Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

Education

Deep Coral Communities: Sentinels of a Changing Ocean

Black coral with squat lobsters. Photo: NOAA

Grade Level

9th-12th

Time Frame

2-5 hours

Materials

- Computer, projector and screen
- Visual materials (all available for download):
  - ◊ Deep-Sea Coral Video
  - ◊ Introduction Training PowerPoint
  - ◊ Deep-Sea Coral Community Video
  - ◊ ROV Deployment and Transect Training Video
  - ◊ Sanctuary Transect Videos
  - ◊ Deep-Sea Species ID Guide
- Text documents (all available for download):
  - ◊ Introduction Presentation Talking Points
  - ◊ Outline of Transects
  - ◊ Question Sheet for Students
  - ◊ Teacher Answer Guide
  - ◊ Transect Data Sheet
  - ◊ Abundance Graph Template

Spider hard coral polyps. Photo: NOAA

Activity Summary

This lesson focuses on the species found in deep-sea coral communities, the threats that face them and what individuals and communities can do help protect them. Students will learn about the five national marine sanctuaries on the West Coast, protected ocean places in Washington and California. They will investigate the unique biology of deep-sea corals and learn to identify the soft corals, hard corals, invertebrates and fish found within these communities. Students will view real scientific transects taken with Remotely Operated Vehicles (ROVs), while recording data on the presence of specified species. They will then graph and analyze their data to evaluate the composition of deep-sea coral communities according to habitat type, depth and temperature.

Learning Objectives

Students will be able to:

- Describe the physical and biological components of the deep sea in the five national marine sanctuaries on the West Coast;
- Experience the challenges associated with identifying species and recording data taken with ROVs;
- Explain how scientists analyze data by using species diversity and abundance from recorded video;
- Explain the importance of characterizing habitat and be able to describe the various habitat types found in deep-sea coral communities;
- Understand the human-caused threats that face deep-sea coral communities;
- Explain actions that individuals and communities can take to protect these special places

Teacher Background Information

National Marine Sanctuaries

Under the National Oceanic and Atmospheric Administration (NOAA), the Office of National Marine Sanctuaries manages the National Marine Sanctuary System, a network of underwater parks encompassing more than 170,000 square miles of marine and Great Lakes waters. This system preserves the extraordinary scenic beauty, biodiversity, historical connections and economic productivity of these underwater treasures. The U.S. West Coast hosts an oceanographic phenomenon known as upwelling, a wind-driven process where cold, nutrient rich water from the ocean floor moves upwards to replace warmer, nutrient-depleted surface waters. This influx of nutrients stimulates the growth of primary producers, such as phytoplankton, fuels their activity and thus, strengthens the ocean's food web. Upwelling along the West Coast creates incredibly diverse and unique ecosystems, and five national marine sanctuaries have been designated to protect this special region: Olympic Coast, Greater Farallones, Cordell Bank, Monterey Bay and Channel Islands national marine sanctuaries.

Deep-Sea Coral Communities

Corals are often associated with the warm, clear waters of the tropics, yet scientists have discovered nearly as many species of cold water deep-sea corals as shallow water species. The West Coast has both soft corals (such as sea fans, sea pens and black coral) and hard corals (such as cup corals and the reef-building *Lophelia* or spider hard coral). These corals may live hundreds and even thousands of feet beneath the ocean's surface, forming complex and vibrant deep-sea communities which serve as vital habitat for numerous fish and invertebrates. All of the coral communities highlighted in this curriculum are found at depths of 50 meters-300 meters (150-1,000 feet), although they are also found in both shallower and deeper waters. Rather than relying on sunlight, these corals obtain energy for growth and survival by trapping plankton in passing currents. Like their shallow water cousins, deep-sea corals grow extremely slowly, making them especially vulnerable to human disturbances on the sea floor, such as fishing gear from bottom trawling, marine debris and activities associated with energy (oil and gas) exploration and development. Increasingly, scientists are concerned that ocean acidification will impact the ability of deep-sea hard corals to grow and maintain their skeletons, and thus, make them more susceptible to other threats, and even natural occurrences, such as predation.

