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Deepwater Coral Expedition: Reefs, Rigs and Wrecks

Forests of the Deep Ocean
(adapted from the 2004 Gulf of Alaska Expedition)

Focus
Morphology and ecological function in habitat-forming deep-sea corals

Grade Level
7-8 (Life Science)

Focus Question
How does the physical form of deep-sea corals contribute to their ecological function?

Learning Objectives
Students will be able to describe at least three ways in which habitat-forming deep-sea corals benefit other species in deep-sea ecosystems.

Students will be able to explain at least three ways in which the physical form of habitat-forming deep-sea corals contributes to their ecological function.

Students will be able to explain how habitat-forming deep-sea corals and their associated ecosystems may be important to humans.

Students will be able to describe and discuss conservation issues related to habitat-forming deep-sea corals.

Materials
- ❒ (Optional) Images of deep-sea corals (see Learning Procedure)
- ❒ Paper, rulers, pencils or markers for constructing Sierpinski triangles (see Learning Procedure)
- ❒ Stream table or large pan or tray (at least 30 cm wide x 60 cm long x 8 cm deep)
- ❒ Modeling clay
- ❒ 20 short dowels or pencils, about 10 cm long x 6 mm diameter

Audio/Visual Materials
- ❒ (Optional) Images of deep-sea corals

Teaching Time
One or two 45-minute class periods, plus time for student research and presentations

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Gulf of Mexico
Deepwater coral
Endemic
Form and function
Corallidae
Isididae
Paragordiidae
Primnoidae
Antipathidae
Oculinidae
Caryophylliidae
Stylasteriidae

Background Information

In recent years, rising costs of energy and a growing desire to reduce the United States' dependence upon foreign petroleum fuels have led to intensified efforts to find more crude oil and drill more wells in the Gulf of Mexico. This region produces more petroleum than any other area of the United States, even though its proven reserves are less than those in Alaska and Texas. Managing exploration and development of mineral resources on the nation's outer continental shelf is the responsibility of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of the Deepwater Corals Expedition: Reefs, Rigs and Wrecks mission is to protect unique and sensitive environments where these resources are found.

To locate new sources of hydrocarbon fuels, MMS has conducted a series of seismic surveys to map areas between the edge of the continental shelf and the deepest portions of the Gulf of Mexico. These maps provide information about the depth of the water as well as the type of material that is found on the seafloor. Hard surfaces are often found where hydrocarbons are present. Carbonate rocks (such as limestone), in particular, are a part of nearly every site where fluids and gases containing hydrocarbons have been located. This is because when microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. This rock, in turn, provides a substrate where the larvae of many other deep sea bottom-dwelling organisms may attach, particularly corals. In addition to carbonate rocks associated with hydrocarbon seeps, deepwater corals in the Gulf of Mexico are also found on anthropogenic (human-made) structures, particularly ship wrecks and oil platforms.

Deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. Recent studies suggest that deepwater reef ecosystems may have a diversity of species comparable to that of coral reefs in shallow waters, and have found deepwater coral species on continental margins worldwide. One of the most conspicuous differences between shallow- and deepwater corals is that most shallow-water species have symbiotic algae (zooxanthellae) living inside the coral tissue, and these algae play an important part in reef-building and biological productivity. Deepwater corals do not contain symbiotic algae (so these corals are termed "azooxanthellate"). Yet, there are just as many species of deepwater corals (slightly more, in fact) as there are species of shallow-water corals. Deepwater reefs provide habitats for a variety of plant, animal, and microbial species, some of which have not been found anywhere else. Branching corals and other sessile (non-motile) benthic (bottom-dwelling) species with complex shapes provide essential habitat for other organisms including commercially-important fishes such as longfin hake, wreckfish, blackbelly rosefish, and grenadiers. In addition, recent research has shown that less obvious, obscure benthic species may contain powerful drugs that directly benefit humans.

The major structure-building corals in the deep sea belong to the genus *Lophelia*, but other organisms contribute to the framework as well, including antipatharians (black corals), gorgonians (sea fans and sea whips), alcyonaceans (soft corals), anemones, and sponges. While these organisms are capable of building substantial reefs, they are also quite fragile, and there is increasing concern that deepwater reefs and their associated resources may be in serious danger. Many investigations have reported large-scale damage due to commercial fishing trawlers, and there is also concern about impacts that might result from exploration and extraction of fossil fuels. These impacts are especially likely in the

Gulf of Mexico, since the carbonate foundation for many deepwater reefs is strongly associated with the presence of hydrocarbons. Potential impacts include directly toxic effects of hydrocarbons on reef organisms, as well as effects from particulate materials produced by drilling operations. Since many deepwater reef organisms are filter feeders, increased particulates could clog their filter apparatus and possibly smother bottom-dwelling organisms.

