Exploration of Vailulu'u Seamount in American Samoa

Ocean Exploration and Research

This activity explores Vailulu'u Seamount in more detail, illustrating how to use the Ocean Exploration Digital Atlas and how to explore ocean features with the 3D software used by ocean explorers called Fledermaus.

(This free software must be downloaded to view and manipulate the image in the figure below. Download iView4D software from https://www.qps.nl/downloads/fledermaus/)

Background

Vailulu'u Seamount, located at the southeast end of the Samoan archipelago, has an incredibly dynamic history. Back in 2005, as a NOAA Office of Ocean Exploration and Research (OER) expedition team prepared to make their first dive on this underwater volcano, they made an unexpected discovery. A multi-beam sonar image showed the volcano's "crater" that had not been present when Vailulu'u was visited five years earlier. More surprises were in store for the scientists as they investigated the new cone (which they named Nafanua for the Samoan goddess of war), including features that they named "Eel City" and "Moat of Death."

Vailulu'u lies approximately 20 miles east of Ta'u Island in American Samoa. Like the Samoan Islands, Vailulu'u (and Nafanua) are believed to be the result of a hotspot; a sort of natural pipeline to reservoirs of magma in the Earth's mantle.

Hotspots are relatively stationary, and produce volcanic eruptions on tectonic plates as the plates pass over the hotspot. Two well-known examples of hotspot volcanic activity are Yellowstone Park and the Hawaiian Islands. The geologic history of the Samoan Islands (which were formed by hotspot activity) and the recent emergence of Nafanua make it very likely that Vailulu'u will continue to erupt at intervals and eventually emerge from the sea surface as a new member of the Samoan Island chain (for more information, please see "Volcanic Islands and Seamounts in the Samoan Region" by Matt Jackson: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/background/geology/welcome.html.)

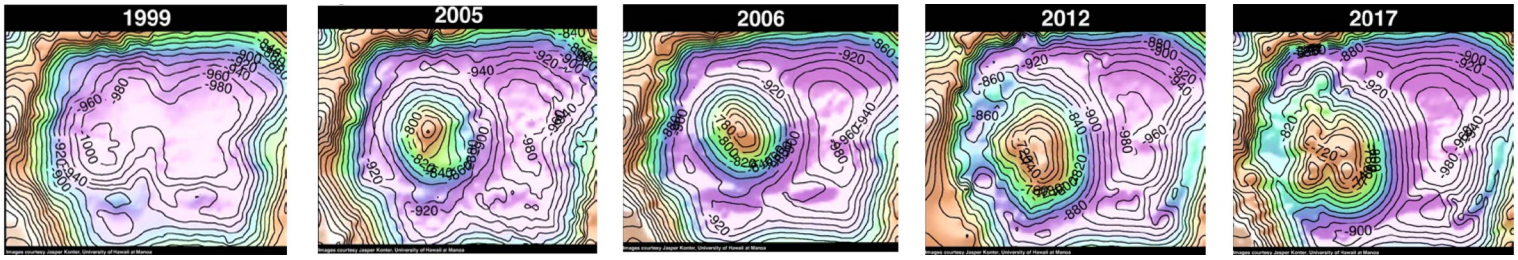
More recently, during the 2017 NOAA OER American Samoa Expedition, a team of scientists and technicians both at-sea and on shore conducted exploratory investigations to collect critical baseline information of unknown and poorly known deepwater areas in American Samoa and Samoa, with an emphasis on Rose Atoll Marine National Monument, National Marine Sanctuary of American Samoa, and National Park of American Samoa. This expedition was part of a major multi-year effort focused on deepwater areas of U.S. marine protected areas in the central and western Pacific called the Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE). A summary of expedition accomplishments and initial findings can be found here.
https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/summary/welcome.html.

Setting the Stage for Students

On February 24, 2017, the ninth dive of the NOAA OER American Samoa Expedition 2017, an exploration team investigated Vailulu'u Seamount, an active volcano lying in the southeastern region of the Samoan archipelago.

