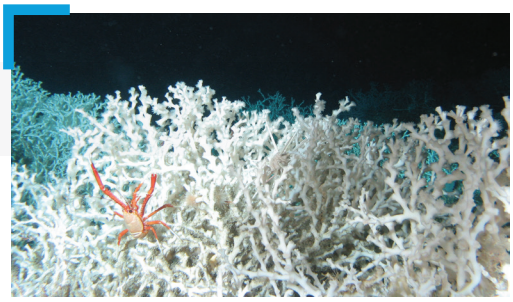
Investigation: Laying the Foundation for Deep-Sea Coral Gardens

Overview



Deep-sea corals provide many vital roles for other organisms living with in the deep-sea coral ecosystem. Here a squat lobster uses the *Lopheila pertusa* coral to position itself up above the seafloor to catch the next prey item that swims by. *Image courtesy of NOAA Ocean Exploration.*

TOPIC: Deep-Sea Coral

FOCUS: Students analyze data and images to make sense of deep-sea corals' role as foundation species in coral gardens.

GRADE LEVEL: 9th-12th

TIME NEEDED: Two 45- or 50-minute class periods

PHENOMENON (DRIVING QUESTION): How does the presence of *Lophelia pertusa* (a species of deep-sea coral) affect other organisms in a deep-sea coral ecosystem?

OBJECTIVES/: LEARNING OUTCOMES:

Students will:

- Construct an explanation of how the presence of *Lophelia pertusa* corals leads to biotic and abiotic conditions that promote biodiversity in a deep-sea coral ecosystem.

MATERIALS:

Deep-sea Coral Community Slides (1-19) (for student groups; print or digital copies)

- Slide 1: Expedition Map and introduction to the phenomenon
- Slide 2: Why does *Lophelia pertusa* have so many "friends?"
- Slides 3-14: Deep-sea Coral Community organisms
- Slides 15-17: Foundation Species examples
- Slides 18-19: Foundation Species Graphic Organizers

Videos

- Ancient Coral Garden video (3:27) NOAA Ocean Exploration
- Architects of the Deep video (4:42) NOAA Ocean Exploration

Student Worksheets and Graphic Organizers (included in slides for easy sharing)

- *Lophelia pertusa* Friends Student Worksheet (page 8 or slide 2)
- Foundation Species Graphic Organizers (page 9 or slides 18-19)

EQUIPMENT:

- Video projection or online sharing capability
- Student notebooks for students to record their observations, questions, and explanations
- *Optional: Student laptops or tablets for extensions and/or additional research*

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectations (PEs): HS-LS2

Crosscutting Concepts (CCs)
Cause and Effect

Disciplinary Core Ideas (DCIs)
LS2.A Interdependent Relationships Within Ecosystems
LS2.C Ecosystem Dynamic, Functioning and Resilience

Science & Engineering Practices (SEPs)
Analyzing and Interpreting Data
Constructing Explanations
Obtaining, Evaluating, and Communicating Information

COMMON CORE CONNECTIONS
ELA/Literacy - RST.11-12.1, RST.11-12.7, WHST.11-12.7, WHST.9-12.2;
Mathematics - MP.2

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
Principle 5; FC e,f

Overview cont.

SET-UP INSTRUCTIONS: Cue up all slides and videos for student viewing

For in-person instruction:

- Copy the *Lophelia pertusa* Friends Student Worksheet (page 8) *(one per student)*
- Print the Deep-sea Coral Community organisms (slides 3-14) *(one image per student group)*
- Copy the Laying the Foundation Graphic Organizers (page 9) *(one per student)* or have students copy in their science notebooks

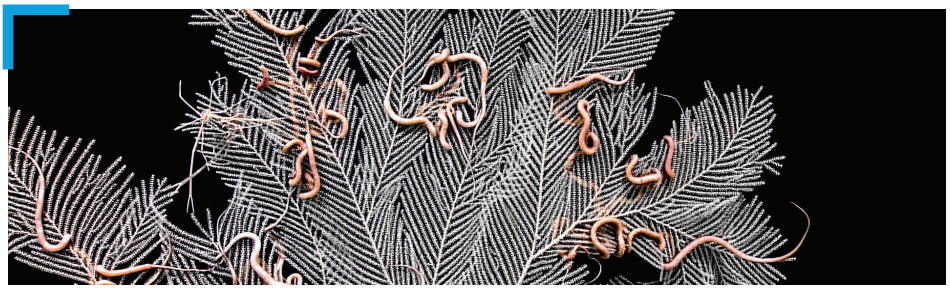
For online learning:

- Share all videos, Deep-sea Coral Community Slides, and worksheets with students using an online learning platform.