A primary goal of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks is to obtain more information about the biology and ecology of deepwater coral communities so that effective strategies to protect these communities can be developed. In this activity, students will research deep-sea corals, and draw inferences about how their morphology contributes to their ecological function in deep-water ecosystems.

Learning Procedure

1. To prepare for this lesson, review introductory essays for the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html.

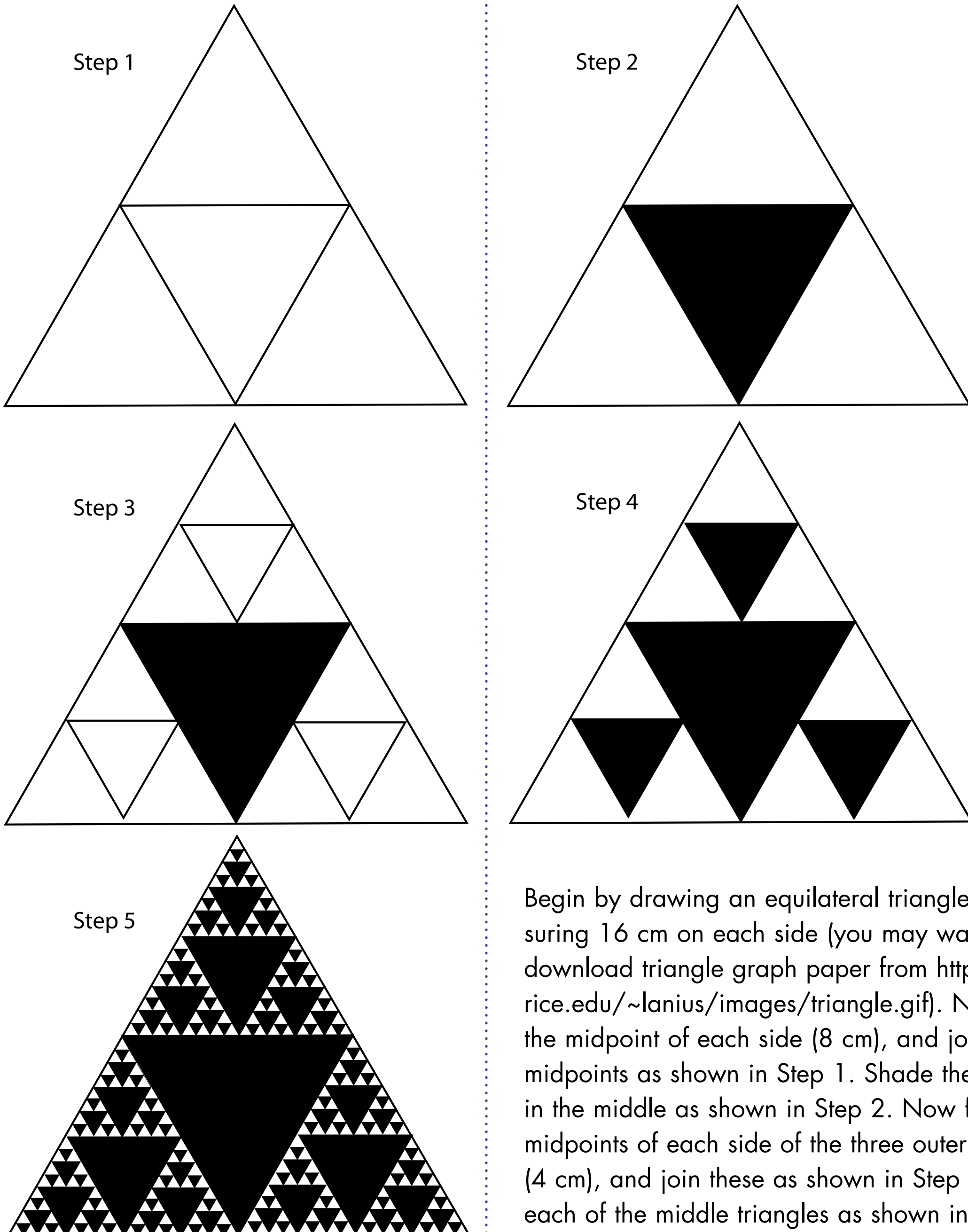
   You may also want to visit http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html for images of deep-sea corals and seamount communities.

