TECHNOLOGY

NOAA OCEAN EXPLORATION

NOAA Ocean Exploration is the only US federal organization dedicated to exploring the deep ocean. By leading national efforts to explore our ocean and make exploration more accessible, we are filling gaps in the basic understanding of deep waters and the seafloor, providing deep-ocean information needed to effectively manage, conserve, regulate, and use ocean resources that are vital to our economy and to all of our lives. Explore with us: oceanexplorer.noaa.gov

Collecting and Visualizing Deep-Sea Data

Data visualization is an incredibly helpful tool for breaking down and communicating complex information. It helps preserve our knowledge about the ocean for future generations and maximize its immediate value to the nation.

Katharine Egan, Megan Cromwell, and Shannon Hoy
NOAA Ocean Exploration, National Centers for Environmental Information

What Is Data and Data Visualization?

Data is information that we collect about the world. In the context of NOAA Ocean Exploration, it is the information that we collect about the deep sea. Data can be both quantitative and qualitative. Quantitative data refers to information that is numeric: it is anything that can be counted or measured. In the deep sea, quantitative data types can include things like the number of fish seen or the area covered by deep-sea corals. Qualitative data is more descriptive and refers to things that can be observed but not necessarily measured numerically. For example, in the deep sea, we may collect qualitative data about the behavior of a particular organism.

Data visualization is the representation of data through the use of graphics such as charts, plots, infographics, maps, and animations. These visual displays of information communicate complex data in a way that is easy to understand. People sometimes better absorb information from a picture or a graph compared to text alone. Images and graphics are effective for all kinds of storytelling, especially when the story is complicated, which is often the case in science. Data visualization can also allow us to see trends and patterns in the data that we might not see if we were just looking at numbers alone. Scientific visuals can be essential for analyzing data, communicating results, and for making new discoveries.

What Kind of Data Do Ocean Explorers Collect?

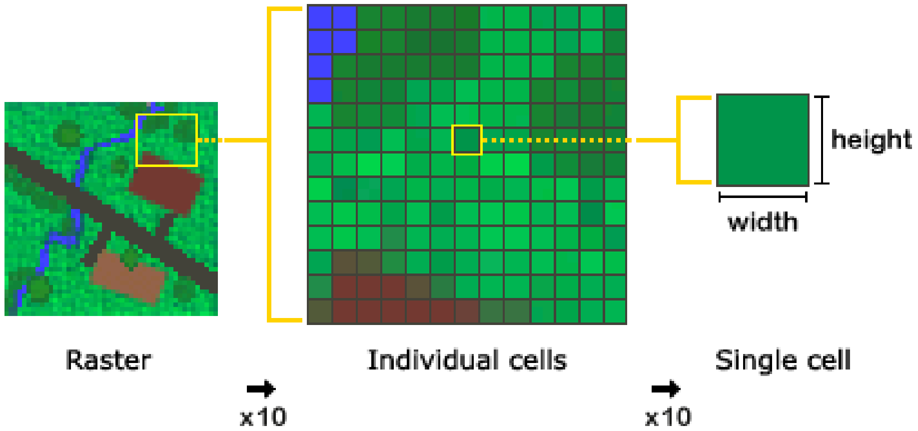
Mapping Data Types

Two types of data are often collected when mapping: bathymetry and backscatter data. Both of these use sonar—devices that use sound waves to detect objects. Bathymetry is the measurement of the depth of the seafloor, similar to elevation on land. A special instrument called a multibeam echosounder is mounted on the bottom of a ship. The multibeam echosounder emits sound into the water, and that sound hits the seafloor and “echoes” back to the ship. We are able to measure how long it takes the sound to travel back to the ship, and can then calculate the depth of the seafloor using the known speed of sound through water.

This information can be used to create maps that are important tools for navigating the ocean. The same instrument, along with others mounted on the ship, also collects backscatter data. Backscatter data can determine the relative hardness of the seafloor or other objects that the signal encounters in the water column. Rather than measure the time for an echo to return to the ship (like with bathymetry), backscatter is computed by measuring how loud the sound return is compared to the original sound emitted. When an area of the seafloor has sand or soft sediment, much of the sound will be absorbed, and the return to the sonar will be low.