Ocean Acidification

Fundamental changes in seawater chemistry are occurring in the ocean. Since the beginning of the industrial revolution, the release of carbon dioxide (CO_2) from humankind's industrial and agricultural activities has increased the amount of CO_2 in the atmosphere. The ocean absorbs about a quarter of the CO_2 we release into the atmosphere every year; therefore, as atmospheric CO_2 levels increase, so do the levels in the ocean. Once in the ocean, CO_2 lowers the concentration of the minerals (principally calcium carbonate) many major groups of marine organisms, including corals, use to form skeletal structures. The presence of calcium carbonate in the ocean naturally decreases with depth; therefore, the effect of ocean acidification on deep-sea corals could be even greater than in shallower waters. Projected increases in ocean acidity could result in severe ecological changes for deep-sea corals, and may influence the marine food web from carbonate-based phytoplankton up to higher trophic levels. It should be noted that the ocean is *not* actually becoming acidic, which would indicate a pH below 7; rather, the ocean is becoming *less basic*. Historically, the ocean has been estimated to have an average pH of 8.3; however, at present, it is closer to an average pH of 8.1.

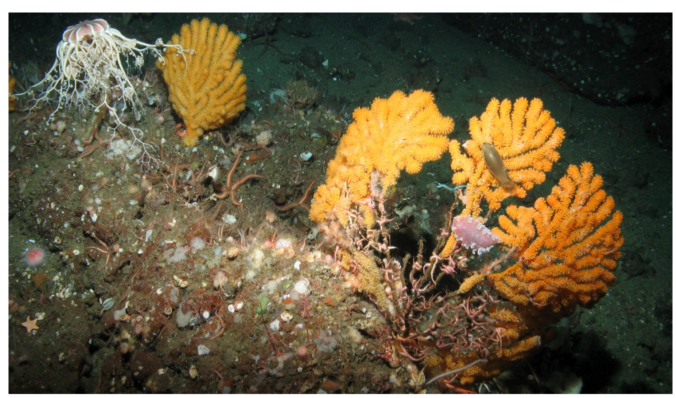
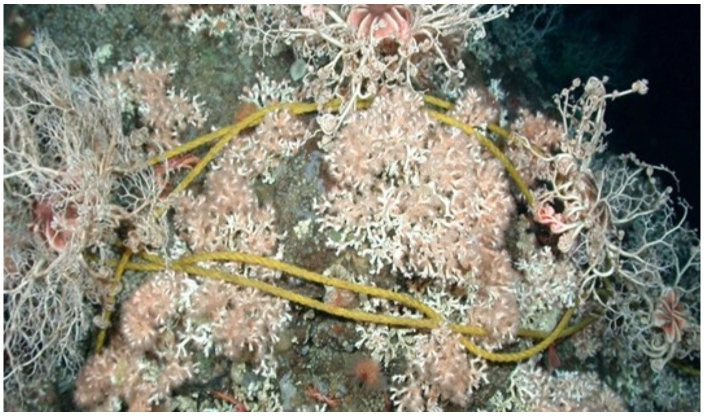


Photo: NOAA


Rope entangling spider hard coral. Photo: NOAA

Bottom Trawling and Other Bottom-tending Fishing Gear Impacts

Disturbances to deep-sea coral and sponge ecosystems from bottom-tending fishing gear, especially bottom trawl gear, have been well documented in the U.S. and other regions around the world. Bottom trawling is widespread and considered a major threat to deep-sea corals in most U.S. regions where such fishing is allowed and overlaps with areas where deep-sea corals are present.

The area of seafloor contacted by bottom trawls is relatively large, the force against the seafloor from the trawl gear is substantial and the distribution of bottom trawling is extensive. Although not as destructive as bottom trawls and dredges, other types of fishing gear can also have detrimental effects on deep-sea corals. Bottom-set gillnets, bottom-set longlines, pots and traps all impact the seafloor. Vertical hook and line fishing, used in both recreational and commercial fishing, has the potential for some damage to fragile corals by the weights used, but such damage is minimal compared to other bottom-tending gear.

Marine Debris

Our ocean is filled with items that do not belong in it. Each day, large amounts of consumer plastics, metals, rubber, paper, textiles, derelict fishing gear, vessels and other lost or discarded items enter the marine environment, making marine debris one of the most widespread pollution problems facing the ocean and waterways. Marine debris is defined as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes. It is both a global and an everyday problem. Moreover, there is no part of the world left untouched by debris and its impacts, including the deep-sea environment. Debris can cause physical damage to corals, entangle animals, or cause harm, or even death, if ingested by marine life. Marine debris is a significant threat to all marine ecosystems; however, it is also one of the most preventable problems that faces our ocean.