2. Lead a brief discussion based on students' knowledge about coral reefs. This is most likely be focussed upon shallow-water reefs. Be sure students realize that these reefs are among the most biologically-productive and diverse ecosystems known on Earth, that shallow-water corals often have a symbiotic relationship with photosynthetic zooxanthellae, and for this reason are typically limited to depths where photosynthesis is possible. You may also want to mention that these reefs are threatened in many places by increasing water temperatures, pollution, and impacts from human activities. Tell students that recent explorations into the deep ocean have discovered corals without zooxanthellae that are able to create reefs that have as many species as shallow-water reefs. Briefly introduce the mission Deepwater Coral Expedition: Reefs, Rigs, and Wrecks, emphasizing that very little is known about deep-water coral communities, but these communities may be important to humans in a variety of ways, including their potential as sources for new drugs to treat human diseases (for more information on this point, see the 2003 Ocean Explorer Deep Sea Medicines expedition, http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html).

3. Tell students that one of the most important characteristics of many deep- and shallow-water corals is that they create habitat for other corals. The branching growth form, in particular, contributes to this ecological function by providing numerous small spaces within the coral colonies that serve as sheltered areas where other organisms may live. To illustrate this effect, show students how to construct a Sierpinski triangle as in Figure 1, on Page 4. The basic principle is that repeatedly dividing a fixed space produces an infinite series of increasingly smaller spaces that in nature are potential habitats for a wide variety of organisms).

   Another important characteristic of branching corals is their ability to moderate ocean currents. These currents are often fairly strong, but the branched structure of the corals reduces the flow, which in turn causes suspended particles to settle and become available to organisms sheltering beneath the coral branches. Use a stream table or large tray to illustrate this by sticking about 20 dowels (ca. 10 cm x 6 mm diameter) into a slab of modeling clay so the dowels are about 1 cm apart. With water flowing through the stream table or tray, add a few drops of food coloring or ink to visualize the flow. Then place the clay block with dowels into the stream, and add a few more drops into the flow upstream of the block. Students should

Figure 1.



Begin by drawing an equilateral triangle measuring 16 cm on each side (you may want to download triangle graph paper from http://math.rice.edu/~lanius/images/triangle.gif). Next, find the midpoint of each side (8 cm), and join these midpoints as shown in Step 1. Shade the triangle in the middle as shown in Step 2. Now find the midpoints of each side of the three outer triangles (4 cm), and join these as shown in Step 3. Shade each of the middle triangles as shown in Step 4. Continue this process for three more iterations, until the midpoints measure 0.5 cm, shading the middle triangles after each iteration until the drawing appears similar to Step 5. Theoretically the process can continue indefinitely.

see the coloring slow and eddy around the dowels, simulating the motion of water around branched corals.

4. Point out that most people do not even know that deep-water coral communities exist, and that public understanding is an essential part of efforts to protect these communities. Assign student groups one of the following families of habitat-forming deep-sea corals:
   Corallidae
   Isididae
   Paragordiidae
   Primnoidae
   Antipathidae
   Oculinidae
   Caryophylliidae
   Stylerasteriidae

   Tell students that their task is to create a presentation to introduce and describe deep-water coral communities to students in their grade level at another school. This presentation may be in the form of a PowerPoint® slide show, musical or dramatic performance, or written report, and must include answers to the following questions:
   (a) What is the taxonomic position of the family (phylum, class, order)?
   (b) What do corals in this family looks like (appearance and type of skeletal structure)?
   (c) What is the depth range over which these corals occur?
   (d) How old are the oldest known deep-water coral reefs?
   (e) How do corals in this family provide and modify habitat for other species?
   (f) How does physical form contribute to the function of these corals in their ecosystem?
   (g) What are some ways in which these corals or associated species may be important to humans?
   (h) What needs to be done to manage and protect these corals?

   Some Web sites that may be useful for students' research are listed under "Resources."