When we are mapping over hard substrate, such as rock or coral reef, the backscatter return will be greater because the sound is bouncing off the hard substrate and less sound is absorbed into the sediment. Backscatter can also tell us if there are organisms or other objects located in the water column. We can identify the presence of large organisms, like big fish or whales, or whether there are groups of smaller organisms such as plankton or schools of small fish. Backscatter can also be used to detect bubbles in the water column, which can help us identify the location of seeps—areas on the ocean floor where gases percolate through underlying rock and sediment layers and emerge on the ocean bottom.

Using special software, we are able to make these data into grids, called rasters. These are matrices of pixels organized into rows and columns where each cell contains a value representing information. In this case, the rows and columns represent the location on the Earth (such as latitude and longitude), and each cell would be defined as depth (bathymetry) or intensity (backscatter) of the seafloor or other objects. Another way that data can be made available for use is through geographic information systems (GIS). These systems store geographic information in layers and use specialized software to create, store, analyze, and visualize spatial information.

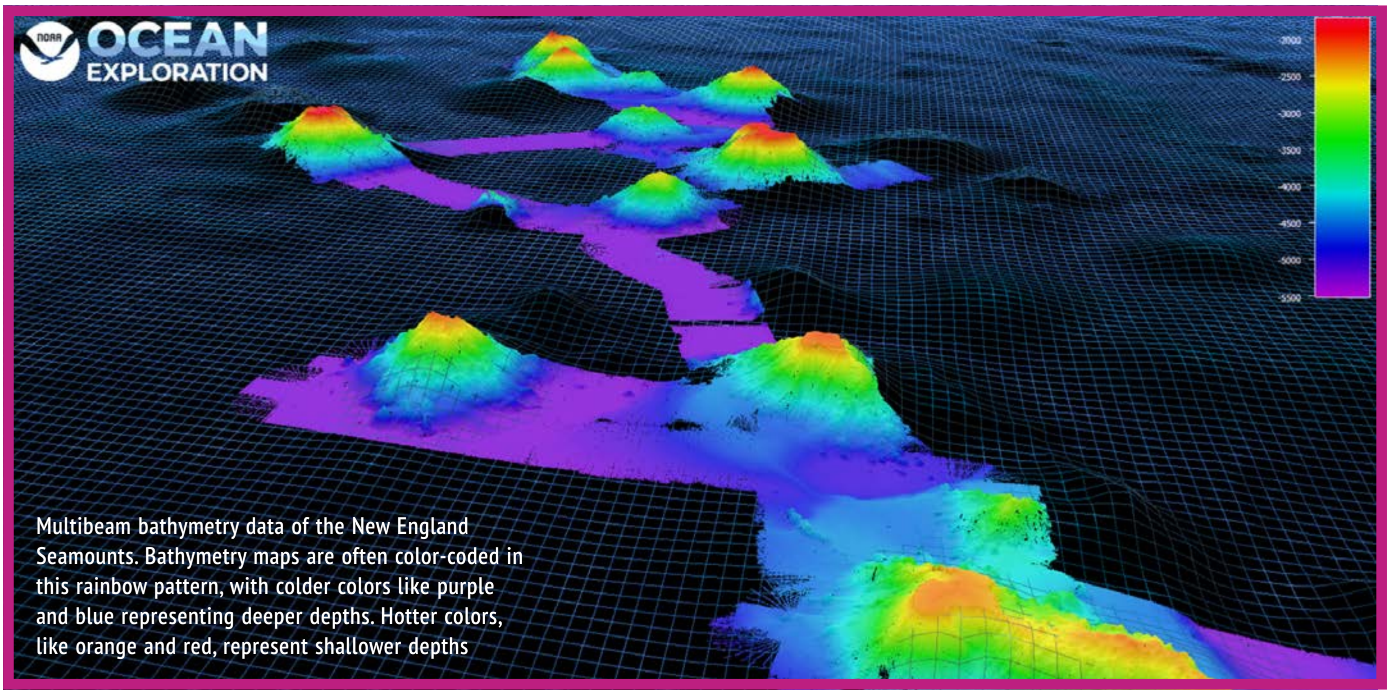


Rasters are pixelated and made up with individual cells. The resolution of a raster is the height and width of that particular cell. In the case of bathymetry data, each cell would contain the depth of the seafloor within that area. Images adapted from ESR

Remotely Operated Vehicle Data Types

Remotely operated vehicles (ROVs) are commonly used to collect video and imagery of the water column and seafloor. The video and imagery collected by the ROVs are often the first images of an area ever collected and are important for making discoveries about the deep sea.