Initial student questions:

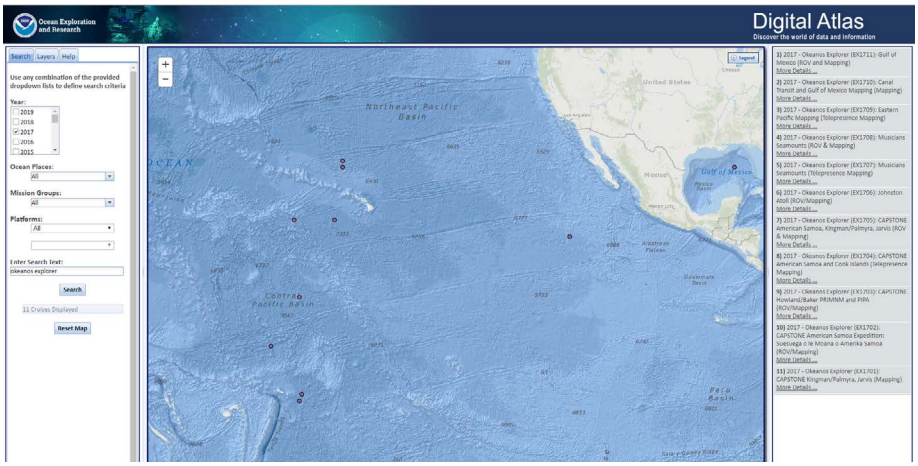
- When thinking about plate tectonics, what do you think the term "hot spot" is referencing?
- What changes do you see over time in these bathymetric contour maps of the ocean floor at the southeast end of the Samoan archipelago? Note: Bathymetric contour maps are like topographic maps of mountains, only under the water. The red portions of the maps are the shallower portions (closer to the sea surface) and the purples are the deepest portions. The numbers indicate the number of meters below the surface.



- Why might scientists be interested in exploring this area over time?

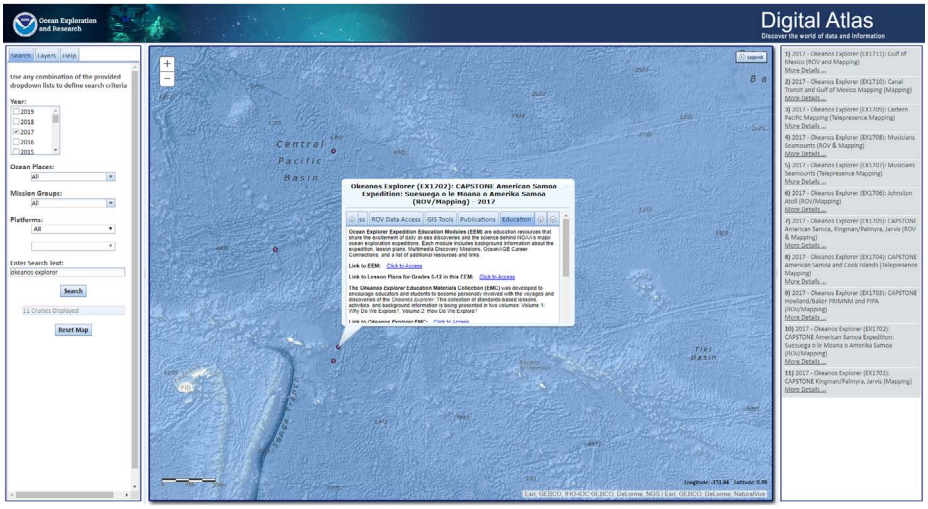
Using the Digital Atlas

1. Open the Ocean Explorer Digital Atlas at https://www.ncddc.noaa.gov/website/google_maps/OE/mapsOE.htm



2. In the left column click on the **Search by Text** tab. Select the year 2017 and in the text box type *Okeanos Explorer*. The dots that will appear on the map are all of the 2017 *Okeanos Explorer* expeditions.

3. In the column on the right, scroll to find the 2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa (EX1702). At the time of this writing, this is #10 in the list. Tell students that cruises are named with an abbreviation of the ship name ("EX" is used as an abbreviation for *Okeanos Explorer*), the last two digits of the year in which the cruise took place ("17"), and the number of the cruise (this was the second cruise for 2017).