Energy and Natural Gas Exploration and Development

Exploration for and production of oil and natural gas resources can impact deep-sea coral communities in a variety of ways. Potential threats include the physical impact of drilling, placement of structures on the seafloor, such as platforms, anchors, pipelines or cables, discharges from rock-cutting during the drilling process, and intentional or accidental well discharges or the release of drilling fluids. For instance, in the North Sea, scientists observed how drilling muds and cuttings smothered and killed *Lophelia pertusa* colonies living on an oil platform close to drilling discharge points. The use of anchors, pipelines and cables for oil exploration and extraction can be destructive to sensitive benthic habitats as well. The deployment of oil and gas pipelines can cause localized physical damage to deep-sea corals, and the use of anchors, pipelines and cables can be destructive to sensitive benthic habitats.


Photo: NOAA
Exploration for natural gas and oil pose a serious threat to deep-sea communities.

Deep-Sea Research

Less than 5% of our ocean has actually been explored due to the challenges of reaching deep ocean habitats. It is very important that we study these deep-sea ecosystems in our sanctuaries in order to understand how human activities can impact them, and how to keep them healthy and thriving. Humans have developed unique methods and advanced technologies, such as Remotely Operated Vehicles (ROVs), for exploration. By utilizing modern technology, we can study deep-sea organisms and their environments. Scientists can then use mathematical models to better understand how the organisms interact with one another and their environment, so that we can make educated decisions about how to protect them.

Background Information on Ecosystem Monitoring

What is Ecosystem Monitoring?

Monitoring an ecosystem involves identifying both the physical and biological resources that are present and measuring how they change over time. Mapping and conducting a species inventory, characterizing the habitat and recording environmental factors can accomplish the first step. Threats to the ecosystem must also be identified and evaluated. Long-term ecosystem monitoring can provide critical scientific information for sanctuary managers and other regulating agencies to make decisions that lead to positive impacts on the environment, such as managing human activities in protected areas, setting agendas for research, monitoring, education, outreach and enforcement programs, and using the most appropriate methods to restore an area.

Ecosystem monitoring can provide detailed reports that contain information on the biological and physical environment, cultural history and human-use patterns. They can chronicle the history of discovery and use, the record of scientific investigations, the pressures placed on natural and cultural resources, and the nature of attempts to protect the resources.

Exploring remote environments

How do scientists explore and study underwater habitats offshore that cannot be visited using SCUBA? Over the last century, marine technology has improved considerably, allowing scientists to go deeper and further in the ocean than ever before.

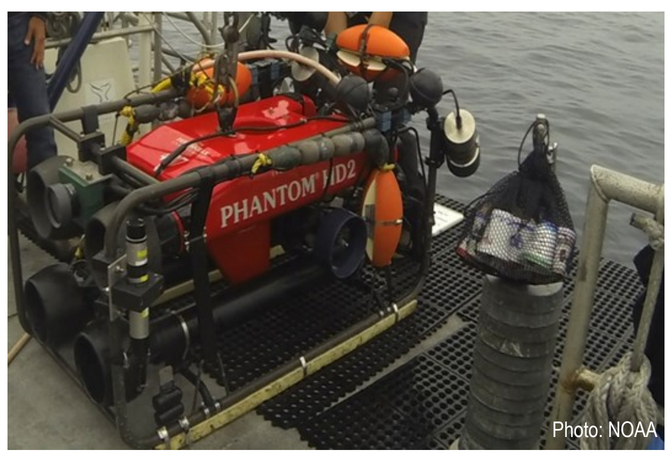
There are numerous marine environments being explored for the first time with this technology. Within our national marine sanctuaries, underwater technology allows us to safely monitor and observe these important deep-sea ecosystems.

Scientists are able to conduct ecosystem monitoring in our national marine sanctuaries using remotely operated vehicles (ROVs). Attached to a boat by a long cable or tether, an ROV is a motorized vehicle with cameras and sensors operated by a person at the ocean's surface.

Using monitors and data delivered by the sensors, operators can see where they drive an ROV; however, an operator's view of the ocean is confined to what an ROV's camera lens captures and then delivers to screens on the ship. Additional ROV limitations include: how the distance traveled is fixed by the length of the tether, the underwater currents and the inability to see far ahead while driving the vehicle.

Transects

In order to monitor an ecosystem, scientists can employ a variety of means to document the presence and



Scientists utilize Remotely Operated Vehicles to study the deep-sea environment.