Underwater video can be used to describe geological, physical, chemical, and biological processes and can also be used to document possible archaeological sites. In the case of NOAA Ocean Exploration, two ROVs continuously film and transmit high-resolution video data during a dive. ROV Deep Discoverer is also equipped with two lasers, spaced 4 in apart, which can be used to measure the lengths of organisms or objects.



Multibeam bathymetry data of the New England Seamounts. Bathymetry maps are often color-coded in this rainbow pattern, with colder colors like purple and blue representing deeper depths. Hotter colors, like orange and red, represent shallower depths

WINDOWS TO THE DEEP 2019 EXPEDITION

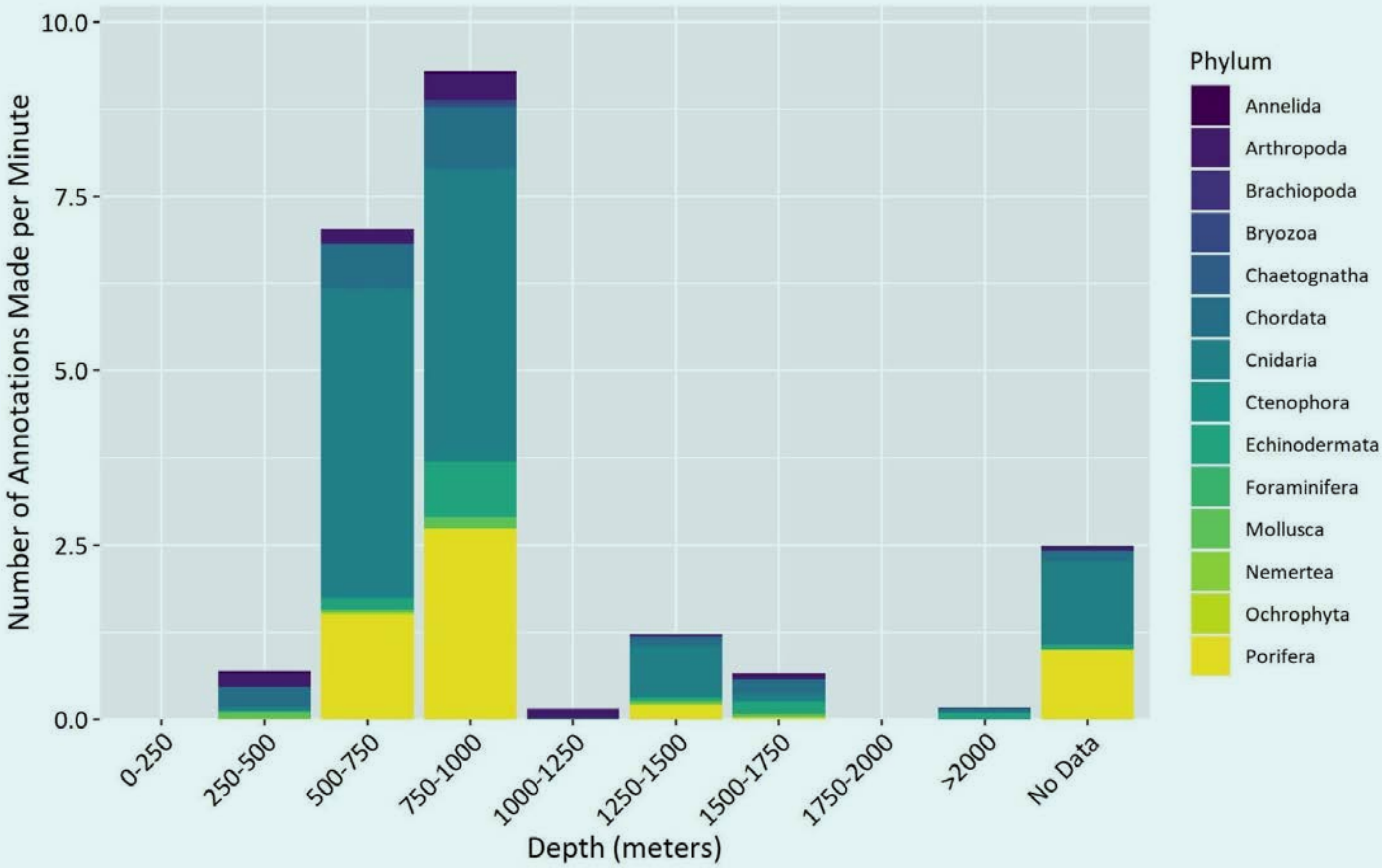
In the summer of 2019, NOAA Ocean Exploration and its partners conducted ocean exploration work in the deep waters of the southeastern United States (offshore North Carolina to Florida), on an expedition called Windows to the Deep 2019: Exploration of the Deep-Sea Habitats of the Southeastern United States. During the expedition, scientists explored a diversity of features through mapping and remotely operated vehicle (ROV) deployment, including deep-sea fish habitats, deep-sea coral and sponge communities, midwater habitats, cold seeps, submarine canyons, submarine landslides, and other unique geological features.