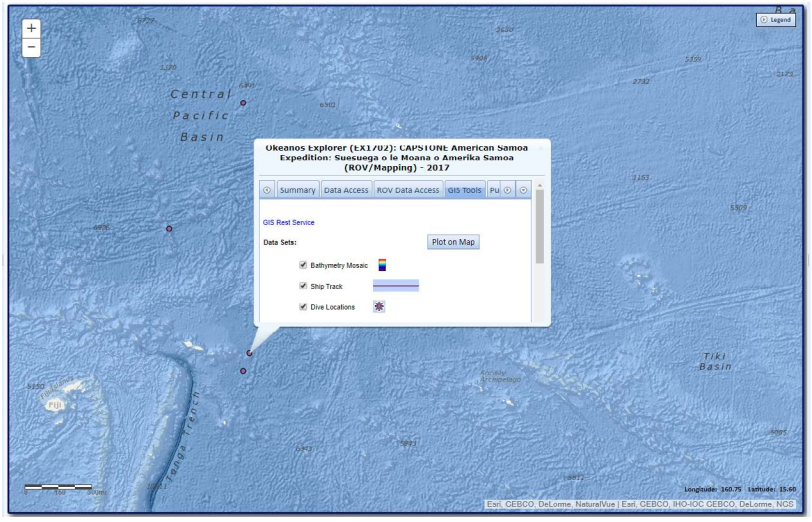


Click on this cruise and you will see a pop up box as illustrated in the figure to the left.

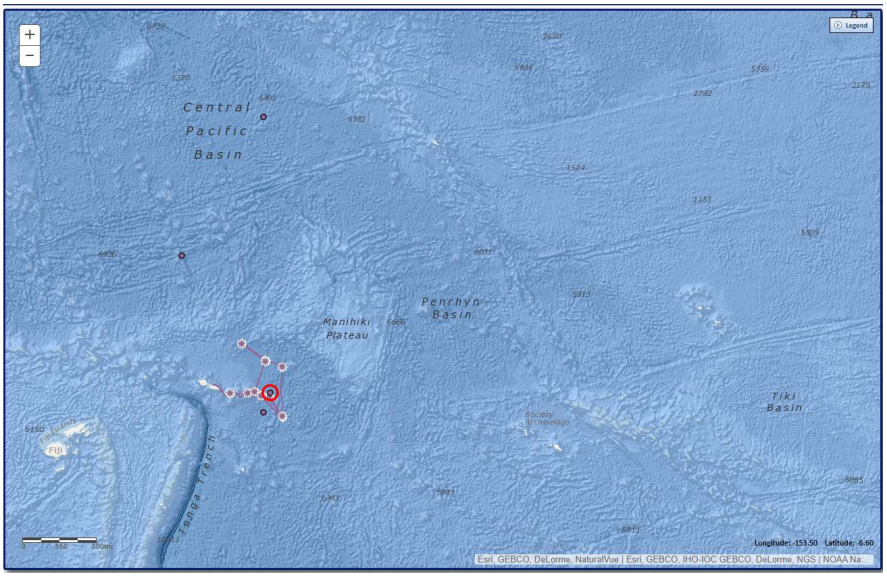
Notice the tabs provided at the top of the pop up window.

For educator information related to this cruise, click on the **Education** tab. This will take you to several educational resources available on the Ocean Explorer website related to this expedition including an Expedition Education Module which provides background information, essays, lessons, a webinar for educators, and more resources associated with the expedition.