Vocabulary

MONITORING – Tracking changes in an environment over time.
BIODIVERSITY – A measure of the variety of organisms present in a given ecosystem.
SUBSTRATE – The surface or material, on which an organism lives, grows or obtains its nourishment.
ECOSYSTEM – A system formed by the interaction of a community of organisms with their environment.
ECOSYSTEM MONITORING – Systematic sampling or study of an ecosystem over time in order to determine and evaluate risks and impacts, human or natural.
HORIZONTAL TRANSECT – A measurement along a consistent depth contour that documents the presence of species.
VERTICAL TRANSECT – A measurement along a line from top to bottom with known intervals, measuring physical and or biological conditions.
REMOTELY OPERATED VEHICLES (ROV) – A machine that is equipped with sensors, cameras and motors used to investigate habitats below the surface of the ocean and is attached to the topside vessel with a tether and operated remotely.

abundance of species relative to the environment's physical factors. One method is to conduct vertical and horizontal transects.

Vertical transects in the ocean are useful to profile the ocean's physical and biological layering. Imagine dropping a line from one point in the water column down to another. Physical factors are observed and recorded at various points along this line, or transect. Increments along the transect are usually evenly spaced, and when combined with similar transects, they describe/define the environment, and may reveal changes taking place due to water depth, temperature or other phenomena.

Horizontal transects are conducted in a similar way. These are most often used along the seafloor or at a particular depth. For instance, a horizontal transect at a depth of 600 meters (2,000 feet) might look for distribution of fish along this depth. A horizontal transect conducted from a submersible can have several different protocols.

During a horizontal transect, identify or keep in mind:

- The ROV's speed
- The field of vision in which species are counted
- How to measure abundance
- How to remain consistent among observers

Vertical and horizontal transects provide researchers with two methods to construct models of an ecosystem while only studying small portions of it. The models then help people understand how an ecosystem functions. For example, a model can describe the flow of energy through a system or allow scientists to predict the effects of natural or human-caused events in an ecosystem.

Diving is only the first part!

Collecting ROV video footage, still images and other data are only the first stage in the process of monitoring a deep-sea ecosystem. Experts then review the videos and still images over and over again. They identify the habitat, and how frequently it changes during the transect, identify the species size and abundance, and how the species use the habitat. In order to return to the same location for long-term monitoring, sometimes researchers will even leave physical markers or record GPS coordinates. Then, all the data is compiled and analyzed in graphs and charts and used to create models that explain species interactions with one other and their habitat, and how species respond to changing ocean conditions and human impacts. All of the data collection, analysis and modeling allow scientists to better understand these special ecosystems so that we can make informed decisions about how to protect them.

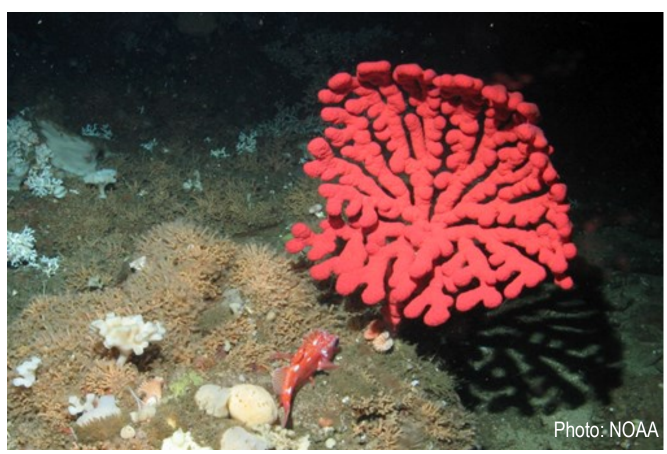
Preparation for Activity

- Download all associated videos and text materials for this program.
- Choose which sanctuary or sanctuaries to focus on (teacher may choose from 1-5 sanctuaries).
- Make copies of species identification guides and data sheets for students.

Directions for Activity

- Ask your students the following guiding questions:
  - ◊ What do you think the deep-sea looks like? What type of environment is it?
  - ◊ How would you study this environment? What technology would you use?
  - ◊ What parts of these ecosystems would you want to measure? What physical and/or biological components should be measured and how?