Educator Guide

Background

When we think of corals, we often think of the brightly colored varieties that make up shallow, warm-water tropical coral reefs. These corals rely on symbiotic algae to capture energy through photosynthesis, and these algae lend color and critical nutrients to shallow-water corals. In fact, a loss of those colors is a potential sign of stress that can lead to the death of shallow corals. It is less well known that we can also find corals in deeper, colder waters where little-to-no light is available for photosynthesis. These deep-sea corals live in waters deeper than 50 meters (164 feet) and can be found throughout the world's ocean basins, even in polar waters. Deep-sea corals survive by filter feeding, rather than relying on symbiotic algae, and they often have a white color even when perfectly healthy. Shallow water and deep-sea corals have one important thing in common: they each serve as **foundation species** in unique ecosystems that provide habitat and food for a wide variety of other organisms.

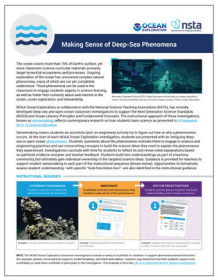


Deep-sea corals are foundation species in deep-sea coral habitats. They fulfill many essential roles that shape the community structure, including providing shelter, and/or food for other species. *Image courtesy of NOAA Ocean Exploration.*

Educator Note

A variety of student interaction techniques and examples of student questions are provided throughout this activity to engage students in the process of sensemaking to move their learning forward.

Learn more about the instructional strategies and tools included in the NOAA Ocean Exploration student investigations.



FOR MORE INFORMATION:

- *Deep-Sea Corals - What Are They?* *Fact Sheet*

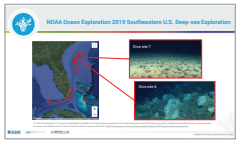
- *Deep-Sea Corals and Sponges - Foundation Species* *Fact Sheet*

Educator Guide cont.

Experience the Phenomenon

Begin by telling students you are sharing an interesting phenomenon with them, and ask them to make a t-chart on a sheet of paper with one column labeled "I Notice..." and a second column labeled "I Wonder...."

Show students slide 1, which highlights images from remotely operated vehicle (ROV) dives 6 and 7 during the 2019 Southeastern U.S. Deep-sea Exploration.



Ask students to record observations ("I Notice…") and questions ("I Wonder…") on their t-charts as they observe the two images. Have students turn to a partner and share their observations. Circulate and listen to student observations. They will likely focus on the fact that there is no life evident on the seafloor at site 7 while the seafloor is covered with corals at site 6. Encourage students to focus on observations, rather than inferences. For example, ask students, "Which observations make you say that?"

Tell students that you will be taking a closer look at site 6, by exploring video footage from the remotely operated vehicle (ROV) dive. Show students the Ancient Coral Garden video recorded at dive site 6 (3:27, NOAA Ocean Exploration). Play this video at least twice for students. After the first viewing, lead a short discussion to help students to connect this likely unfamiliar phenomenon. You can use the following questions to prompt this discussion.

Video courtesy of NOAA Ocean Exploration.

TEACHING NOTE

The term Coral Gardens is used to describe deep-sea coral ecosystems with a very high density of coral coverage.

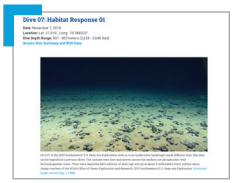
- *What does this (site 6) remind you of?*
- *What have you experienced before that this reminds you of?*
- *Can you think of an ecosystem on land that has any similarities to this deep-sea coral garden?*

Now, ask students to add to their Notice and Wonder charts as they watch the video a second time. Replay the video again if students need more opportunities to make observations.

Ask students to share their observations and questions with a partner and then with the whole class. As students share their ideas with the class, record them on a full class Notice and Wonder chart.