5. Lead a discussion of students' presentations. The following points should be included:
   - Taxonomy:
     Corallidae – Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
     Isididae – Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
     Paragordiidae – Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
     Primnoidae – Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
     Antipathidae – Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia, Order Antipatharia
     Oculinidae – Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia, Order Scleractinia
     Caryophylliidae – Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia, Order Scleractinia
     Stylasteriidae – Phylum Cnidaria, Class Hydrozoa, Order Stylasterina

   - Deep-sea corals are found off all U.S. coasts, including Alaska and Hawaii.

   - Radiocarbon dating has established that some coral colonies are 10,000 - 12,000 years old (around the end of the last Ice Age).

   - Two-thirds of known coral species live in deep, cold water, and are suspension feeders.

   - The majority of deep-sea corals have not been located; very few deep-sea coral reefs have been intensively studied.
   - Deep-sea coral colonies may host hundreds of other organisms (e.g., more than 2,000

individual animals and hundreds of species, including worms, crabs, shrimp and fishes were found in a small coral colony with a head the size of a basketball).

- Deep-sea corals provide multiple benefits to other species, including shelter, protection from predators, nursery areas, reduction of strong currents, and feeding areas.
- The branching growth form of deep-sea corals also increases the surface area available to other organisms (particularly microorganisms).
- The branching growth form of deep-sea corals reduces the force of strong currents that are often found in the vicinity of deep-water coral communities, making it possible for more delicate species to live in these communities.
- Deep-sea coral reefs provide essential habitat for many commercially-important fish species, including red porgy, amberjack, snappers, groupers, and orange roughy.
- Besides supporting commercial fisheries, deep-sea coral communities may also contain other species that can provide new pharmaceuticals; recent research has discovered a variety of deep-sea bottom-dwelling invertebrates that produce powerful drugs that can be used to treat cancer, inflammatory diseases, and heart disease.
- Skeletons of deep-sea corals contain records of climate change over thousands of years.
- Destructive fishing gear, particularly bottom trawls, is one of the greatest threats to deep-sea coral ecosystems. Areas where an extensive amount of deep-sea coral is known to have been destroyed by trawling include Canada, Scotland, Norway, Australia, New Zealand, and the east coast of the United States.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Habitats," then "Coastal," then "Coral Reef" for resources on corals and coral reefs.

The "Me" Connection

Have students write a short essay on how deep-sea coral communities might be potentially important to their own lives.

Connections to Other Subjects

English/Language Arts, Mathematics, Earth Science

Assessment

Student presentations provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html to find out more about the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and to learn about opportunities for real-time interaction with scientists on the current expedition.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Shipwreck Mystery

(10 pages, 322k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/shipwreck.pdf

Focus: Marine Archaeology (Earth Science/Physical Science/Social Science)

In this activity, students will be able to draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck; use a grid system to document the location of artifacts recovered from a model shipwreck site; and identify and explain types of evidence and expertise that can help verify the nature and historical content of artifacts recovered from shipwrecks.

I, Robot, Can Do That!

(9 pages, 357k) (from the 2005 Lost City Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf

Focus - Underwater Robotic Vehicles for Scientific Exploration (Physical Science/Life Science)

In this activity, students will be able to describe and contrast at least three types of underwater robots used for scientific explorations, discuss the advantages and disadvantages of using underwater robots in scientific explorations, and identify robotic vehicles best suited to carry out certain tasks.

Sonar Simulation

(PDF, 308kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/sonarsim.pdf

Focus: Side scan sonar (Earth Science/Physical Science)

In this activity, students will describe side-scan sonar, compare and contrast side-scan sonar with other methods used to search for underwater objects, and make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

This Old Ship

(9 pages, 272 kb) (from the 2006 Phaedra Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/old_ship.pdf

Focus: Ancient and Prehistoric Shipwrecks

In this activity, students will be able to describe at least three types of artifacts that are typically recovered from ancient shipwrecks, explain the types of information that may be obtained from at least three types of artifacts that are typically recovered from ancient shipwrecks, and compare and contrast, in general terms, technological features of Neolithic, Bronze Age, Hellenistic, and Byzantine period ships.

Mapping the Aegean Seafloor

(8 pages, 288 kb) (from the 2006 Phaedra Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/seafloor_mapping.pdf

Focus: Bathymetric mapping of deep-sea habitats (Earth Science)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, create a three-dimensional model of landforms from a two-dimensional topographic map, and interpret two- and three-dimensional topographic maps.

