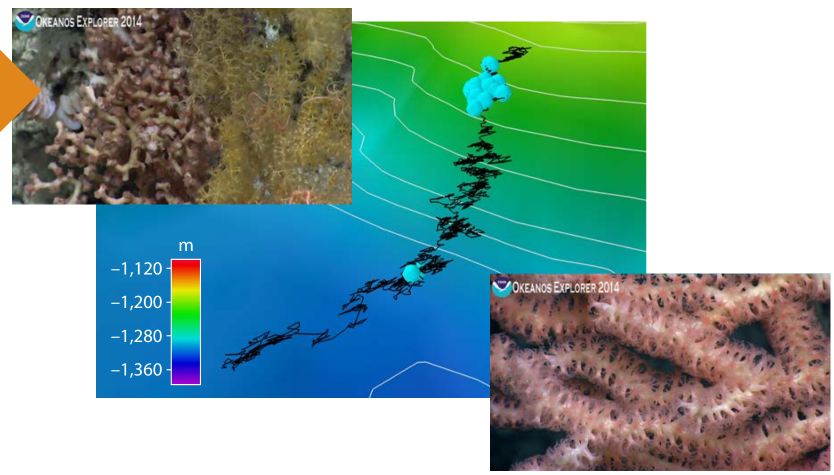


Figure 4. This photo exemplifies a deep-sea coral community near 1,260 m depth with a brittle star (center), two octocorals, a shrimp, and crab. The source video for this image, which was taken by ROV *Deep Discoverer* in the northern Gulf of Mexico during 2014, was used to produce Figure 3.

Figure 5. Researchers mapped the distribution of corals (blue spheres) along ROV tracks (black lines) in McMaster Canyon, which incises the continental slope off of Delaware. Some of the coral species observed included a cup coral (top left image), as well as many bamboo corals (bottom right image). *Image credit: Kristen Mello and Jennifer Dijkstra, UNH CCOM/JHC*



2. Gulf of Mexico. The OER Data Management Team collaborated with the Northern Gulf Institute and Mississippi State University to develop techniques for mapping deep-sea environments using video collected by ROV *Deep Discoverer* during OER's 2014 Exploration of the Gulf of Mexico expedition (Ruby, 2017). Videos from 10 ROV dives were examined and annotated using biological, geological, and substrate descriptors found within CMECS. Researchers then combined CMECS annotations with ROV coordinates and the surrounding water column information in order to map the recorded environments (Figure 3). Considering that the viewable distance within a video is limited to the ROV's light source and camera angle, maps were constrained to areas viewed by *Deep Discoverer*'s main, forward-facing camera. The research team determined that map layers are an efficient toolset for spatially viewing ROV video content and quickly assessing complex environmental relationships that stimulate scientific inquiry. For example, Figure 4 shows deep-sea corals associated with rock and coarse substrates.

3. Atlantic Ocean. In collaboration with OER, researchers at the University of New Hampshire's Center for Coastal and Ocean Mapping/Joint Hydrographic Center examined community structure among ROV dive sites, and classified the substrate encountered during the dives using CMECS. The researchers analyzed full underwater video footage collected by ROV *Deep Discoverer* during three cruise legs of the 2013 and 2014 *Okeanos Explorer* expeditions along the Atlantic continental margin. During these cruises, the ROV sampled seamounts, seeps, and canyons spanning a depth range of 580 m to 1,875 m. UNH CCOM/JHC researchers mapped the distribution, abundance, and assemblage of taxa along ROV tracks (Figure 5). Results of this study are being used to help ground truth high-resolution multibeam sonar bathymetry and backscatter data collected by NOAA and UNH CCOM/JHC in order to inform improved CMECS classification of large areas off the US east coast between the shelf break and 5,000 m depth.

Harnessing Citizen Scientists for Video Exploration

Citizen science is the collection and analysis of data by the general public. Citizen science engages the public in research collaborations and is particularly effective when labor-intensive tasks can be completed by volunteers. Video analysis involves time-consuming review and annotation, and thus is often a major bottleneck in extracting useful scientific information from raw video footage. Using a new portal being developed as part of Ocean Video Lab (http://www.oceanvideolab.org), citizen scientists will gain access to thousands of hours of video from ROVs and other platforms (Figure 6). By creating "bookmarks," these volunteers will identify observations of interest that will then be routed to an expert for more detailed annotations. For example, instead of watching a full dive, a coral specialist can focus on video footage where corals have been bookmarked. With the help of citizen scientists around the globe, Ocean Video Lab hopes to make major contributions to ocean exploration by filling in knowledge gaps within valuable legacy video. The Schmidt Ocean Institute provides funding for Ocean Video Lab, and a NOAA Big Earth Data Initiative grant funded integration of the OER citizen science video interface into the Ocean Video Lab portal.