4. Click on the **GIS Tools** tab in the pop up window, select all three boxes, and click **Plot on Map**.

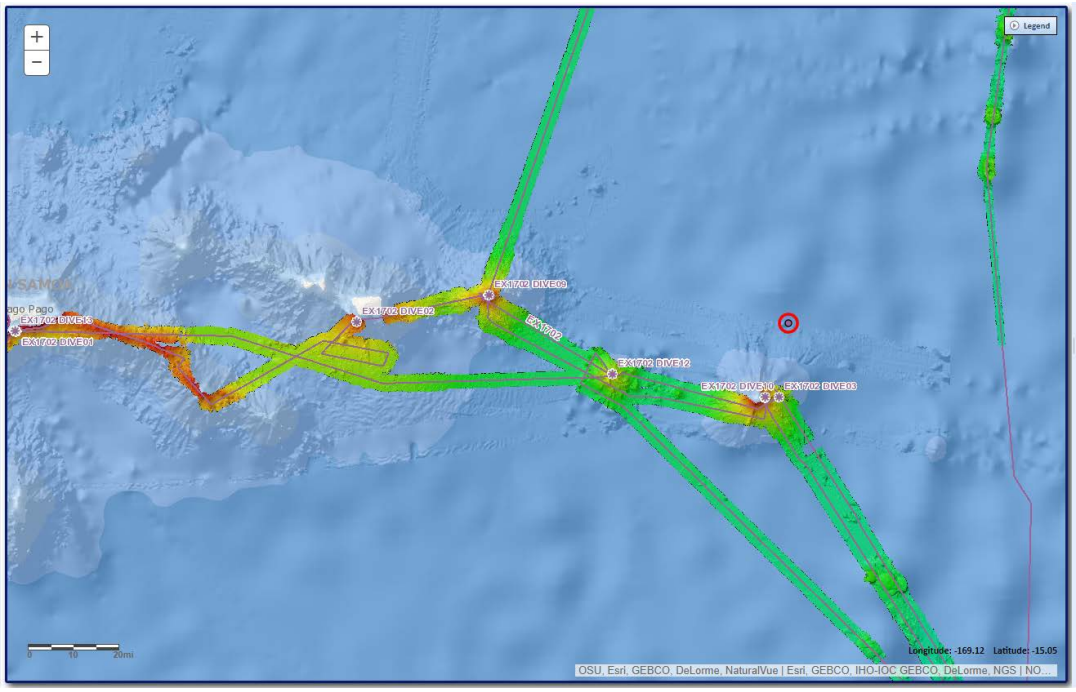


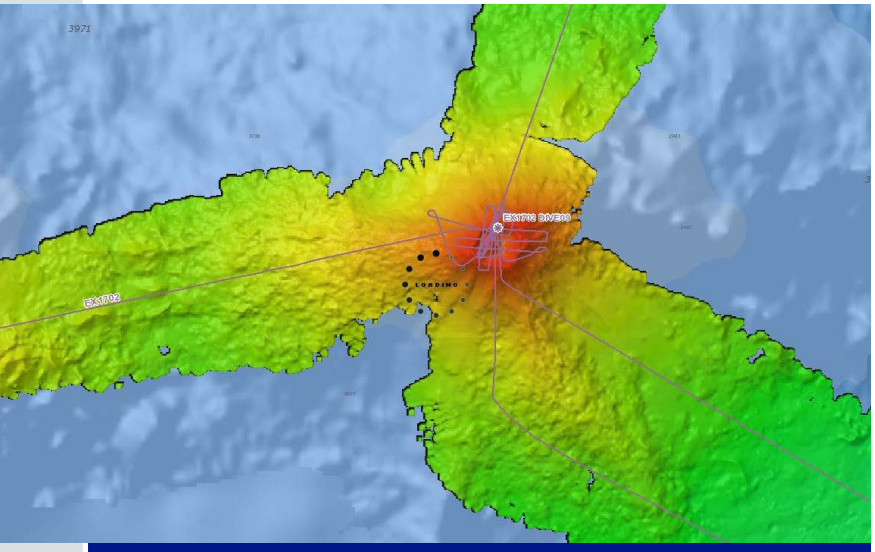
Give the map a moment to load and what appears should look like the figure to the right.



Click on the map and holding the left mouse button down, move the view slightly to the right until the purple dive tracks are in the center of your screen.

Using the center mouse button, zoom in and you will see the entire cruise track and the false color bathymetric mapping work done throughout the expedition. Again, red is the shallowest followed by orange, yellow, green, blue and purple, with purple being the deepest.





BASED ON THE BATHYMETRIC MAPPING PREVIOUSLY DONE HERE, THE EXPEDITION TEAM SELECTED THE LOCATION OF DIVE 9 TO SEND THE *DEEP DISCOVERER* ROV FOR A CLOSER LOOK.