Monsters of the Deep

(6 pages, 464k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/monsters.pdf

Focus: Predator-prey relationships between cold-seep communities and the surrounding deep-sea environment (Life Science)

In this activity, students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities; and will be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment. Students will also be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe at least five deep-sea predator organisms.

One Tough Worm

(8 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/worm.pdf

Focus: Physiological adaptations to toxic and hypoxic environments (Life Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three physiological adaptations that enhance an organism's ability to extract oxygen from its environment. Students will also be able to describe the problems posed by hydrogen sulfide for aerobic organisms, and explain three strategies for dealing with these problems.

Let's Go to the Video Tape!

(11 pages; 327kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/videotape.pdf

Focus: Characteristics of biological communities on deepwater coral habitats (Life Science)

In this activity, students will recognize and identify some of the fauna groups found in deep-sea coral communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral communities, and discuss the meaning of "biological diversity." Students will compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity, and given abundance and distribution data of species, will be able to calculate an appropriate numeric indicator that describes the biological diversity of a community.

Treasures in Jeopardy

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/treasures.pdf

Focus: Conservation of deep-sea coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral communities. Students will also describe human activities that threaten deep-sea coral communities and describe actions that should be taken to protect resources of deep-sea coral communities.

Come on Down!
(6 pages, 464k) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l1.pdf

Focus: Ocean Exploration

In this activity, students will research the development and use of research vessels/vehicles used for deep ocean exploration; students will calculate the density of objects by determining the mass and volume; students will construct a device that exhibits neutral buoyancy.

Living by the Code
(5 pages, 400k) (from the 2003 Deep Sea Medicines Expedition)
http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/meds_livingcode.pdf

Focus: Functions of cell organelles and the genetic code in chemical synthesis (Life Science)

In this activity, students will be able to explain why new drugs are needed to treat cardiovascular disease, cancer, inflammation, and infections; infer why sessile marine invertebrates appear to be promising sources of new drugs; and explain the overall process through which cells manufacture chemicals. Students will also be able to explain why it may be important to synthesize new drugs, rather than relying on the natural production of drugs.

Mapping Deep-sea Habitats in the Northwestern Hawaiian Islands
(7 pages, 80kb) (from the 2002 Northwestern Hawaiian Islands Expedition)
http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf

Focus: Bathymetric mapping of deep-sea habitats (Earth Science - This activity can be easily modified for Grades 5-6)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, will create a three-dimensional model of landforms from a two-dimensional topographic map, and will be able to interpret two- and three-dimensional topographic data.

Life is Weird
(8 pages, 268k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_weird.pdf

Focus: Biological organisms in cold seep communities (Life Science)

In this activity, students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment, and describe the process of chemosynthesis in general terms, and will be able to contrast chemosynthesis and photosynthesis.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focussing on the exploration, understanding, and protection of Earth as a whole system

Etnoyer, P. and L. Morgan. 2003. Occurrences of Habitat-forming Deep Sea Corals in the Northeast Pacific Ocean. Report to NOAA's Office of Habitat Conservation. (available online at http://www.mcbi.org/publications/pub_pdfs/Etnoyer_Morgan_2003.pdf)

http://na.oceana.org/en/news-media/publications – Publications on ocean conservation issues

http://www.terranature.org/deepsea_coral.htm – Article about scientists' call for protection of deep-sea coral ecosystems

http://www.terranature.org/trawlingScientists_ban.htm – Text of Scientists' Statement on Protecting the World's Deep-sea Coral and Sponge Ecosystems

Malakoff, D. 2003. Deep-sea mountaineering. Science 301:1034-1037. – Article on seamounts and deep-sea coral communities

http://www.mcbi.org/cgi-bin/photo_library.pl?ID=2 – Images on the Marine Conservation Biology Institute's Web page

http://www.boemre.gov/index.htm – Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) web site

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – NOAA's Ocean Explorer photograph gallery

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.esajournals.org/doi/abs/10.1890/1540-9295(2004)002%5B0123:DCOOSB%5D2.0.CO%3B2

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf – "Chemosynthetic Communities in the Gulf of Mexico" teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students.

http://www.boemre.gov/mmskids/– Kids Page on the BOEMRE Web site, with posters, teaching guides and other resources on various marine science topics

http://www.coast-nopp.org/ – Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ – Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico (COSEE-CGOM)

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environment

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

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 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.

The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying

more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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