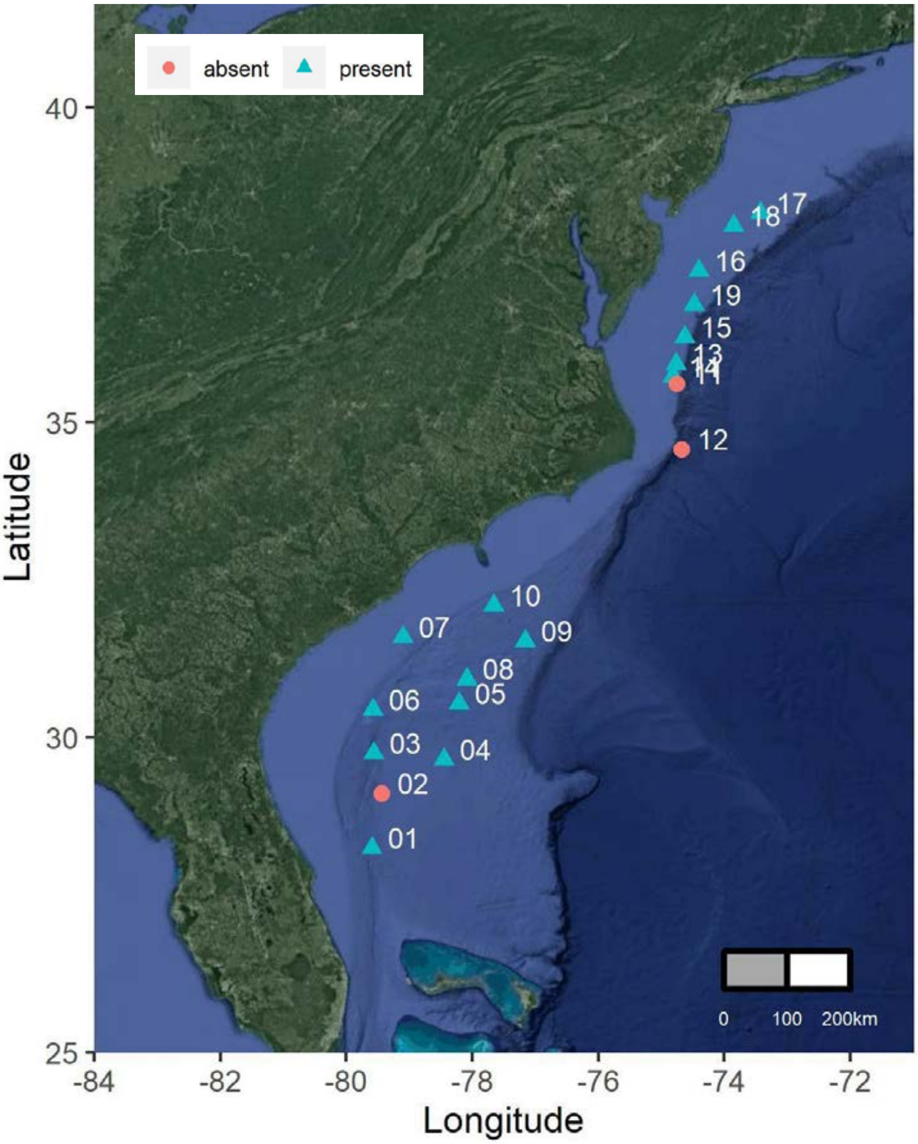
During this expedition, 11,192 mi2 of the seafloor were mapped and 19 remotely operated vehicle dives were conducted at depths ranging from 298 to 3,490 m (978–11,450 ft). Of those ROV dives,18 revealed deep-sea coral and sponge communities.