Students might ask questions like:

- *Why do corals live at dive site 6 and not at site 7?*
- *How did this mound first form? or Why do these corals form mounds?*
- *What is floating in the water in the shot of the sunfish?*
- *What are the dark objects on the seafloor at site 7? (You or your students can learn the answer to that question by reading this Daily Updates and this Mission Log from the expedition.)*
- *What type(s) of coral are found here? or What is* Lophelia pertusa*?*
- *What other types of organisms live here?*
- *How do these organisms survive? or How do they get food/energy and other resources? (Consider exploring the Feeding the Million Mounds of Deep-sea Coral investigation focused on the correlation between the coral mounds and the Gulf Stream with your students.)*
- *Are some of the other animals feeding on the corals?*



TEACHING NOTE

Compile student questions without evaluating them or attempting to answer them. A few of the questions above have links to additional information because they are not addressed directly in this lesson. The remaining questions will be addressed within this lesson. You can direct students back to the video to answer factual clarifying questions. For example, students can conclude from the video that *Lophelia* is a type of coral.

Say to students, "We now have two big questions. Some of our smaller questions relate to the big question of ***why* Lophelia pertusa *prefer living here and not in other locations,*** while our other smaller questions relate to the big question of ***how the presence of* Lophelia pertusa *affects other organisms in deep-sea coral ecosystems***. For now we are going to focus on this second question."

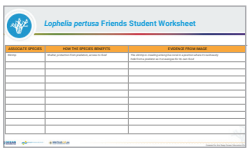
Educator Guide cont.

Investigate

Analyzing Images

Tell students they will be investigating the driving question, ***How does the presence of* Lophelia pertusa *affect other organisms in deep-sea coral ecosystems?***, by analyzing images captured during NOAA Ocean Exploration expeditions that have explored deep-sea coral ecosystems. Assign each image provided in slides 3-14 to a pair or small group of students.

Provide each group with a paper or electronic copy of the *Lophelia pertusa* Friends Student Worksheet (on page 8 or slide 2). The first row of the chart provides a sample response based on an organism shown in the Ancient Coral Garden video.



Instruct students to look at their images depicting a variety of species that are associated with *Lophelia pertusa* corals, and use evidence from the images to infer how the associated species might be benefitting from biotic or abiotic factors provided by *Lophelia pertusa* colonies.

Have students use the chart to record their inferences and evidence as they analyze their assigned image. Point out that one image may show more than one associated species.

After small groups have had time to analyze their images, have each group present their findings to the class. Have students use their charts to record information presented by other groups.

Put the Pieces Together

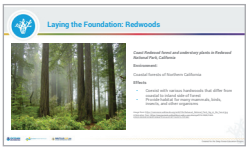
Tell students they will now be exploring some science ideas that will help them make sense of the evidence they gathered from the images. Show the Architects of the Deep video (4:42 mins, NOAA Ocean Exploration). Have students add to their Notice and Wonder charts and share additions with the class, as appropriate.

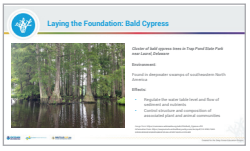
Video courtesy of NOAA Ocean Exploration.

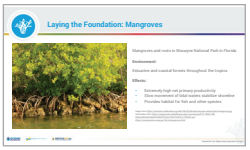
Say to students: *Deep-sea corals can be called* ***foundation species*** *because they form the foundation of their ecosystems. This is similar to the way that certain types of trees create certain types of forest ecosystems.* Note: They actually create an ecosystem that provides other organisms with the resources they need to survive.

Let's take a look at three examples.

Share slides 15-17, which provide examples of three foundation species that are found in different parts of the United States. Ask students what they think is meant by the term foundation species. Help students understand that a foundation species shapes and defines a particular ecosystem without necessarily having a primary role as a food source for other organisms. They serve as "ecosystem engineers." As in the examples given on the slides, the ecosystem is often named for its foundation species, as the system could not exist in its current state without that species.





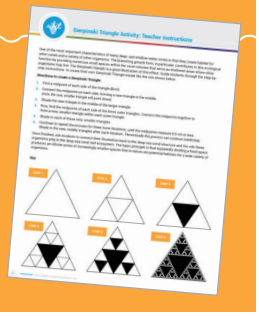


Tell students they will be reading some scientific sources to further develop their explanation of how *Lophelia pertusa* corals act as a foundation species in this deep-sea coral. Students will read and share information from four sources through the jigsaw method.

OPTIONAL ACTIVITY

Sierpinski Triangles

An additional scaffold to student understanding of the connection between the shapes and structures of deep-sea corals and habitat they create for other invertebrates.