  *Allow your students to contemplate their answers before beginning the program.
- Introduce the West Coast Deep-Sea Coral Communities Video (*5 minutes, 44 seconds*)
- Go through the Deep-Sea Coral Communities Introduction PowerPoint (*script for talking points available for download*). Explain that the class will investigate the deep-sea habitats of one to five national marine sanctuaries on the West Coast by recording and graphing data from real deep-sea transects. Students should understand the methods and technology needed for deep-sea exploration, the importance of studying these habitats and the human-caused threats that could potentially harm these ecosystems. Students should also be familiar with identifying habitat types and estimating abundance.
- Break students into groups. It is recommended that each student have his/her own ID guide and data sheet.
- Hand out data sheets to students. To prepare students to use the data sheet, go over what each row and column is for:
  - ◊ The top of the data sheet should be labeled with the sanctuary name, habitat type (*students will determine this when the video is played*), depth and temperature (*if available*). Then there are separate columns for Common Name, Species and Genus, then one column each for the one minute segments of the transects (0-1, 1-2, 2-3). The last column is for Total Abundance. After the transect is complete, each student will tally up his/her total assigned species counted and assign an abundance rating (**single, few, many, abundant**) for the overall transect.
- **Assign species**: Have the student groups divide the groups of organisms on the identification guide so that each person is only looking for certain species or a group of organisms instead of all of them. Explain that any of the species may be abundant or absent in any given habitat – no transects will have *all* of the species on the ID guide.
- **Measuring Abundance**: During the transect, students can either use tally marks to note how many times they see a particular species, or continuously count and then record species numbers. This task can be difficult depending on the species; however, it is also difficult for the experts that review transects. Encourage students to count or estimate the best they can.
- **Explain that they do not need to identify every organism down to species, just common names or genus.** Each transect should be broken into one minute segments. The teacher should watch the time and pause the transect at the end of each one minute segment to allow students to catch up on writing on their data sheets. Students may ask to pause the videos *briefly* during a segment if they want extra time to count a dense patch of organisms or identify species. After the transect is complete, each student should tally his/her assigned species count and assign an abundance category for the entire transect:
  - ◊ **Single: One solitary individual or colony**
  - ◊ **Few: 2-10 individuals or colonies**
  - ◊ **Many: 11-50 individuals or colonies**



A bubblegum coral and juvenile rockfish.

Flabellum cup coral.

◊ **Abundant: 50+ individuals or colonies**

**Students that count fish or sea fans will have a difficult time with large groups. If students cannot count the individuals in large groups, have them estimate whether the number of individuals is between 11-50 or greater than 50 and write many or abundant instead.*

***Note that abundance should be assigned for the ENTIRE transect. For example, if there is only one individual or colony during the first minute, then 10 individuals or colonies during the second minute and none in the last minute, the overall abundance category would be few.*

- During the Introduction PowerPoint, there is a video of an ROV deployment followed by a one minute practice transect. The students will be able to watch underwater footage at the ROV's speed.
- Assign species ID groups to students. Then, before the video, allow students to look over their identification guides.
- Play the practice transect and have students record data. Conduct a debrief exercise with students regarding what was hard and what they need to do differently next time. They may discover that they need to go over the video more than once to see everything, or have it paused in order to estimate an area of dense species diversity.
  - ◊ Ask your students – How would you visually represent this data?
  - ◊ Have students graph their data from the practice transect before showing them the graph on the PowerPoint. Have them compare their findings to this graph.
- Choose which transects to view from the five national marine sanctuaries on the West Coast. The teacher may select only one sanctuary or up to all five sanctuaries for an extended program. The five sanctuaries are listed below (*Please download the descriptions of transects for a detailed breakdown of species abundance and diversity*):
  - ◊ Channel Islands National Marine Sanctuary: A total of six transects are used to estimate biodiversity and abundance by depth. There are three shallow (<100 meters) and three deep-sea (>100 meters) transects, as well as two additional deep-sea transects with a higher density of species. Students will also examine temperature in relation to depth and extrapolate how this may determine species distribution.
  - ◊ Monterey Bay National Marine Sanctuary: One transect explores species diversity on a rocky slope of the Davidson Seamount.
  - ◊ Greater Farallones National Marine Sanctuary: A total of three transects are used to estimate abundance and biodiversity in three different habitat types.
  - ◊ Cordell Bank National Marine Sanctuary: Two transects are used to explore biodiversity and abundance in the Bodega Canyon region.