Dense fields of Lophelia pertusa, a common reef-building coral, found on the Blake Plateau knolls during the Windows to the Deep 2019 expedition. The white coloring shown here is healthy—deep-sea corals do not rely on symbiotic algae, so they cannot bleach.

During ROV dives, many ocean exploration organizations will live stream the video back to shore, so anyone can watch the dive, right from their own home! We call this technology telepresence. Through telepresence, we can see exactly where the ship is located and how much seafloor we have mapped. Scientists from around the world tune into the ROV dives from shore and make annotations of imagery and video that are collected. This means they mark a timestamp in the live video and enter information about what is being seen, such as organisms or geological features of interest, in order to keep a record of scientific observations. These dive annotations also provide a wealth of data about the deep sea that can also be visualized.

The ROVs also contain instrumentation used for georeferencing, meaning that the geographic coordinates of the ROVs can be determined as they survey the deep sea. Because of this, we also have the latitude and longitude for each of the annotations that are made. We can look at an organism of interest and then plot its location on a map.





Pictured here is a map showing where all 19 of the ROV dives took place during the expedition. On some dives (shown in blue), marine debris, or trash, was spotted on the seafloor. The numbers next to each dot represent the ROV dive number. In this map, we can see that marine debris was not spotted on three dives (shown in pink). Does that mean there is no marine debris located in that area? Not necessarily. The ROV only surveys a small area of the seafloor so there might have been marine debris just out of view of the camera.

Remotely operated vehicles are often fitted with other specialized equipment in addition to lights and cameras, including manipulator arms and suction samplers, which are used to collect biological and geological specimens. These specimens can provide a general representation of the biological and geological information of the site we explore. When we collect biological specimens, NOAA Ocean Exploration sends them to the Smithsonian Institution's National Museum of Natural History. Scientists then study them for a variety of purposes, ranging from determining if they represent a species new to science to better understanding the relationships between organisms. Geological samples, specifically rock samples, are collected to understand the geological history of a location. For example, the geology of the deep sea can reveal information about how that section of the ocean floor was formed.

Environmental Sensor Data Types

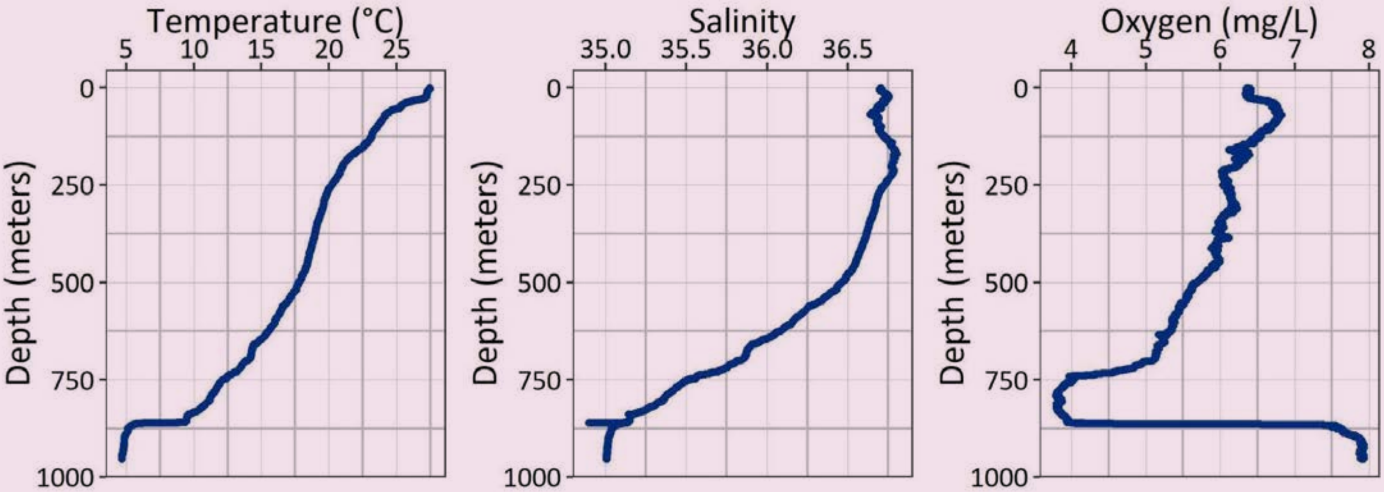
There are also a number of specific electrical sensors that can measure the environmental conditions of the water column. Together, the group of sensors is called a CTD, which stands for conductivity, temperature, and depth.