5. Look for the label for Dive 9. Zoom in more until you see the purple lines that indicate the track of the ship over the region of Dive 9.

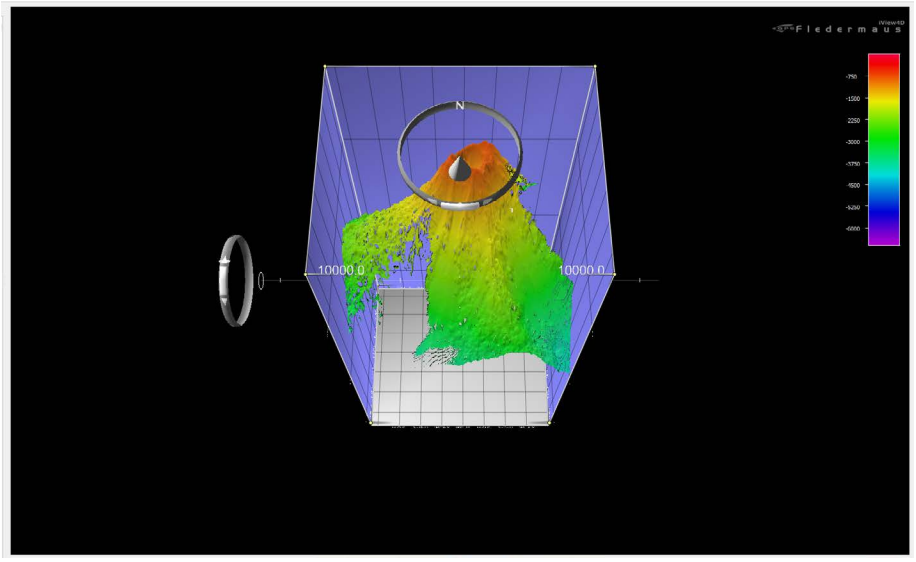
Possible guiding questions:

- What do you think the ship was doing here to make those purple lines on the map? Why?
- Can you think of anything in your life that makes similar patterns?

Explain to students that the first step in the ship's exploration strategy is mapping and that the ship is obtaining high-resolution multibeam maps of the area being explored (this tracking back and forth is called "mowing the lawn"). You will see both the track of the ship and the false color bathymetry of Vailulu'u Seamount.

6. Click on https://www.ncei.noaa.gov/waf/OER-Media/ex1702/EX1702_DiveSite2-Vailulu_40m.sd. This will open an interactive scene file of Vailulu'u Seamount within a three dimensional data visualization system called Fledermaus.
(This free software must be downloaded to view and manipulate the image in the figure below. Download the iView4D software from the dropdown menu at https://www.qps.nl/downloads/fledermaus/.)

This image of the Vailulu'u Seamount was created from the multibeam sonar data collected as the ship traveled over and mapped the seafloor in this region.



7. **Orientation to Fledermaus manipulation tools:**

   a) Notice on the top left box that the exaggeration is set at 6.00x. You can view actual bathymetry at 1.00x. The image has been exaggerated to six in order to view the structure in more detail. Try changing the exaggeration to 3.00x and see what happens.

   b) The white x and y axis orients the viewer to distance in meters.

   c) The rings on the left and at the top of the image can be used to manipulate the view. *(Note: Use Camera and Reset Camera in the menu bar to return to the original view.)*

   d) The ocean floor is shown as a three-dimensional image. The x-axis represents longitude, the y-axis represents latitude, and the z-axis represents depth. When you move the cursor over the image, the window near the bottom of the screen shows the geo coordinates (x, y, and z) for the location beneath the cursor.

Have students analyze the image and develop questions based on their own curiosity.