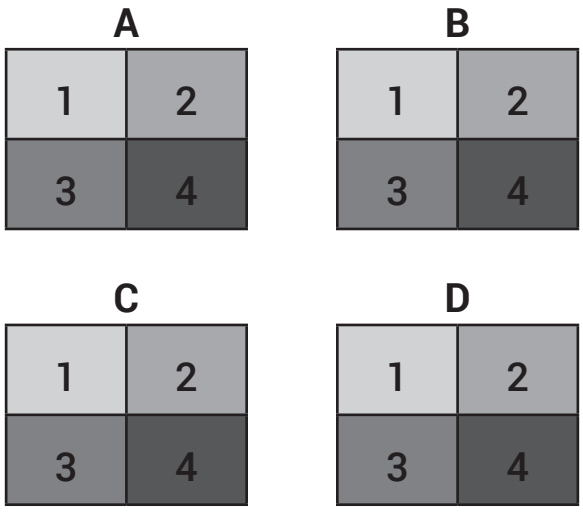
Educator Guide cont.

Put the Pieces Together cont.

Jigsaw Procedure

- Assign students to groups of four and identify these groups by letter: group A, group B, group C, etc. These will be the home groups.
- Within each home group, assign students an "expert" number 1-4 based on which source they will read. These numbers represent expert groups.
- Have each student read their assigned text. As they read, have students use the Laying the Foundation: *Lophelia pertusa* graphic organizer on slide 18 to record key information about characteristics of *Lophelia pertusa* and how these characteristics benefit associate species.
- Allow expert groups to meet and discuss their findings.
- Have students return to their home groups and share their findings from the expert groups.

Jigsaw Reading Groups



Home Groups = Letters Expert Groups = Numbers

Jigsaw Expert Readings

1. Living Geology: How Cold-water Corals Shape the Seafloor
2. Life in the Deep-Sea Coral Forest
3. Dive 06: Isolated Mound, Central Blake Plateau: November 6: 2019 Southeastern US Deep-sea Exploration
4. Charting "Million Mounds" Deep-Sea Corals exploration note

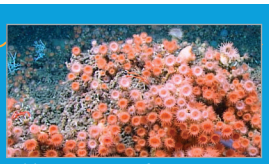
Once student groups have wrapped up their group discussions, have students spend a few minutes quietly writing out explanations to the question: How does *Lophelia pertusa* coral act as a foundation species in deep-sea coral communities? As students write, circulate around the room to get a sense of what ideas students are using to explain how *Lophelia pertusa* coral facilitates the presence of other species.

After student groups have had a chance to write their initial explanation about characteristics of *Lophelia pertusa* and how these characteristics benefit associated species, **facilitate** a whole-class discussion to build a consensus explanation. Based on your observations of student explanations, call on select students to highlight useful or contrasting ideas or questions. Encourage students to elaborate on their evidence and reasoning and to build on and critique others' claims, evidence, and explanations.

Guide students to revise their explanations, drawing on all the evidence they have recorded from the videos, images, readings, and discussions. Have students spend a few minutes quietly writing out their ideas on paper. Remind students that they can use a drawing or model to support their explanation. As students work, again circulate around the room to get a sense of what ideas students are using to explain how *Lophelia pertusa* coral facilitates the presence of other species.

TEACHING NOTE

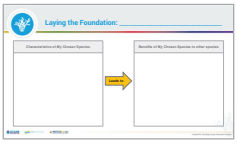
Preview the jigsaw readings to identify main ideas that can be used to guide students' discussions. You can also gain some useful background knowledge from this video about the Million Mounds (4:17 mins, NOAA Ocean Exploration) area. In particular, the video discusses the role *Lophelia pertusa* plays as a foundation species beginning at 3:06.



Video courtesy of NOAA Ocean Exploration.

Educator Guide cont.

Extensions



- Challenge students to apply the concept of a foundation species to a local ecosystem or an ecosystem of their choice. Have students conduct research on that ecosystem and use the generic Laying the Foundation graphic organizer on page 9 or slide 19 to compile evidence about the foundation species in that ecosystem. Students should then construct an explanation about how the foundation species facilitates the presence of other species in the ecosystem. You may choose to have students present these explanations orally in class, on posters, or through a digital platform. The following ideas are options to provide to students if needed.
  - Deep Sea Symphony: Exploring Musicians Seamounts, Hawaii (NOAA Ocean Exploration)

    In this instance you might note that this example is "messy" and it is not so easy to point to just one species. Have students try to use the graphic organizer to work backwards and make a case for the foundation species (corals and sponges).
  - With Beethoven in the background, the Coral in Concert video (NOAA Ocean Exploration) can help students understand how coral and sponge communities like those of Musicians Seamounts act as hotspots for biodiversity in the deep sea.