A CTD device's function is to measure how the conductivity and temperature of the water column change with depth. As the pilots guide the ROVs down to the seafloor, the CTD sensors constantly measure the environmental properties of the water column as compared to depth. For example, we can see that the water temperature is generally warmer at the surface and gets much colder the deeper an ROV descends. Conductivity is a measure of how well a solution conducts electricity, and it is directly related to salinity, or the "saltiness" of the water. The depth value is derived from the pressure measured by one of the electrical sensors.

Pictured here is a CTD rosette. The bottom of the rosette is where all of the electrical environmental sensors that measure depth, temperature, conductivity, salinity, and dissolved oxygen are located. The gray tubes with numbers on them are for collecting water samples throughout the water column. The CTD rosette is lowered vertically into the water using a long cable and the environmental sensors continuously collect data as it goes down into the water column. The water bottles can be "fired" at certain depth intervals, meaning that when the CTD is at a certain depth, a survey technician on the ship initiates a bottle to snap closed at that specific depth. The bottle then seals in the water from that spot and will not leak or open. This way we can conduct analyses on the water at specific depths to see how the water properties change at different depths. Water samples can be used to understand things like metal and nutrient concentrations.

WHAT IS THE OXYGEN MINIMUM ZONE?

Dissolved oxygen sensors measure the concentration of oxygen in water. When conducting a CTD rosette cast anywhere in the world, you will always find an area of the water column where the dissolved oxygen is very low compared to the rest of the water column. This is called the oxygen minimum zone, and it occurs at depths of about 200 to 1,500 m (656–4921 ft). Generally, warmer waters have less oxygen than colder waters. Many organisms live closer to the surface where the water is warmer. When these organisms die, they “rain down” into the deeper depths of the ocean. Oxygen is used up by bacteria in the oxygen minimum zone to feed on this organic matter, which is why the oxygen is low in this area of the water column. The depth at which the oxygen minimum zone occurs can only be spotted by visualizing the data that comes from the dissolved oxygen sensor attached to a CTD rosette or to an ROV. In the graph, we are able to clearly see the “peak” where the oxygen concentration drops.



These three line graphs show the temperature, salinity, and oxygen concentration as derived from the environmental sensors on the CTD rosette. The data pictured here was collected from one CTD rosette cast conducted during the Windows to the Deep 2019 expedition. We can see that during the cast, the temperature got much colder the deeper down the CTD rosette went. The salinity graph is showing a similar trend—the water is saltier at the surface because water at the surface evaporates, leaving the salts behind. For the oxygen graph, a greater number means there is more dissolved oxygen in the water. In this figure, we can see the oxygen minimum zone is about 800 m. Once the CTD rosette passes out of this zone, the oxygen levels spike again at around 1000 m.

Environmental sensor data is visualized through a line graph. On the y-axis we have our independent variable, which is depth. The x-axis contains the dependent variable, which is either temperature, conductivity, salinity, or dissolved oxygen. These variables are dependent on depth. Below is a graph of how CTD data are normally visualized.

Ocean explorers work to combine the different data types described in this article to tell a story about an area of the deep sea that we have explored. By combining all this data and visualizing it, we can understand things like why organisms live in that particular area of the ocean. Is it due to the environmental conditions determined using the CTD sensors? Is it the way the seafloor is shaped, which we can picture using mapping data? Is it all of the above? Data visualization also provides a way to tell other scientists what data we collected so they can build upon it to further our understanding of the deep sea. Data visualization can also provide the public with a better appreciation of the deep sea. Just like books, each data type or point of data can be thought of as a word or a sentence. When put together, they reveal a fuller picture of one of the most unexplored but important ecosystems in our ocean.