Habitat Suitability Modeling for Deep-Sea Corals and Sponges

Accompanying advances in video data management, exciting new analyses are enabling researchers to more thoroughly characterize explored areas and predict unexplored areas. The high-resolution images collected by ROV *Deep Discoverer* provide important data such as species identity, number, and size. NOAA's Deep Coral Ecology Laboratory is using these images to assess the abundance and health of deep-sea corals, and then making these images publicly available through NOAA's growing National Database of Deep Sea Corals and Sponges (Hourigan et al., 2015). The public can access the database through a web portal at https://deepseacoraldata.noaa.gov. The portal debuted in 2015, and has since grown to house more than 575,000 observations of corals or sponges around the world. By pooling these records, the database provides the resources to answer questions such as: Has this species been observed in this region or at this depth before? How common or rare is that type of sponge? (Figure 7)

Among the most powerful applications of deep-sea coral data are habitat suitability models that predict where a species is likely to be observed, and where it is not. NOAA scientists construct the models by combining image observations from *Okeanos Explorer* with environmental data and records from museums and other research expeditions, and then overlaying this information with additional environmental data (depth, temperature, bottom type) in a geographic information system. The models provide exploration teams with new targets to examine that will in turn help verify these models.

When growth rates are known, as in the case of some fish and corals, the size of an organism can then be correlated to age. Noninvasive, image-based sampling techniques that employ scaled lasers may one day replace destructive sampling of long-lived organisms (Etnoyer et al., 2017). Age class structure is important information for coastal managers who seek to conserve and protect deep-sea corals that can be hundreds or thousands of years old. The use of video data to assess and predict marine habitats enables well-informed ocean management decisions, providing a tangible return on investments made in ocean exploration.

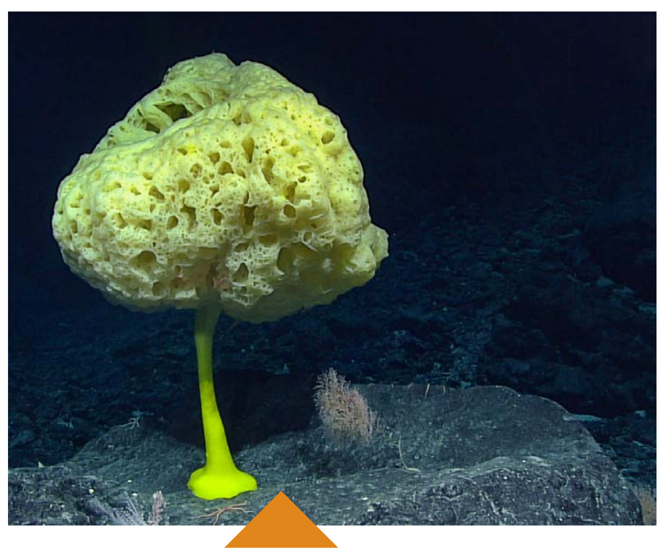


Figure 7. ROV *Deep Discoverer* observed this vibrant yellow glass sponge (*Bolosoma* sp.) at 2,479 m depth on Sibelius Seamount.

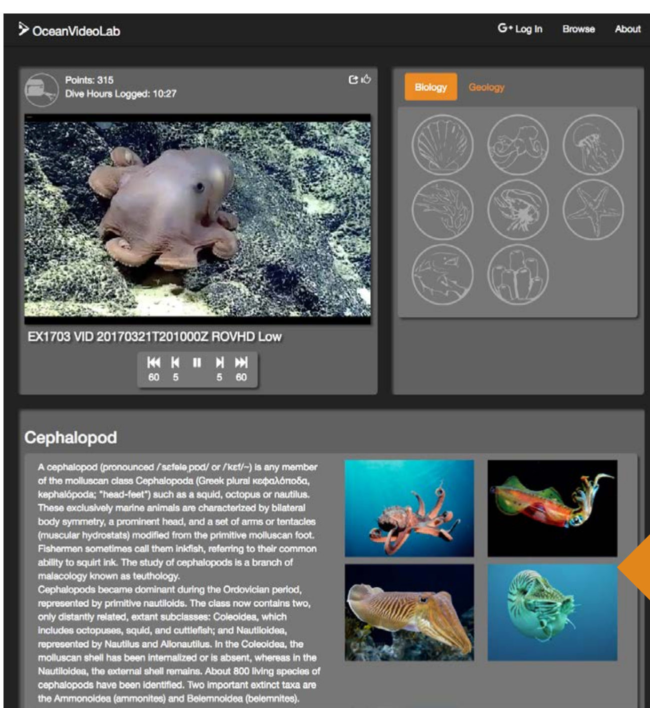


Figure 6. Ocean Video Lab's citizen science interface is being developed in partnership with NOAA's Office of Exploration and Research, Lamont-Doherty Earth Observatory, and the Inner Space Center located at the University of Rhode Island. *Image credit: Vicki Ferrini, LDEO*