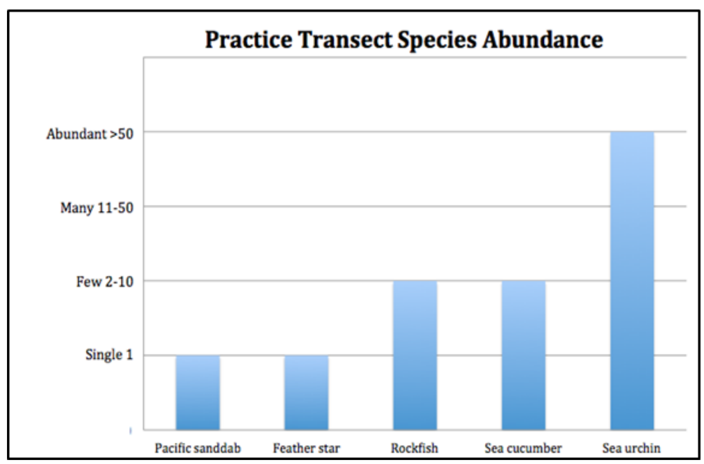


Image: Graph of species abundance found in the ROV Deployment and Training Transect Video.

Education Standards

California State Science Standards	9-12 Ecology – 6.a, 6.b; 9-12 Earth Sciences – 5.d; Investigation and Experimentation – 1.a, 1.c, 1-d
Washington State Science Standards	9-11 LS2D-7.2.E; 9-11 LS2E; 9-11 LS2F
Next Generation Science Standards	HS-LS2-2, LS2.C; HS-LS2-7
Ocean Literacy Principles	5.f, 6.e, 6.g, 7.a, 7.b, 7.d, 7.e
Climate Literacy Principles	6.c, 7.d

    ◊ Olympic Coast National Marine Sanctuary: One brief transect is used to explore biodiversity off of the Olympic Coast.

- As the students view each chosen transect, they will identify the substrate type (soft or rocky bottom, mixed type or ledge). As the transect progresses, they will identify species and abundance on their data sheets.
- Students may ask to pause the video for up to 30 seconds to identify a species on their ID guides and mark abundance. The teacher should watch the time and let the students know when each one minute segment ends.
- After each transect, have students tally their species count and assign an abundance category for the entire transect. (*Some transects are very dense with life; therefore, teachers and/or students may want to view these videos more than once.*)
- After the class has completed all transects, have students share their individual data with their respective group so that each student has an abundance code for every species on the data sheet. Specifically, each student should have a completed data sheet for each sanctuary habitat.

Analyze the Data

In order to visualize the data, students will create a graph for each of the sanctuary transects. Teachers may choose to have their students use the graph template provided or a computer-based program, such as Excel. It may be best to assign each group to graph a different transect. Using their graphs, have students compare and contrast species abundance and diversity in each transect. Also, have them discuss observer consistency – did everyone have similar data? Have each group answer the Transect Data Questions and Ecosystem Monitoring Questions. Review the Teacher Answer Sheets and discuss their answers.

Optional Transect Extension Activity

For a more in-depth analysis of the transects, have students graph species data collected from minute to minute to determine whether or not species abundance categories can change within a single transect and have them correlate species presence/absence with habitat type. This would reinforce the idea that each type of habitat is not uniform, but rather incredibly dynamic and dense with life. Be certain to emphasize the fact that these transects are only one small part of an entire ecosystem.

Optional Writing Extension Activity

Have students choose one of the human-caused threats to deep-sea coral communities and come up with a specific solution to mitigate that threat. Encourage them to construct a letter with an argument for special protection that includes their specific transect data and what they learned during this lesson. They should be able to outline why their deep-sea ecosystem should be protected, exactly what causes the threat and how they propose to protect this place in the ocean.

Conclusion

Have students revisit the challenges of studying the deep-sea and why it is so important. Discuss how the future might look if these ecosystems are both protected and conversely unprotected from human-caused threats. Allow them to brainstorm actions that people can take to mitigate these threats and how deep-sea coral communities might thrive from special protection.

For More Information

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Additional Resources

NOAA's Ocean Acidification Program
NOAA's PMEL Carbon Program
NOAA National Marine Sanctuaries
NOAA Deep-Sea Coral Research and Technology Program
The State of Deep-Sea Coral and Sponge Ecosystems of the United States: 2015
Marine Conservation Institute: Ocean Acidification, Deep-Sea Corals and U.S. Fisheries
The Ocean Portal: Deep-Sea Corals
NOAA's Coral Reef Conservation Program: Threats to Deep-Sea Corals
Ocean Explorer: Deep Water Octocorals
Octocoral Research Center
University of Southern California — Practicing Quadrats and Transects Activities
Next Generation Science Standards

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Photo: NOAA