  - Florida Keys National Marine Sanctuary, Coral Barrier Reef, Florida
  - Allegheny National Forest, Pennsylvania. Or find a national forest in your area.
  - Pacific Northwest Temperate Rainforest, Washington. Or find a national park in your area.
  - A beaver pond. These are found in many locations. One example can be seen on the Beaver Ponds Trail in Yellowstone National Park.
- Consider wrapping up with any or all of the following videos:
  - The Mighty Black Coral (1:46 min, NOAA Ocean Exploration). Focus: diversity and fragility of deep-sea coral ecosystems.
  - Discovering Deep-Sea Corals of the Phoenix Islands 2- Communities Above and Below (4:52 mins, Schmidt Ocean Institute). Focus: pristine and diverse ocean environments and the excitement of ocean exploration.
  - Discovering Deep-Sea Corals of Phoenix Islands 2 - Searching for the Origin of Immunity (4:17, Schmidt Ocean Institute). Focus: coral predators (corallivory) and what we can learn about our own immune system from observing deep-sea corals react to infection.
  - The Blake Plateau (entire video 3:07 mins, NOAA Ocean Exploration). Focus: understanding why scientists are interested in exploring this area.
  - Deep Corals of PIPA (7 mins, Schmidt Ocean Institute). Focus: value of these communities and associated innovative technology.
- In many of the resources provided in this lesson, it is emphasized how long these corals can live, however, aging corals is not a simple process. Have students check out Dyeing Corals to Track Growth Exploration Note to learn how this can be done.

Educator Guide cont.

Scientific Terms

Foundation Species: Species that have a strong role in structuring a community; habitat-forming organism(s) that define an ecosystem (e.g. kelp beds, coral reefs, hardwood forests).

***Lophelia*:** A genus of cold water coral which grows in deep waters throughout the North Atlantic Ocean as well as parts of the Gulf of America, Caribbean Sea, and Mediterranean Sea. *Lophelia pertusa* is the dominant species of the Million Mounds coral region and is used as the example foundation species in this investigation.

Coral rubble: Fragments of reef building coral, broken from reefs and resting on the seafloor.

Assessment

Opportunities for formative assessment are embedded throughout the lesson. The student models and explanations that are developed at the end of the lesson (whether written or drawn) could be used as an opportunity for summative assessment of learning.

LOOK FORS

The following components should be included in students' final explanations. These may be represented through a combination of words, pictures, and symbols.

CHARACTERISTICS OF *LOPHELIA PERTUSA*	BENEFITS OF *LOPHELIA PERTUSA* TO OTHER SPECIES
• Living coral has a highly branching structure • Dead coral rubble provides a harder surface than bottom sediments • Rubble forms mounds that rise above the seafloor • Living coral reaches up above the mound surface • Rubble also provides many small openings ("nooks and crannies") • *Lophelia pertusa* corals filter feed on organic matter falling from the water column above (or within currents rushing by). This allows them to serve as the base of a food web even at depths where little to no light is available.	• Mound structure and vertical structure of corals lifts other organisms into currents, which provide nutrients and removes sediments • Coral branches provide shelter, habitat, and anchor points for many organisms, including other filter feeders and multiple levels of predators • Harder rubble surface provides an attachment point for species like sponges • Some species feed directly on living coral

Lophelia pertusa Friends Student Worksheet

ASSOCIATED SPECIES	HOW THE SPECIES BENEFITS	EVIDENCE FROM IMAGE
Shrimp	*Shelter, protection from predators, access to food*	*The shrimp is crawling among live coral in a position where it could easily hide from a predator as it scavenges for its own food.*

Foundation Species Graphic Organizer

Characteristics of *Lophelia pertusa*		Benefits of *Lophelia pertusa* to other species
	Leads to	

Characteristics of My Chosen Species		Benefits of My Chosen Species to other species
	Leads to	

Investigation: Laying the Foundation for Deep-Sea Coral Gardens

Page 1:
- Coral (image): https://oceanexplorer.noaa.gov/explorations/19deepsearch/background/corals/media/img2-hires.jpg
- Deep-sea Coral Community (slides): https://oceanexplorer.noaa.gov/edu/materials/deep-sea-coral-community.pdf
- Ancient Coral Garden (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/dailyupdates/coral-garden/coral-garden-1280x720.mp4
- Architects of the Deep (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1711/dailyupdates/media/video/architects/architects-1280x720.mp4