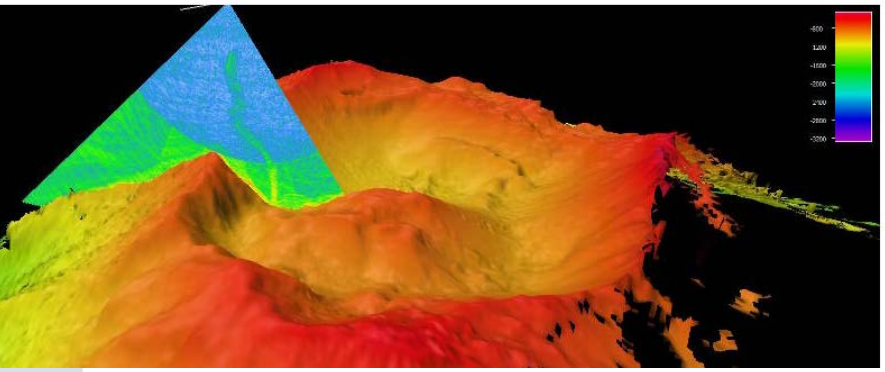
Questions for students to consider might include:

- What is the length of the seamount from east to west?
- What is the length of the seamount from north to south?
- What is the deepest point of this seamount? What is the shallowest point?
- What depth variations do you notice in the center of the volcano?
- How tall is the cone in the center of the volcano?

Based on what they observe in the image and where they know the seamount is located:

- What might be the reason this seamount is an active volcano?
- What organisms might live here? Why?
- What is succession and what might that mean in this environment?
- Do you think different organisms live at different depths on this seamount? Why or why not?
- Why did the scientists select these dive locations? If you were the scientist leading this expedition and exploring this seamount for the first time, where would you choose to send the ROV? What considerations do you think need to be made when deciding what regions to select for further exploration?

8. Have students read about findings from 2005 and watch the associated short video of "Eel City." These eels, small synaphobranchids *(Dysommina rugosa)*, had never before been studied in their natural habitat.
https://oceanexplorer.noaa.gov/explorations/05vailuluu/welcome.html
https://oceanexplorer.noaa.gov/explorations/05vailuluu/media/movies/eel_city_video.html

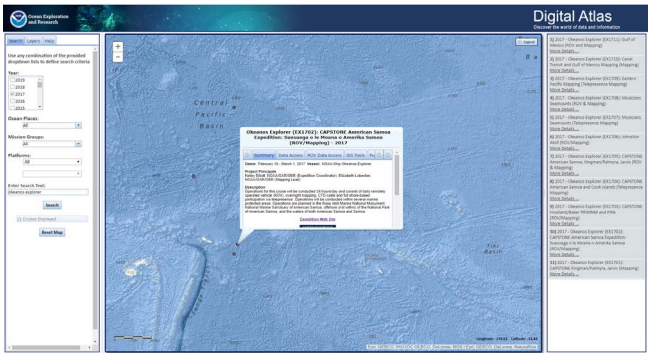


NOW HAVE STUDENTS LOOK AT THIS FLEDERMAUS IMAGE. THE MULTIBEAM SONAR SWATH SHOWS A VENT FIELD PERCOLATING FROM THE CALDERA (YELLOW AND GREEN DATA STREAM).

Image: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/feb22/media/vailulu2.html

Read more here: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/feb22/welcome.html

9. Now go back in the atlas and click on the expedition box on the right, EX1702, again. In the pop up window **Summary** tab will be a link to the expedition on the Ocean Explorer website. Click on **Expedition Website**.



This is the main 2017 American Samoa Expedition webpage. In the menu on the right, click on the Daily Updates and scroll do Dive 9, February 25, 2017. Read the exploration teams log and watch the Vailulu'u Volcano video to hear them describe their findings with the ROV.

10. Now that students have reviewed the most recent exploration, revisit their questions from #7.

Teacher Information

Video from the ninth expedition dive, and audio commentary accompanying the video, provides students with access to a limited amount of empirical evidence about ecosystems associated with Nafanua and the Vailulu'u crater. When the video was made, all lavas on Nafanua (and all associated ecosystems) were less than 18 years of age since Nafanua did not exist when the crater was mapped in 1999. Additional empirical evidence is provided in the "Eel City and the Moat of Death: An Active Volcano on the Samoan Hotspot" by Young and Staudigel from the Vailulu'u 2005 Ocean Explorer Expedition (https://oceanexplorer.noaa.gov/explorations/05vailuluu/welcome.html). It is reasonable to infer that living organisms in the vicinity of the crater have been strongly influenced by major physical and chemical changes accompanying volcanic eruptions and hydrothermal activity. To begin the discussion, ask students to describe some ways that physical ecosystem components affect biological components. Shelter, substrates (hard surfaces for attached organisms, sediments for burrowing organisms, etc), and energy sources (food) should be identified fairly quickly. You may need to prompt students to consider extreme conditions: Obviously, physical conditions must be within the tolerance range of living organisms; otherwise, the organisms cannot exist. Tolerance range, though, varies widely among species, as shown by the presence of thriving ecosystems in the vicinity of hydrothermal vents. Sudden changes in physical conditions, though, can result in mass mortalities such as those seen at the "Moat of Death."

Organisms living on recently-erupted lava at Vailulu'u include carnivorous sponges, anemones, ophiuroid brittle stars, and stalked hydroids. Discuss the nutritional strategies used by these organisms. Sponges, anemones, and hydroids are all sessile and are adapted to capture particles and small animals from water flowing over the lava surface. Adaptations of carnivorous sponges are particularly interesting (see Lundsten et al., 2014, for more information at http://www.mapress.com/zootaxa/2014/f/zt03786p123.pdf and the associated article from Monterey Bay Aquarium Research Institute, https://www.mbari.org/researchers-describe-four-new-species-of-killer-sponges-from-the-deep-sea/), and the images of partially digested prey species captured by the sponges provide evidence that a variety of other species are present in addition to those directly observed in the video. Ophiuroids may also feed on suspended material, as well as detritus, small crustaceans or worms. The prevalence of suspension feeders in the video supports inferences about the importance of currents around Vailulu'u in supplying food to resident species. In general, current flow is often a key factor that contributes to unusually high productivity and biodiversity in seamount ecosystems. Organisms living on older lava on the summit of Nafanua included the same species, as well as Anthomatus soft corals. Expedition scientists commented on the more extensive sediment cover on the summit, as well as higher biological diversity and the larger size of many organisms. These observations are consistent with a lack of recent volcanic activity (i.e., more stable conditions) on the Nafanua summit.

11. Ask students if they were to take what was learned from this exploration and go back to investigate further, what would be their area of interest? What would they want to know?

Next Generation Science Standards and Ocean Literacy Essential Principles and Fundamental Concepts

Activities presented here may be used to support specific elements of the NGSS and Ocean Literacy Essential Principles and Fundamental Concepts as described below.

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics
Performance Expectation
MS LS 2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

- Science and Engineering Practice: Engaging in Argument from Evidence
- Disciplinary Core Idea: LS2.C Ecosystem Dynamics, Functioning and Resilience
- Cross Cutting Concept: Stability and Change

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics
Performance Expectation
HS LS 2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

- Science and Engineering Practice: Engaging in Argument from Evidence
- Disciplinary Core Idea: LS2.C Ecosystem Dynamics, Functioning and Resilience
- Cross Cutting Concept: Stability and Change

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1. Earth has one big ocean with many features.

Fundamental Concept b. Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys and flattest plains are all in the ocean.

Essential Principle 5. The ocean supports a great 5 diversity of life and ecosystems.

Fundamental Concept e. The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 7. The ocean is largely unexplored.

Fundamental Concept a. The ocean is the largest unexplored place on Earth. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

Fundamental Concept d. New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.

Fundamental Concept e. Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

Additional Resources

Ocean Explorer Seamounts Theme page
https://oceanexplorer.noaa.gov/edu/themes/seamounts/welcome.html
This page compiles some of the best ocean explorer education resources on seamounts including essays, lessons, multimedia activities and links to past expeditions.

Seamounts, Les Watling Ph.D., University of Hawai'i at Manoa
https://vimeo.com/88841596 – In this 45 minute video, Dr. Les Watling, marine scientist at the University of Hawai'i at Manoa, provides an excellent description of the formation of seamounts, their geology and their associated ecological and biological diversity.

For Information and Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to: oceanexeducation@noaa.gov.

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