Page 2:
- Deep-Sea Corals (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1811/dailyupdates/nov1/media/nov1-2-hires.jpg
- NOAA/NSTA Sensemaking Guide (pdf): https://oceanexplorer.noaa.gov/edu/materials/NOAA-sensemaking-phenomenon.pdf
- Deep-Sea Corals - What Are They Fact Sheet (pdf): https://oceanexplorer.noaa.gov/edu/materials/deep-sea-corals-fact-sheet.pdf
- Deep-Sea Corals and Sponges - Foundation Species Fact Sheet (pdf): https://oceanexplorer.noaa.gov/edu/materials/DSC-foundation-species-fact-sheet.pdf

Page 3:
- Deep-Sea Coral Community (slides): https://oceanexplorer.noaa.gov/edu/materials/deep-sea-coral-community.pdf
- 2019 Southeastern U.S. Deep-sea Exploration (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/welcome.html
- Ancient Coral Garden (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/dailyupdates/coral-garden/coral-garden-1280x720.mp4
- Daily Update (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/dailyupdates/nov7/nov7.html
- Mission Log (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/logs/nov7/nov7.html
- Feeding the Million Mounds Investigation (webpage): https://oceanexplorer.noaa.gov/edu/themes/deep-sea-corals/lessons/feeding-million-mounds.html

Page 4:
- Deep-Sea Coral Community (slides): https://oceanexplorer.noaa.gov/edu/materials/deep-sea-coral-community.pdf
- Ancient Coral Garden (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/dailyupdates/coral-garden/coral-garden-1280x720.mp4
- Architects of the Deep (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1711/dailyupdates/media/video/architects/architects-1280x720.mp4
- Sierpinski Triangles (pdf): https://oceanexplorer.noaa.gov/edu/materials/sierpinski-triangles-activity.pdf

Page 5:
- Living Geology (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/background/living-geology/living-geology.html
- Life in the Deep-Sea Coral Forest (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1606/logs/aug9/welcome.html
- Dive 06 (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1907/dailyupdates/nov6/nov6.html
- Charting "Million Mounds" Deep-Sea Corals (exploration note): https://oceanexplorer.noaa.gov/edu/materials/million-mounds-exploration-notes.pdf
- Million Mounds (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex2107/gallery/media/million-mounds-1280x720.mp4

Page 6:
- Deep-Sea Coral Community (slides): https://oceanexplorer.noaa.gov/edu/materials/deep-sea-coral-community.pdf
- Deep-Sea Symphony (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1708/welcome.html
- Coral in Concert (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1708/dailyupdates/media/video/concert/concert-1280x720.mp4
- Florida Keys National Marine Sanctuary, Coral Barrier Reef (webpage): https://floridakeys.noaa.gov/corals/welcome.html?s=explore
- Allegheny National Forest (webpage): https://www.fs.usda.gov/main/allegheny/about-forest/about-area
- Find a national forest (webpage): https://www.fs.fed.us/ivm/
- Pacific Northwest Temperate Rainforest (webpage): https://www.nps.gov/olym/learn/nature/temperate-rain-forests.htm
- Find a national park (webpage): https://www.nps.gov/findapark/index.htm
- Beaver Ponds Trail (webpage): https://www.nps.gov/thingstodo/yell-trail-beaver-ponds.htm
- The Mighty Black Coral (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1903/dailyupdates/june22/media/black-coral-log.html
- Discovering Deep-Sea Corals of the Phoenix Islands 2 - Communities Above and Below (video): https://www.youtube.com/watch?v=Ud3A8YJEvLI
- Discovering Deep Sea Corals of the Phoenix Islands 2 - Searching for the Origin of Immunity (video): https://www.youtube.com/watch?v=pI0QPerCq8w
- The Blake Plateau (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex2107/gallery/gallery.html#cbpi=/okeanos/explorations/ex2107/gallery/media/blake-plateau.inc
- Deep Corals of PIPA (video): https://schmidtocean.org/cruise-log-post/deep-corals-pipa-wrap-video/
- Dyeing Corals to Track Growth (exploration note): https://oceanexplorer.noaa.gov/edu/materials/dyeing-corals-exploration-notes.pdf

Partners

OCEAN EXPLORATION

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